Code-Making Panel 2

Public Input Report (A19)

Public Input No. 1073-NFPA 70-2017 [Global Input]

Change all written percentages to numerical percentages.

Statement of Problem and Substantiation for Public Input

To standardize how percentages are represented in the NEC

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 1071-NFPA 70-2017 [Section No. 690.8(B)(1)]	
Public Input No. 1070-NFPA 70-2017 [Section No. 690.8(B)(1)]	

Submitter Information Verification

Submitter Full Name: Kevin Nutley
Organization: Puget Sound Electrical Apprenticeship JATC
Street Address:
City:
State:
Zip:
Submittal Date: Sat Jun 24 16:11:26 EDT 2017

Public Input No. 3453-NFPA 70-2017 [Global Input]

Remove the phrase "the provisions of" throughout the entire NEC and editorial revise each segment of text as required.

Statement of Problem and Substantiation for Public Input

The phrase is unnecessary and redundant. This global public input seeks to request that each NEC Panel (technical committee) review the articles under their responsibility and remove this phrase and reword the text accordingly. The requirements are already provided in the NEC so it does not make sense to refer to provisions. In many cases the phrase should refer to a section, then state that section in accordance with the NEC Style Manual requirements.

Substantiation Examples:

90.6 Formal Interpretations. To promote uniformity of interpretation and application of the provisions of this Code, formal interpretation procedures have been established and are found
in the NFPA Regulations Governing Committee Projects.

110.3(A)Examination, Identification, Installation, Use, and Listing (Product Certification) of Equipment.
(1) Suitability for installation and use in conformity with the provisions of this Code

110.30 General. Conductors and equipment used on circuits over 1000 volts, nominal, shall comply with Part I of this article and with 110.30 through 110.41 , which supplement or modify
Part I. In no case shall the provisions of this part apply to equipment on the supply side of the service point.

110.51 General.

(A)Covered. The provisions of this p Part IV shall apply to the installation and use of high-voltage power distribution and utilization equipment that is portable, mobile, or both, such as substations, trailers, cars, mobile shovels, draglines, hoists, drills, dredges, compressors, pumps, conveyors, underground excavators, and the like.

210.13 Ground-Fault Protection of Equipment. Each branch circuit disconnect rated 1000 A or more and installed on solidly grounded wye electrical systems of more than 150 volts to ground, but not exceeding 600 volts phase-to-phase, shall be provided with ground-fault protection of equipment in accordance with the provisions of 230.95.

Exception No. 1: The provisions of this This section shall not apply to a disconnecting means for a continuous industrial process where a nonorderly shutdown will introduce additional or increased hazards.
Exception No. 2: The provisions of this This section shall not apply if ground-fault protection of equipment is provided on the supply side of the branch circuit and on the load side of any transformer supplying the branch circuit.

Section 210.60(B)

(B) Receptacle Placement. In applying the provisions of 210.52(A), the total number of receptacle outlets shall not be less than the minimum number that would comply with the
provisions of that section. These receptacle outlets shall be permitted to be located conveniently for permanent furniture layout. At least two receptacle outlets shall be readily accessible. Where receptacles

are installed behind the bed, the receptacle shall be located to prevent the bed from contacting any attachment plug that may be installed or the receptacle shall be provided with a suitable guard.

Submitter Information Verification

Submitter Full Name: Agnieszka Golriz
Organization: NECA
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 06 10:12:45 EDT 2017

Copyright Assignment

I, Agnieszka Golriz, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Agnieszka Golriz, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 4317-NFPA 70-2017 [Global Input]

Each code making panel should set time aside to review the requirements under their purview to ensure that new and existing requirements are in compliance with the NEC style manual.

Statement of Problem and Substantiation for Public Input

Code making panels are responsible for ensuring that the Code text which agreed upon at the technical panel meetings comply with all requirements of the NEC style manual. It would be prudent for each code making panel to set time aside to review the requirements under their purview to ensure that not only new but existing requirements are in compliance with the requirements of the NEC style manual.

Adherence to the NEC style manual promotes consistency throughout the NEC adding to clarity to the users of the NEC. Code making panels should spend available time reviewing for such important style manual requirements as the following: (These are just some examples and not a comprehensive list of style manual requirements.)

Unenforceable Terms. The NEC shall not contain references or requirements that are unenforceable or vague. The terms contained in Table 3.2.1 of the style manual shall be reviewed in context, and, addressed if the resulting requirement is unenforceable or vague. Examples of unenforceable and Vague Terms include the following:

designed for the purpose.
good
adequate
frequent(ly)

Writing in present text. Requirements must be written in present text and not future text. A good example of this is as follows:

Correct: No conductor shall be used in such a manner that its operating temperature exceeds that designated for the type of insulated conductor involved.
Incorrect: No conductor shall be used in such a manner that its operating temperature will exceed that designated for the type of insulated conductor involved.

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich
Organization: Eaton Corporation
Street Address:
City:
State:
Zip:

Submittal Date: Thu Sep 07 20:19:11 EDT 2017

Copyright Assignment

I, Thomas Domitrovich, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Thomas Domitrovich, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 777-NFPA 70-2017 [Global Input]

The terms “satisfactory” - "equal" - "equivalent", etc., are examples of numerous subjective terms found in the NEC where decisions of suitability fall under the purview of the AHJ. Changing or supplementing these terms to "approved" - "approved equivalent" will continue the alignment of language used throughout the NEC.

I authored a couple of such changes for the 2014 NEC that were adopted in the 2017. It was suggested to me by someone from NFPA that I submit a global input, so a committee would be appointed to locate and revise all such subjective terms to include the word "approved".

This will reduce the number of terms used to determine suitability of equipment as it applies to installation/inspection to one of the following: "Listed" - "Identified" - "Approved"

Statement of Problem and Substantiation for Public Input

I think the language in my global proposal not only states the problem, but offers a viable solution to facilitate uniformity of language throughout the NEC.

Submitter Information Verification

Submitter Full Name: Tom Pernal

Organization: Tom Pernal Electrical Seminars, LLC

Street Address:

City:

State:

Zip:

Submittal Date: Sat May 20 15:35:20 EDT 2017

Public Input No. 1136-NFPA 70-2017 [Definition: Bathroom.]

Bathroom.

An area including a ~~basin~~ sink with one or more of the following: a toilet, a urinal, a tub, a shower, a bidet, or similar plumbing fixtures. (CMP-2)

Statement of Problem and Substantiation for Public Input

Sink is used in the definition of a kitchen as well as in other areas of the Code. A sink and a basin may be used interchangeably but the term "basin" as used in other areas of the Code refer to drainage ditches and trenches. When CMP 2 defined a bathroom the term "basin" may have been used intentionally but sink seems to be the more appropriate way to describe this in the definition of a bathroom. I realize if CMP 2 revises this definition, a change will need to be made in 210.52 (D) as well.

Submitter Information Verification

Submitter Full Name: David Hittinger

Organization: Independent Electrical Contractors

Affilliation: Independent Electrical Contractors Codes and Standard

Street Address:

City:

State:

Zip:

Submittal Date: Wed Jul 12 15:40:22 EDT 2017

Public Input No. 784-NFPA 70-2017 [Definition: Branch Circuit, General-Purpose.]

Branch Circuit, General-Purpose.

A branch circuit that supplies ~~two or more receptacles or outlets~~ receptacle(s) or outlet(s) for lighting and appliances. (CMP-2)

Statement of Problem and Substantiation for Public Input

a single receptacle outlet could be used as a general purpose receptacle along a dwelling unit wall. The general purpose branch circuit can be both an individual branch circuit and a general purpose branch circuit.

Submitter Information Verification

Submitter Full Name: Alfio Torrisi
Organization: Master
Street Address:
City:
State:
Zip:
Submittal Date: Mon May 22 19:03:40 EDT 2017

Public Input No. 580-NFPA 70-2017 [New Part after I.]

Crawl Space Definition

Crawl Space. An area with a height of less than 6.5' that is designed to allow human entry.

Statement of Problem and Substantiation for Public Input

The term "crawl space" is used in several places in the NEC, most notably in the new provisions for equipment installed in limited access locations. This definition will help define what locations qualify as crawl spaces. The less than 6.5' dimension was chosen to correspond to the minimum height typically required for working space.

(This is meant to be a new definition in Article 100, but showed up in Terra as a new Part.)

Submitter Information Verification

Submitter Full Name: Christel Hunter

Organization: Cerro Wire

Street Address:

City:

State:

Zip:

Submittal Date: Sun Apr 23 11:52:35 EDT 2017

Public Input No. 2151-NFPA 70-2017 [New Definition after Definition: Combustible Gas Detection ...]

Common Areas (Public Areas).

Common areas, or public areas includes a public hall and any space used in common by the occupants of a two-family dwelling, a multi-family dwelling, or a multi-occupancy building, or by persons who are not tenants, or exclusively for mechanical equipment of such dwelling, or for storage purposes.

Statement of Problem and Substantiation for Public Input

Proposing a new definition for the term “common areas” to clarify what areas or rooms are intended by this term. The term is used in subsection 210.25(B) and identified the type of buildings but not the locations that are accessible to occupant and public in such buildings. I also have used the term to propose a new subsection under 406.12 to address tamper resistant receptacles in common areas.

Submitter Information Verification

Submitter Full Name: MATHHER ABBASSI

Organization: NYC DEPARTMENT OF BUILDINGS

Street Address:

City:

State:

Zip:

Submittal Date: Sun Aug 13 00:09:37 EDT 2017

Public Input No. 2324-NFPA 70-2017 [New Definition after Definition: Disconnecting Means.]

Dormitory: A space in a buiding where group sleeping accomidations are provided in one room, or in a series of closely associated rooms, for persons not member of the same family group, under joint occupancy and single management, as in organizational camp facilities, college dormitories or fraternity houses.

Statement of Problem and Substantiation for Public Input

This definition is necessary to clarify what a dormitory is defined as when applying the code rules found in Articles 210 and 406.

Submitter Information Verification

Submitter Full Name: Dean Hunter

Organization: Minnesota Department of Labor

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 16 15:46:29 EDT 2017

Public Input No. 3225-NFPA 70-2017 [New Definition after Definition: Disconnecting Means.]

DORMITORY

Dormitory. Any occupancy containing a number of beds with common areas and bathroom facilities where people are housed temporarily

Additional Proposed Changes

File Name	Description	Approved
PC_1618.pdf	70_PC1618	✓

Statement of Problem and Substantiation for Public Input

NOTE: This Public Input appeared as “Reject but Hold” in Public Comment No. 1618 of the (A2016) Second Draft Report for NFPA 70 and per the Regs. at 4.4.8.3.1.

Substantiation: Requirements for AFCI protection in 210.12 and tamper-resistant receptacles in 406.12 now apply to dormitories. Without an NEC definition of the word “dormitory” installers and inspectors find this section problematic. Perhaps the code-making panel will provide some guidance on whether this requirement should apply to bunkhouses, church camps, summer-camp cabins, lodges, homeless shelters, etc.. which will greatly help with the application of the rule. Accepting the original proposal for the 2014 NEC the panel specifically removed the word "college" from the new AFCI requirement, however many dictionaries specifically reference "colleges" in their definition of the term. The lack of a definition appears to make broad application of those rules appropriate.

Submitter Information Verification

Submitter Full Name: CMP ON NEC-P02

Organization: Code-Making Panel 2

Street Address:

City:

State:

Zip:

Submittal Date: Mon Sep 04 13:12:02 EDT 2017

Public Comment No. 1618-NFPA 70-2015 [New Definition after Definition: Disconnecting Means.]

Dormitory. Any occupancy containing a number of beds with common areas and bathroom facilities where people are housed temporarily.

Statement of Problem and Substantiation for Public Comment

Requirements for AFCI protection in 210.12 and tamper-resistant receptacles in 406.12 now apply to dormitories. Without an NEC definition of the word “dormitory” installers and inspectors find this section problematic. Perhaps the code-making panel will provide some guidance on whether this requirement should apply to bunkhouses, church camps, summer-camp cabins, lodges, homeless shelters, etc.. which will greatly help with the application of the rule. Accepting the original proposal for the 2014 NEC the panel specifically removed the word "college" from the new AFCI requirement, however many dictionaries specifically reference "colleges" in their definition of the term. The lack of a definition appears to make broad application of those rules appropriate.

Related Item

First Revision No. 5112-NFPA 70-2015 [Section No. 406.12]

First Revision No. 350-NFPA 70-2015 [Section No. 210.12(B)]

Submitter Information Verification

Submitter Full Name:	MARCUS SAMPSON
Organization:	MINNESOTA DEPARTMENT OF LABOR & INDUSTRY
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Fri Sep 25 15:24:40 EDT 2015

Committee Statement

Committee Action:	Rejected but held
Resolution:	The proposed definition of “Dormitory” is new material that has not had public review and is a violation of sections 4.4.4.2 and 4.4.8.3 of the Regulations Governing Development of Standards. The definition is being held for the 2020 NEC development process. CMP-1 requests that this PC be sent to CMP-2 and CMP-18 for information. This new definition will likely fall under the purview of CMP 2. It should be noted that there is a definition of dormitory in NFPA 5000.

Public Input No. 2806-NFPA 70-2017 [New Definition after Definition: Disconnecting Means.]

Dormitory Unit. That portion of a building at a boarding school, college, or university where students live.

Statement of Problem and Substantiation for Public Input

We really need the definition of dormitory unit added to Article 100, since this term is used in 210.12(B), 210.12(D), 210.60, 210.60(A), 240.24(E), 406.12(7), and 550.4(A).

Submitter Information Verification

Submitter Full Name: Mike Holt

Organization: Mike Holt Enterprises Inc

Street Address:

City:

State:

Zip:

Submittal Date: Sat Aug 26 20:00:30 EDT 2017

Public Input No. 3603-NFPA 70-2017 [New Definition after Definition: Disconnecting Means.]

Dormitory Unit. A space in a building where group sleeping accommodations are provided in one, two, or more individual or multi-occupant sleeping facilities that may include provisions for living, cooking, and sanitation.

Informational Note: A dormitory unit may include, but not limited to, college dormitories, assisted living facilities, halfway houses, and shelters.

Statement of Problem and Substantiation for Public Input

The term "dormitory unit" or "dormitories" is used eight times in 4 different articles in the 2017 NEC. This term needs to be defined in order to promote consistency with enforcement and interpretation of the requirements for such things as GFCI requirements and tamper-resistant receptacles in dormitories.

Submitter Information Verification

Submitter Full Name: L Keith Lofland
Organization: IAEI
Affilliation: Self
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 06 14:54:30 EDT 2017

Public Input No. 2158-NFPA 70-2017 [Definition: Ground-Fault Circuit Interrupter (GFCI).]

Ground-Fault Circuit Interrupter (GFCI).

A device intended for the protection of personnel that functions to de-energize a circuit, or portion thereof, within an established period of time when ~~a current to ground~~ the ground-fault current exceeds the values established for a Class A device. (CMP-2)

Informational Note: Class A ground-fault circuit interrupters trip when the ground-fault current ~~to ground~~ is 6 mA or higher and do not trip when the ground-fault current ~~to ground~~ is less than 4 mA. For further information, see UL 943, *Standard for Ground-Fault Circuit Interrupters.*

Statement of Problem and Substantiation for Public Input

The applicable text of UL 943 is as follows: "3.3 CLASS A – Class A, when applied to a ground-fault circuit-interrupter (GFCI), is an interrupter that will interrupt the circuit to the load when the ground-fault current is 6 mA or more but not when the ground-fault current is 4 mA or less." UL uses the phrase "ground-fault current," which is a commonly used phrase in the industry. The NEC currently uses the phrase "current to ground." The phrase "current to ground" is inaccurate because there is no current to ground (soil). The current still returns to its source, just through an alternate path. The most accurate would be to say "imbalance current between the ungrounded and grounded conductor," but since UL uses "ground-fault current," the suggestion is to bring the NEC into alignment with the UL standard.

Submitter Information Verification

Submitter Full Name: Eric Stromberg

Organization: Los Alamos National Laboratory

Affilliation: Self

Street Address:

City:

State:

Zip:

Submittal Date: Sun Aug 13 13:18:42 EDT 2017

Public Input No. 2801-NFPA 70-2017 [Definition: Ground-Fault Circuit Interrupter (GFCI).]

Ground-Fault Circuit Interrupter (GFCI).

A listed, self-testing device intended for the protection of personnel that functions to de-energize a circuit or portion thereof within an established period of time when a current to ground exceeds the values established for a Class A device. (CMP-2)

Informational Note: Class A ground-fault circuit interrupters trip when the current to ground is 6 mA or higher and do not trip when the current to ground is less than 4 mA. For further information, see UL 943, *Standard for Ground-Fault Circuit Interrupters.*

Statement of Problem and Substantiation for Public Input

To clarify the changes in the listing standards for the GFCI device that was added to the listing of such devices after June, 29th, 2015, to require self-testing or auto-monitoring, which provides visual means that a device is working.
Also, to be uniform across the code articles, there are about 10 locations that "listed" is used to describe GFCI, and about 68 other locations that is not mentioned.

Submitter Information Verification

Submitter Full Name: MATHHER ABBASSI
Organization: NYC DEPARTMENT OF BUILDINGS
Street Address:
City:
State:
Zip:
Submittal Date: Sat Aug 26 19:14:31 EDT 2017

Public Input No. 648-NFPA 70-2017 [New Definition after Definition: Guest Suite.]

Habitable Room

A room in a building for living, sleeping, eating or cooking. Bathrooms, toilet rooms, closets, halls, storage or utility spaces and similar areas are not considered habitable room.

Statement of Problem and Substantiation for Public Input

The obvious is "habitable room" is a vague text in the NEC. The IRC, IBC, define habitable space which clearly fit into the context of habitable rooms. This simple definition will be a proper way of code interpretation.

Submitter Information Verification

Submitter Full Name: Mitch Miller

Organization: City of Aspen, Colorado

Street Address:

City:

State:

Zip:

Submittal Date: Thu May 04 14:16:51 EDT 2017

Public Input No. 663-NFPA 70-2017 [New Definition after Definition: Guest Suite.]

Habitable Space: A space in a building for working, living, sleeping, eating or cooking.

Statement of Problem and Substantiation for Public Input

This will add clarity and usability to the code for both the installer and AHJ in relation to section 404.2(C).

Submitter Information Verification

Submitter Full Name: David Hittinger

Organization: Independent Electrical Contractors

Affilliation: Independent Electrical Contractors Codes and Standard

Street Address:

City:

State:

Zip:

Submittal Date: Sat May 06 13:14:46 EDT 2017

Public Input No. 3048-NFPA 70-2017 [Definition: Kitchen.]

Kitchen.

An area with a sink and permanent provisions for food preparation ~~and~~ or cooking. (CMP-2)

Statement of Problem and Substantiation for Public Input

The issue i see in the field is that the "permanent provisions for cooking" excludes many facilities that have at least the same potential for shock hazards. Ice cream parlors, Starbucks, Smoothie stores, just to name a few do not require gfci protection, because there is no stove or oven. Stainless steel refrigerators & freezers that are also being used as counter tops with moisture & condensation throughout increases the likelihood of the shock hazard that the NEC has tried to minimize. These facilities should be addressed

Submitter Information Verification

Submitter Full Name: James Dorsey
Organization: Douglas County Electrical Insp
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 31 10:19:31 EDT 2017

Public Input No. 36-NFPA 70-2017 [New Definition after Definition: Labeled.]

Laundry Area

Is the area within a room dedicated as "Laundry" and within 6 ft. of the washer, dryer and or laundry basin.

Statement of Problem and Substantiation for Public Input

Clarity on definition and requirements for laundry in dwellings

Submitter Information Verification

Submitter Full Name: Dan Haruch

Organization: Brightwood Career Institute

Street Address:

City:

State:

Zip:

Submittal Date: Tue Jan 24 08:43:13 EST 2017

Public Input No. 37-NFPA 70-2017 [New Definition after Definition: Labeled.]

Laundry Room - (Dwelling)

A room designated as "Laundry" having a measuremnet of 60 sqft. or more.

Statement of Problem and Substantiation for Public Input

Clarity on definition and requirements for laundry in dwellings

Submitter Information Verification

Submitter Full Name: Dan Haruch

Organization: Brightwood Career Institute

Street Address:

City:

State:

Zip:

Submittal Date: Tue Jan 24 09:09:28 EST 2017

Public Input No. 3691-NFPA 70-2017 [New Article after 210]

TITLE OF NEW CONTENT

210.2 Definitions

Dormitory Unit. A space in a building where group sleeping accommodations are provided in one room, or in a series of associated rooms, for persons not members of the same family group and may include provisions for living, cooking and sanitation.

Informational note: A dormitory unit may include but are not limited to, college dormitories, assisted living facilities, halfway houses and shelters.

Additional Proposed Changes

File Name	Description	Approved
210.2_New_Definition.docx	210.2 New Definition pictures	

Statement of Problem and Substantiation for Public Input

Currently the term dormitory is used several times within Article 210. This term needs to be defined in order to promote consistency with enforcement and interpretation of the requirements.
Is it the intent that the term dormitory only apply to universities and colleges?

Submitter Information Verification

Submitter Full Name: Richard Hollander
Organization: City of Tucson
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 06 17:17:40 EDT 2017

Public Input No. 4231-NFPA 70-2017 [New Part after I.]

210.2 Definitions.

An area including a washer, a dryer or both.

Statement of Problem and Substantiation for Public Input

Section 210.52 (F) has requirements for a laundry area, but a laundry area is not defined.

Submitter Information Verification

Submitter Full Name: Rhonda Parkhurst

Organization: City of Palo Alto

Street Address:

City:

State:

Zip:

Submittal Date: Thu Sep 07 16:48:05 EDT 2017

Public Input No. 918-NFPA 70-2017 [New Section after 210.4(A)]

TITLE OF NEW CONTENT

Type your content here ..

Manufacturers should manacture for new installations a cable exclusive for multiwirig: Red, Black, Bare and neutral with 3 vertical lines as blue, red and black and fabricate rolls of white with the same color(red, black and blue) for conduit installations.

For retrofits, upgades, etc., manufacturers should fabricate sleeves (like the shrinking ones) in white with the same colors: red, blue, black vertcal lines.

Statement of Problem and Substantiation for Public Input

My English is not so good, but here is anyway. Many peoples specially the unlicensed one, disconnect those neutrals or not identified those. It will clearly shows the neutral for those multiwiring

Submitter Information Verification

Submitter Full Name: Louis Duke

Organization: Louis Phillip Duke (lpd)

Street Address:

City:

State:

Zip:

Submittal Date: Wed Jun 07 14:34:08 EDT 2017

Public Input No. 2278-NFPA 70-2017 [Section No. 210.4(B)]

(B) Disconnecting Means.

Each multiwire branch circuit that supplies more than one device or equipment on the same yoke, shall be provided with a means that will simultaneously disconnect all ungrounded conductors at the point where the branch circuit originates.

Informational Note: See 240.15(B) for information on the use of single-pole circuit breakers as the disconnecting means.

Statement of Problem and Substantiation for Public Input

The use of simultaneous disconnecting means of all multiwire branch circuits which was implemented in the 2005 NEC has not promoted or increased safety for maintenance people that service these installations. Many would agree, the simultaneous disconnecting requirements for multi-wire branch circuits has had an opposite effect of what was intended. Un-qualified persons are more likely to work on multiwire branch circuits while energized.

Since the introduction of LED lighting technology, the use of multiwire branch circuits is becoming a thing of the past. The technology allows for a large number of luminaires on each circuit, of a multiwire branch circuit, which would cover a large floor space. These facilities will not allow maintenance personnel to disconnect these lighting circuits for routine maintenance (i.e. changing ballasts) or even chance an outage, for fear one breaker would leave the plant in the "dark". The use of general purpose branch circuits that has replaced the multiwire branch circuits which has led to more current carrying conductors and larger raceways. The accidental “sharing” of neutrals occurs and un-qualified individuals are still subject to the hazards.

Submitter Information Verification

Submitter Full Name: Dean Hunter

Organization: Minnesota Department of Labor

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 15 19:06:23 EDT 2017

Public Input No. 780-NFPA 70-2017 [Section No. 210.4(C)]

(C) Line-to-Neutral Loads.

Multiwire branch circuits shall supply only line-to-neutral loads.

Exception No. 1: A multiwire branch circuit that supplies only one utilization equipment.

Exception No. 2: Where all ungrounded conductors of the multiwire branch circuit <u>serving the same piece of utilization equipment</u> are opened simultaneously by the branch-circuit overcurrent device.

Statement of Problem and Substantiation for Public Input

In a single phase system such as 120/240V, a load will either be line to neutral or use all of the ungrounded conductors. However, in a 3 phase system such as 208Y/120V, some loads may use only two out of three ungrounded conductors. As an example, a 4-wire multiwire branch circuit could be serving a combination of 120/208V 3-wire loads on phases A and B, and 120V 2-wire loads on phase C. In such a situation the current wording of the exception would require a 3 pole breaker.

In the above example, the safety goals of 240.4(C) as I understand them would still be met by utilizing a double pole breaker on phases A and B handle tied to a single pole breaker on phase C. In situations where using a 3-pole breaker is not possible, e.g. when the 3-wire and 2-wire loads require different breaker sizes, such a multi-wire branch circuit would yield material savings over running separate circuits for the 3-wire and 2-wire loads. The number of conductors required would go from 5 to 4, and the number of current carrying conductors would go down to 3, possibly reducing the conductor derating required.

Thus the proposed change would provide some opportunities for cost saving with no reduction in safety.

Submitter Information Verification

Submitter Full Name: Wayne Whitney

Organization: None

Affilliation: None

Street Address:

City:

State:

Zip:

Submittal Date: Sun May 21 15:00:03 EDT 2017

Copyright Assignment

I, Wayne Whitney, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Wayne Whitney, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 1374-NFPA 70-2017 [Section No. 210.5(C)(1)]

(1) Branch Circuits Supplied from More Than One Nominal Voltage System.

Where the premises wiring system has branch circuits supplied from more than one nominal voltage system, each ungrounded conductor of a branch circuit shall be identified by phase or line and system at all termination, connection, and splice points in compliance with 210.5(C)(1)(a) and (b).

(a) *Means of Identification.* The means of identification shall be permitted to be by separate color coding, marking tape, tagging, or other approved means.

(b) *Posting of Identification Means.* The method utilized for conductors originating within each branch-circuit panelboard or similar branch-circuit distribution equipment shall be documented in a manner that is readily available or shall be permanently posted at each branch-circuit panelboard or similar branch-circuit distribution equipment. The label shall be of sufficient durability to withstand the environment involved and shall not be handwritten.

Exception <u>No. 1</u> : In existing installations where a voltage system(s) already exists and a different voltage system is being added, it shall be permissible to mark only the new system voltage. Existing unidentified systems shall not be required to be identified at each termination, connection, and splice point in compliance with 210.5(C)(1)(a) and (b). Labeling shall be required at each voltage system distribution equipment to identify that only one voltage system has been marked for a new system(s). The new system label(s) shall include the words “other unidentified systems exist on the premises.”

<u>Exception No. 2: Ungrounded conductors of three phase branch circuits serving line to line connected utlization equipment shall not be required to be identifed by phase.</u>

Statement of Problem and Substantiation for Public Input

In the 2014 and earlier editions of the NEC, Article 210 did not include motor branch circuits and the requirement to identify the motor circuit ungrounded conductors by phase and system did not apply to those conductors. The scope of Article 210 was expanded in the 2017 edition to include motor branch circuits. This requires that the ungrounded motor branch circuit conductors be identified by phase and system and requires that any change in motor rotation be made in the motor junction box, not in the motor starter as have long been the common practice. The proposed exception would permit the motor rotation to be changed at the starter and not in the motor junction box. It is much quicker and less costly to change the rotation in the starter than in the motor junction box, especially in industrial applications where the motor terminations are insulated with rubber and plastic tape. It could take an hour or more to change the rotation at the motor junction box for a large motor, where changing the rotation at the starter would only take a few minutes.

The original requirement to identify the ungrounded conductors by phase and system only applied to multiwire circuits, and there are good reasons for that requirement, but those reasons do not apply to three phase branch circuits serving line to line connected loads. The proposed exception leaves in place the requirement that these conductors be identified by system.

Submitter Information Verification

Submitter Full Name: Don Ganiere

Organization: none

Affilliation: none
Street Address:
City:
State:
Zip:
Submittal Date: Thu Jul 27 12:58:37 EDT 2017

Copyright Assignment

I, Don Ganiere, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Don Ganiere, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 1822-NFPA 70-2017 [Section No. 210.5(C)(1)]

(1) Branch Circuits Supplied from More Than One Nominal Voltage System.

Where the premises wiring system has branch circuits supplied from more than one nominal voltage system, each ungrounded conductor of a branch circuit shall be identified by phase ~~or line~~ and system at all termination, connection, and splice points in compliance with 210.5(C)(1)(a) and (b).

(a) *Means of Identification.* The means of identification shall be permitted to be by separate color coding, marking tape, tagging, or other approved means.

(b) *Posting of Identification Means.* The method utilized for conductors originating within each branch-circuit panelboard or similar branch-circuit distribution equipment shall be documented in a manner that is readily available or shall be permanently posted at each branch-circuit panelboard or similar branch-circuit distribution equipment. The label shall be of sufficient durability to withstand the environment involved and shall not be handwritten.

Exception: In existing installations where a voltage system(s) already exists and a different voltage system is being added, it shall be permissible to mark only the new system voltage. Existing unidentified systems shall not be required to be identified at each termination, connection, and splice point in compliance with 210.5(C)(1)(a) and (b). Labeling shall be required at each voltage system distribution equipment to identify that only one voltage system has been marked for a new system(s). The new system label(s) shall include the words “other unidentified systems exist on the premises.”

Statement of Problem and Substantiation for Public Input

the term "or line" is not understood by the masses. I have been an inspector for 16 years and i do not understand what that would look like. Leaving these 2 words in the article just causes confusion that allows interpreted liberties with no clarity. Either make it clear or simply remove the 2 words

Submitter Information Verification

Submitter Full Name: James Dorsey

Organization: Douglas County Electrical Insp

Street Address:

City:

State:

Zip:

Submittal Date: Mon Aug 07 10:36:56 EDT 2017

Copyright Assignment

I, James Dorsey, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am James Dorsey, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 2522-NFPA 70-2017 [Section No. 210.5(C)(1)]

(1) Branch Circuits Supplied from More Than One Nominal Voltage System.

Where the premises wiring system has branch circuits supplied from more than one nominal voltage system, each ungrounded conductor of a branch circuit shall be identified ~~by~~ as a phase or line ~~and~~ conductor, along with the system, at all termination, connection, and splice points in compliance with 210.5(C)(1)(a) and (b).

(a) *Means of Identification.* The means of identification shall be permitted to be by separate color coding, marking tape, tagging, or other approved means.

(b) *Posting of Identification Means.* The method utilized for conductors originating within each branch-circuit panelboard or similar branch-circuit distribution equipment shall be documented in a manner that is readily available or shall be permanently posted at each branch-circuit panelboard or similar branch-circuit distribution equipment. The label shall be of sufficient durability to withstand the environment involved and shall not be handwritten.

Exception: In existing installations where a voltage system(s) already exists and a different voltage system is being added, it shall be permissible to mark only the new system voltage. Existing unidentified systems shall not be required to be identified at each termination, connection, and splice point in compliance with 210.5(C)(1)(a) and (b). Labeling shall be required at each voltage system distribution equipment to identify that only one voltage system has been marked for a new system(s). The new system label(s) shall include the words “other unidentified systems exist on the premises.”

Statement of Problem and Substantiation for Public Input

As written, this requirement makes load balancing and some service nearly impossible. For example, let's assume the color code is A - Black, B - Blue, and C - Red. If a worker needs to shift a three-pole circuit breaker down one space, the color code is no longer correct.

If, after the system is installed, it is found that the some load should be moved from B phase to A phase, in order to balance the load, it cannot be done.

In addition, changing the rotation on a piece of equipment becomes much more troublesome. Consider the case where the feeder for an existing piece of equipment is changed so that it is fed from a piece of equipment that has a different rotation. Two of the conductors of the feeder must be swapped in order to keep the rotation the same. This section, as currently written, makes that job impossible.

With the Code requirements of identifying all the conductors associated with a multi-wire branch circuit, as well as the requirement for a handle tie for these circuits, it is not necessary to know which conductor is A or B or C. It is simply necessary to know that it is a line or phase conductor and what the voltage level is.

Submitter Information Verification

Submitter Full Name: Eric Stromberg

Organization: Los Alamos National Laboratory

Affilliation: Self

Street Address:

City:

State:

Zip:

Submittal Date: Sat Aug 19 22:47:51 EDT 2017

Copyright Assignment

I, Eric Stromberg, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Eric Stromberg, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 454-NFPA 70-2017 [Section No. 210.5(C)(1)]

(1) Branch Circuits Supplied from More Than One Nominal Voltage System.

Where the premises wiring system has branch circuits supplied from more than one nominal voltage system, each ungrounded conductor of a branch circuit shall be identified by phase or line ~~and system~~ and voltage at all termination, connection, and splice points in compliance with 210.5(C)(1)(a) and (b).

(a) *Means of Identification.* The means of identification shall be permitted to be by separate color coding, marking tape, tagging, or other approved means.

(b) *Posting of Identification Means.* The method utilized for conductors originating within each branch-circuit panelboard or similar branch-circuit distribution equipment shall be documented in a manner that is readily available or shall be permanently posted at each branch-circuit panelboard or similar branch-circuit distribution equipment. The label shall be of sufficient durability to withstand the environment involved and shall not be handwritten.

Exception: In existing installations where a voltage system(s) already exists and a different voltage system is being added, it shall be permissible to mark only the new system voltage. Existing unidentified systems shall not be required to be identified at each termination, connection, and splice point in compliance with 210.5(C)(1)(a) and (b). Labeling shall be required at each voltage system distribution equipment to identify that only one voltage system has been marked for a new system(s). The new system label(s) shall include the words "other unidentified systems exist on the premises."

Statement of Problem and Substantiation for Public Input

There are facilities that have several voltage systems, and identifying them by system is essentially impossible. 120/208 wye, 120/240 single phase, 120/240 three phase, 277/480 wye, 480 impedance grounded, and 480 ungrounded all exist in one of the facilities that I consult for. Creating a unique system of identification would be next to impossible. A similar PI is being submitted to 215.12 for consistency.

Submitter Information Verification

Submitter Full Name: Ryan Jackson

Organization: Ryan Jackson

Street Address:

City:

State:

Zip:

Submittal Date: Fri Mar 31 14:39:26 EDT 2017

Copyright Assignment

I, Ryan Jackson, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Ryan Jackson, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 2900-NFPA 70-2017 [Section No. 210.6(C)]

(C) 277 Volts to Ground.

Circuits exceeding 120 volts, nominal, between conductors and not exceeding 277 volts, nominal, to ground shall be permitted to supply the following:

(1) Listed electric-discharge or listed light-emitting diode-type luminaires

(2) Listed incandescent luminaires, where supplied at 120 volts or less from the output of a stepdown autotransformer that is an integral component of the luminaire and the outer shell terminal is electrically connected to a grounded conductor of the branch circuit

(3) Luminaires equipped with mogul-base screw shell lampholders

(4) Lampholders, other than the screw shell type, applied within their voltage ratings

(5) Auxiliary equipment of electric-discharge lamps

Informational Note: See 410.137 for auxiliary equipment limitations.

(6) Cord-and-plug-connected or permanently connected utilization equipment

(7) Listed electric-discharge luminaires converted with a listed retrofit kits to accept LED lamps.

Statement of Problem and Substantiation for Public Input

To provide additional energy efficacy, there are now listed retrofit kits available to convert existing listed electric-discharge luminaires to allow them to accept LED lamps. These lamps have integral LED drivers that operate on voltages in the 120 -277 V range. The listing requirements for the LED retrofit kits require labels be added to the retrofitted luminaire that explain that the luminaire has been retrofitted and that only LED lamps are to be used.

Submitter Information Verification

Submitter Full Name: Michael OBoyle

Organization: Philips Lightolier

Street Address:

City:

State:

Zip:

Submittal Date: Mon Aug 28 20:31:14 EDT 2017

Copyright Assignment

I, Michael OBoyle, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Michael OBoyle, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 1206-NFPA 70-2017 [Section No. 210.8]

210.8 Ground-Fault Circuit-Interrupter Protection for Personnel.

Ground-fault circuit-interrupter protection for personnel shall be provided as required in 210.8(A)through (~~E~~ F). The ground-fault circuit interrupter shall be installed in a readily accessible location.

> Informational Note No. 1: See 215.9 for ground-fault circuit-interrupter protection for personnel on feeders.

> Informational Note No. 2: See 422.5(A) for GFCI requirements for appliances.

For the purposes of this section, when determining distance from receptacles the distance shall be measured as the shortest path the cord of an appliance connected to the receptacle would follow without piercing a floor, wall, ceiling, or fixed barrier, or passing through a door, doorway, or window.

(A) Dwelling Units.

All 125-volt, single-phase, 15- and 20-ampere receptacles installed in the locations specified in 210.8(A)(1) through (10) shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Garages, and also accessory buildings that have a floor located at or below grade level not intended as habitable rooms and limited to storage areas, work areas, and areas of similar use

(3) Outdoors

> *Exception to (3): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.*

(4) Crawl spaces — at or below grade level

(5) Unfinished portions or areas of the basement not intended as habitable rooms

> *Exception to (5): A receptacle supplying only a permanently installed fire alarm or burglar alarm system shall not be required to have ground-fault circuit-interrupter protection.*

> Informational Note: See 760.41(B) and 760.121(B) for power supply requirements for fire alarm systems.

Receptacles installed under the exception to 210.8(A)(5) shall not be considered as meeting the requirements of 210.52(G).

(6) Kitchens — where the receptacles are installed to serve the countertop surfaces

(7) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

(8) Boathouses

(9) Bathtubs or shower stalls — where receptacles are installed within 1.8 m (6 ft) of the outside edge of the bathtub or shower stall

(10) Laundry areas

(B) Other Than Dwelling Units.

All single-phase receptacles rated 150 volts to ground or less, 50 amperes or less and three-phase receptacles rated 150 volts to ground or less, 100 amperes or less installed in the following locations shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Kitchens

(3) Rooftops

Exception: Receptacles on rooftops shall not be required to be readily accessible other than from the rooftop.

(4) Outdoors

Exception No. 1 to (3) and (4): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22, as applicable.

Exception No. 2 to (4): In industrial establishments only, where the conditions of maintenance and supervision ensure that only qualified personnel are involved, an assured equipment grounding conductor program as specified in 590.6(B)(3) shall be permitted for only those receptacle outlets used to supply equipment that would create a greater hazard if power is interrupted or having a design that is not compatible with GFCI protection.

(5) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

Exception No. 1 to (5): In industrial laboratories, receptacles used to supply equipment where removal of power would introduce a greater hazard shall be permitted to be installed without GFCI protection.

Exception No. 2 to (5): For receptacles located in patient bed locations of general care (Category 2) or critical care (Category 1) spaces of health care facilities other than those covered under 210.8(B) (1), GFCI protection shall not be required.

(6) Indoor wet locations

(7) Locker rooms with associated showering facilities

(8) Garages, service bays, and similar areas other than vehicle exhibition halls and showrooms

(9) Crawl spaces — at or below grade level

(10) Unfinished portions or areas of the basement not intended as habitable rooms

(C) Boat Hoists.

GFCI protection shall be provided for outlets not exceeding 240 volts that supply boat hoists installed in dwelling unit locations.

(D) Kitchen Dishwasher Branch Circuit.

GFCI protection shall be provided for outlets that supply dishwashers installed in dwelling unit locations.

(E) Crawl Space Lighting Outlets.

GFCI protection shall be provided for lighting outlets not exceeding 120 volts installed in crawl spaces.

210.8(F) **Outside Branch Circuits.** GFCI protection shall be provided for branch circuit **conductors** installed outside of a building. The ground fault circuit interrupter shall be installed in the circuit **before** the conductors leave the building from which they are supplied. This does not apply to outlets, luminaires, and devices mounted on exterior walls of a building as long as the circuit conductors are installed inside of the walls of the building.

Statement of Problem and Substantiation for Public Input

June of this year I have read about three electrocutions that could have been prevented if the outside conductors were protected by a GFCI device. One, an improperly spliced UF cable feeding an air pump & vacuum unit at a convenience store killed a man sitting on the ground as reported on page 10 in the March issue of EC&M magazine. Second, an eleven year old died after coming in contact with an unused boat lift in Toms River, NJ on June 17 as reported in USA today June 21. Third, a nineteen year man died June 16 in the water at a marina in Put-in-Bay Township, Ohio near his family's boat. Current was felt by others and stopped when shore power to the boat was disconnected
If they were GFCI protected, stray currents and the shock hazard from damaged and improperly installed or spliced conductors installed outside where people can have contact with earth can be eliminated.

Submitter Information Verification

Submitter Full Name: Robert Morin
Organization: Milldale Electric
Street Address:
City:
State:
Zip:
Submittal Date: Fri Jul 21 10:01:54 EDT 2017

Public Input No. 2730-NFPA 70-2017 [Section No. 210.8]

210.8 Ground-Fault Circuit-Interrupter Protection for Personnel.

Ground-fault circuit-interrupter protection for personnel shall be provided as required in 210.8(A)through (E). The ground-fault circuit interrupter shall be installed in a readily accessible location.

Informational Note No. 1: See 215.9 for ground-fault circuit-interrupter protection for personnel on feeders.

Informational Note No. 2: See 422.5(A) for GFCI requirements for appliances.

For the purposes of this section, when determining distance from receptacles the distance shall be measured as the shortest path the cord of an appliance connected to the receptacle would follow without piercing a floor, wall, ceiling, or fixed barrier, or passing through a door, doorway, or window.

(A) Dwelling Units.

All 125-volt, single-phase, 15- and 20-ampere receptacles installed in the locations specified in 210.8(A)(1) through (10) shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Garages, and also accessory buildings that have a floor located at or below grade level not intended as habitable rooms and limited to storage areas, work areas, and areas of similar use

(3) Outdoors

Exception to (3): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

(4) Crawl spaces — at or below grade level

(5) Unfinished portions or areas of the basement not intended as habitable rooms

Exception to (5): A receptacle supplying only a permanently installed fire alarm or burglar alarm system shall not be required to have ground-fault circuit-interrupter protection.

Informational Note: See 760.41(B) and 760.121(B) for power supply requirements for fire alarm systems.

Receptacles installed under the exception to 210.8(A)(5) shall not be considered as meeting the requirements of 210.52(G).

(6) Kitchens — where the receptacles are installed to serve the countertop surfaces

(7) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

(8) Boathouses

(9) Bathtubs or shower stalls — where receptacles are installed within 1.8 m (6 ft) of the outside edge of the bathtub or shower stall

(10) Laundry areas

(B) Other Than Dwelling Units.

All single-phase receptacles rated 150 volts to ground or less, 50 amperes or less and three-phase receptacles rated 150 volts to ground or less, 100 amperes or less installed in the following locations shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Kitchens

(3) Rooftops

Exception: Receptacles on rooftops shall not be required to be readily accessible other than from the rooftop.

(4) Outdoors

Exception No. 1 to (3) and (4): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

Exception No. 2 to (4): In industrial establishments only, where the conditions of maintenance and supervision ensure that only qualified personnel are involved, an assured equipment grounding conductor program as specified in 590.6(B)(3) shall be permitted for only those receptacle outlets used to supply equipment that would create a greater hazard if power is interrupted or having a design that is not compatible with GFCI protection.

(5) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

Exception No. 1 to (5): In industrial laboratories, receptacles used to supply equipment where removal of power would introduce a greater hazard shall be permitted to be installed without GFCI protection.

Exception No. 2 to (5): For receptacles located in patient bed locations of general care (Category 2) or critical care (Category 1) spaces of health care facilities other than those covered under 210.8(B) (1), GFCI protection shall not be required.

(6) Indoor wet locations

(7) Locker rooms with associated showering facilities

(8) Garages, service bays, and similar areas other than vehicle exhibition halls and showrooms

(9) Crawl spaces — at or below grade level

(10) Unfinished portions or areas of the basement not intended as habitable rooms

(C) Boat Hoists.

GFCI protection shall be provided for outlets not exceeding 240 volts that supply boat hoists installed in dwelling unit locations.

(D) Kitchen Dishwasher Branch Circuit.

GFCI protection shall be provided for outlets that supply dishwashers installed in dwelling unit locations.

(E) Crawl Space Lighting Outlets.

GFCI protection shall be provided for lighting outlets not exceeding 120 volts installed in crawl spaces.

(F) Specific Appliances. Unless GFCI protected as permitted in 422.5(B), GFCI protection shall be provided for outlets supplying the following appliances:

(1) Automotive vacuum machines provided for public use

(2) Drinking water coolers

(3) High-pressure spray washing machines — cord-and-plugconnected

(4) Tire inflation machines provided for public use

(5) Vending machines

Statement of Problem and Substantiation for Public Input

The Terra software made a mess of this public input. The only proposed revision is a new first level subdivision (F) for specific appliances.

This public input attempts to correlate requirements for GFCI protection of appliances. Revisions in the 2017 cycle added GFCI requirements for branch circuits in 422.5. That does not add clarity or usability for the user of the NEC. In fact, it creates confusion.

This proposed revision attempts correlate requirements. It permits 422.5 to retain permissive GFCI requirements while moving requirements for protection of the outlet where it is properly located in 210.8 with permissive text to defer to 422.5.

It is understood that there is a purview conflict with CMP-2 and CMP-17 on this issue. The NEC Correlating Committee should monitor this issue to ensure correlation, clarity and usability.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2728-NFPA 70-2017 [Section No. 422.5]	

Submitter Information Verification

Submitter Full Name: James Dollard
Organization: IBEW Local Union 98
Street Address:
City:
State:
Zip:
Submittal Date: Fri Aug 25 12:08:52 EDT 2017

Copyright Assignment

I, James Dollard, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am James Dollard, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 558-NFPA 70-2017 [Section No. 210.8]

210.8 Ground-Fault Circuit-Interrupter Protection for Personnel.

Ground-fault circuit-interrupter protection for personnel shall be provided as required in 210.8(A) through (E). The ground-fault circuit interrupter shall be installed in a readily accessible location.

Informational Note No. 1: See 215.9 for ground-fault circuit-interrupter protection for personnel on feeders.

Informational Note No. 2: See 422.5(A) for GFCI requirements for appliances.

For the purposes of this section, when determining distance from receptacles the distance shall be measured as the shortest path the cord of an appliance connected to the receptacle would follow without piercing a floor, wall, ceiling, or fixed barrier, or passing through a door, doorway, or window.

(A) Dwelling Units.

All 125-volt, single-phase, 15- and 20-ampere receptacles installed in the locations specified in 210.8(A)(1) through (10) shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Garages, and also accessory buildings that have a floor located at or below grade level not intended as habitable rooms and limited to storage areas, work areas, and areas of similar use

(3) Outdoors

Exception to (3): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

(4) Crawl spaces — at or below grade level

(5) Unfinished portions or areas of the basement not intended as habitable rooms

Exception to (5): A receptacle supplying only a permanently installed fire alarm or burglar alarm system shall not be required to have ground-fault circuit-interrupter protection.

Informational Note: See 760.41(B) and 760.121(B) for power supply requirements for fire alarm systems.

Receptacles installed under the exception to 210.8(A)?(5) shall not be considered as meeting the requirements of 210.52(G).

(6) Kitchens — where the receptacles are installed to serve the countertop surfaces

Exception to (6): 125volt receptacles installed behind gas ranges or under gas cook-tops, are not permitted to be ground-fault protected.

Informational Note: When a gfci device has tripped, gas may still be allowed to escape into the room without ignition.

(1) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

(2) Boathouses

(3) Bathtubs or shower stalls — where receptacles are installed within 1.8 m (6 ft) of the outside edge of the bathtub or shower stall

(4) Laundry areas

(B) Other Than Dwelling Units.

All single-phase receptacles rated 150 volts to ground or less, 50 amperes or less and three-phase receptacles rated 150 volts to ground or less, 100 amperes or less installed in the following locations shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Kitchens

(3) Rooftops

Exception: Receptacles on rooftops shall not be required to be readily accessible other than from the rooftop.

(4) Outdoors

Exception No. 1 to (3) and (4): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22, as applicable.

Exception No. 2 to (4): In industrial establishments only, where the conditions of maintenance and supervision ensure that only qualified personnel are involved, an assured equipment grounding conductor program as specified in 590.6(B)(3) shall be permitted for only those receptacle outlets used to supply equipment that would create a greater hazard if power is interrupted or having a design that is not compatible with GFCI protection.

(5) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

Exception No. 1 to (5): In industrial laboratories, receptacles used to supply equipment where removal of power would introduce a greater hazard shall be permitted to be installed without GFCI protection.

Exception No. 2 to (5): For receptacles located in patient bed locations of general care (Category 2) or critical care (Category 1) spaces of health care facilities other than those covered under 210.8(B) (1), GFCI protection shall not be required.

(6) Indoor wet locations

(7) Locker rooms with associated showering facilities

(8) Garages, service bays, and similar areas other than vehicle exhibition halls and showrooms

(9) Crawl spaces — at or below grade level

(10) Unfinished portions or areas of the basement not intended as habitable rooms

(C) Boat Hoists.

GFCI protection shall be provided for outlets not exceeding 240 volts that supply boat hoists installed in dwelling unit locations.

(D) Kitchen Dishwasher Branch Circuit.

GFCI protection shall be provided for outlets that supply dishwashers installed in dwelling unit locations.

(E) Crawl Space Lighting Outlets.

GFCI protection shall be provided for lighting outlets not exceeding 120 volts installed in crawl spaces.

Statement of Problem and Substantiation for Public Input

I have inspected many homes where the coffee machine has tripped the gfci device and a child could easily turn on the flow of gas into the home. Manufacturers I have contacted stated the industry is only installing a relay in gas ovens at this time. The cook top still works without power.

Submitter Information Verification

Submitter Full Name:	Ronald Deering
Organization:	City of Portage
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Tue Apr 18 17:44:35 EDT 2017

Public Input No. 1080-NFPA 70-2017 [Section No. 210.8 [Excluding any Sub-Sections]]

Ground-fault circuit-interrupter protection for personnel shall be provided as required in 210.8(A)through (E). The ground-fault circuit interrupter shall be installed in a readily accessible location.

Informational Note No. 1: See 215.9 for ground-fault circuit-interrupter protection for personnel on feeders.

Informational Note No. 2: See 422.5(A) for GFCI requirements for appliances.

For the purposes of this section, when determining distance from receptacles the distance shall be measured as the shortest path the cord of an appliance connected to the receptacle would follow without piercing a floor, wall, ceiling, or fixed barrier, or passing through a door, doorway, or window.

Additional Proposed Changes

File Name	Description	Approved
GFCI_under_sink_-_Not_required.docx	image from IAEI power point	✓

Statement of Problem and Substantiation for Public Input

Slide number 64 in the IAEI power point titled "Analysis of Changes - 2017 NEC" illustrates the intent to delete the requirement for GFCI protection with the accompanying verbiage: This revision, along with addition to parent text of 210.8 will eliminate the necessity for GFCI protection for receptacles installed inside a cabinet (such as a receptacle for the garbage disposer) as the measurement to the sink would constitute “penetrating a cabinet door” in order to achieve this required 1.8 m (6 ft) measurement. I propose that the code making panel for this section 210.8(A)(7), expand the words to REQUIRE the GFCI protection be extended to the receptacles located in the cabinet under the sink.

Reason 1) We as parents and grandparents watch the children toss out the pots and pans and use the cabinet under the sink as a play station and hiding place as they play their games. Should ANY piece of equipment that is plugged into the receptacle(s) located there fail, and become energized, the child or children would be exposed to electricity and under this section that is already part of the 2017 NEC there is no GFCI protection required. We do not want to explain to the parents that the child died because the Code said it was not a requirement to protect them while they played under the sink.

Reason 2) This is a wet location with grounded surfaces exposed to the repairman (normally a plumber). When the sink leaks, or when the disposal fails and needs servicing, this indeed is a wet location. If the repairman (or plumber) plugs in a trouble light or drill and it is a bit defective, using the unprotected receptacle under the sink exposes the repairman to electricity that is (under the 2017 NEC) Not required to be GFCI protected. I propose the wording of 210.8(A)(7) be modified to read: "or passing through a personnel door, doorway, or window" This change will effectively eliminate the definition of a cabinet door as a "door".

When employed for the City of Lincoln, NE, I was charged with the investigation of electrocution and shock injury incidents, one of which would not even have happened if GFCI had been installed to protect the victim. He would have arrived on time to see his family.

Thank you for your kind consideration.

Ray Paulson
Secretary, Nebraska Chapter IAEI
Chief Electrical Inspector, Hickman, Nebraska
2321 South 13th Street, Lincoln, Nebraska

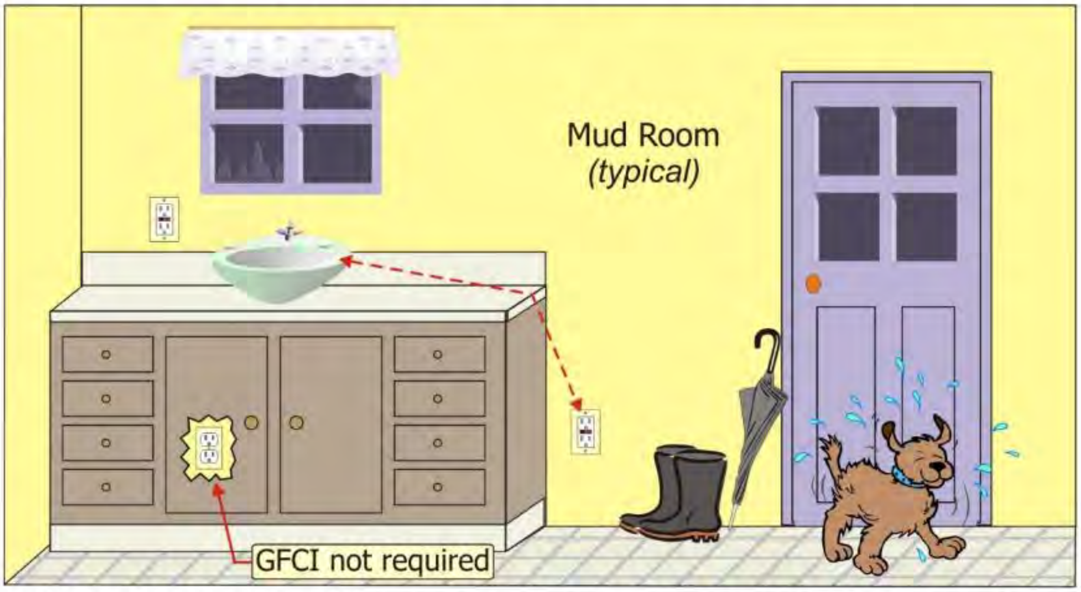
rpaulson@neb.rr.com 402-416-8899 cell

Submitter Information Verification

Submitter Full Name: Raymond Paulson
Organization: National Electrical Continuing Education
Street Address:
City:
State:
Zip:
Submittal Date: Tue Jun 27 21:20:58 EDT 2017

Copyright Assignment

210.8(A)(7) GFCI Protection at Sinks



GFCI required for all 125-volt, single-phase, 15- and 20-ampere receptacles installed within 1.8 m (6 ft) from the top inside edge of a dwelling unit sink *(laundry, utility, mud room, kitchen, wet bar, etc.)* without the measurement piercing a floor, wall, ceiling, or fixed barrier, or passing through a door, doorway, or window

Note: Same requirement at 210.8(B)(5) for non-dwelling unit sinks

Public Input No. 1939-NFPA 70-2017 [Section No. 210.8 [Excluding any Sub-Sections]]

Ground-fault circuit-interrupter protection for personnel shall be provided as required in 210.8(A)through (E). The ground-fault circuit interrupter shall be installed in a readily accessible location.

Informational Note No. 1: See 215.9 for ground-fault circuit-interrupter protection for personnel on feeders.

Informational Note No. 2: See 422.5(A) for GFCI requirements for appliances.

For the purposes of this section, when determining distance from receptacles the distance shall be measured as the shortest path the cord of an appliance connected to the receptacle would follow without piercing a floor, wall, ceiling, or fixed barrier, or passing through a <u>cabinet</u> door <u>opening</u> ,<u>door,</u> doorway, or window.

Statement of Problem and Substantiation for Public Input

Questions have surfaced regarding whether the term “doorway” includes cabinet door openings and whether cabinet door openings were intended to be included in the scope of the measuring requirement. Adding the words “cabinet door opening” as proposed will clarify that measurements are not made through cabinet door openings.

Submitter Information Verification

Submitter Full Name: David Clements

Organization: Intl Assoc Elec Insp

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 09 09:06:24 EDT 2017

Public Input No. 2260-NFPA 70-2017 [Section No. 210.8 [Excluding any Sub-Sections]]

Ground-fault circuit-interrupter protection for personnel shall be provided as required in 210.8(A)through (E). The ground-fault circuit interrupter shall be installed in a readily accessible location.

Informational Note No. 1: See 215.9 for ground-fault circuit-interrupter protection for personnel on feeders.

Informational Note No. 2: See 422.5(A) for GFCI requirements for appliances.

For the purposes of this section, when determining distance from receptacles the distance shall be measured as the shortest path the cord of an appliance connected to the receptacle would follow without piercing a floor, wall, ceiling, or fixed barrier, or passing through a door, doorway, or window.

<u>Exception: With special permission from the authority having jurisdiction a receptacle outlet shall be permitted to be installed without GFCI protection where all of the following conditions are met:</u>

<u>(1) The receptacle outlet is not readily accessible</u>

<u>(2) The receptacle outlet is the single locking-type or nonlocking-type</u>

<u>(3) The receptacle outlet is enclosed in a lockable outlet box hood or similar enclosure, product or assembly</u>

<u>(4) The receptacle outlet supplies equipment that is not otherwise required to be GFCI protected elsewhere in this code</u>

Statement of Problem and Substantiation for Public Input

With concepts and wording borrowed from 210.8(A)(5), 406.9(B), 422.16(B) and 525.23(B), authorities having jurisdiction (AHJ) need a specific provision that would allow the AHJ to approve installations that meet all of the stated conditions. Lacking such a provision, installers often inappropriately alter cord-and-plug-connected equipment in an attempt to permanently connect the equipment. There are countless examples of equipment that is not otherwise required to be GFCI-protected elsewhere in the code, yet because the equipment is manufactured with an attachment cord and plug and plugged into a receptacle outlet, the equipment is forced to be provided with GFCI protection. GFCI protection is not necessary, desirable or warranted in every single installation. NEC 90.1 makes very clear that in addition to persons, the purpose of the code also is the practical safeguarding of property. Unwanted or unintended interruption of power can directly result in catastrophic property damage.

Submitter Information Verification

Submitter Full Name: John Williamson

Organization: Mn Dept Labor And Industry

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 15 16:44:41 EDT 2017

Copyright Assignment

Public Input No. 2291-NFPA 70-2017 [Section No. 210.8 [Excluding any Sub-Sections]]

Ground-fault circuit-interrupter protection for personnel shall be provided as required in 210.8(A)through (E). The ground-fault circuit interrupter shall be installed in a readily accessible location.

Informational Note No. 1: See 215.9 for ground-fault circuit-interrupter protection for personnel on feeders.

Informational Note No. 2: See 422.5(A) for GFCI requirements for appliances.

For the purposes of this section, when determining distance from receptacles; the distance shall be measured as the shortest path the cord of an appliance connected to the receptacle would follow without piercing a floor, wall, ceiling, or fixed barrier, or passing through a ~~door~~ personnel door , doorway, or window.

Statement of Problem and Substantiation for Public Input

This proposal clarifies that the requirement would only apply to walk doors. Receptacles that are located within 6' of the kitchen sink, located behind cabinet doors shall have GFCI protection, to protect individuals a potential shock hazard.

Submitter Information Verification

Submitter Full Name: Dean Hunter
Organization: Minnesota Department of Labor
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 16 07:59:14 EDT 2017

Public Input No. 3429-NFPA 70-2017 [Section No. 210.8 [Excluding any Sub-Sections]]

Ground-fault circuit-interrupter protection for personnel shall be provided as required in 210.8(A)through (E). The ground-fault circuit interrupter shall be installed in a readily accessible location.

Informational Note No. 1: See 215.9 for ground-fault circuit-interrupter protection for personnel on feeders.

Informational Note No. 2: See 422.5(A) for GFCI requirements for appliances.

~~For the purposes of this section, when determining distance from receptacles the distance shall be measured as the shortest path the cord of an appliance connected to the receptacle would follow without piercing a floor, wall, ceiling, or fixed barrier, or passing through a door, doorway, or window.~~

Statement of Problem and Substantiation for Public Input

The paragraph is not needed. A receptacle within six feet of the bathtub, sink or shower stall no matter how it is measured needs to have GFCI protection. Since the 2014 code was published we have required GFCI protection for the receptacles under the kitchen sink as well as those above the sink without any difficulties. There has not been any nuisance tripping reported. For years we have had people being shocked near the sinks, disposals and dishwashers. (A web search will verify that) It doesn't make sense to remove this safety feature after being in the code for a couple years without documented problems.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 06 07:40:25 EDT 2017

Public Input No. 4130-NFPA 70-2017 [Section No. 210.8 [Excluding any Sub-Sections]]

Ground-fault circuit-interrupter protection for personnel shall be provided as required in 210.8(A)through (E). The ground-fault circuit interrupter shall be installed in a readily accessible location.

Informational Note No. 1: See 215.9 for ground-fault circuit-interrupter protection for personnel on feeders.

Informational Note No. 2: See 422.5(A) for GFCI requirements for appliances.

For the purposes of this section, when determining distance from receptacles the distance shall be measured as the shortest path the cord of an appliance connected to the receptacle would follow without piercing a floor, wall, ceiling, or fixed barrier, or passing through a door assembly , doorway assembly , or window.

Statement of Problem and Substantiation for Public Input

The use of Door Assembly was taken from the NFPA Glossary of Terms. It is defined as "Any combination of a door, frame, hardware, and other accessories that is placed in an opening in a wall that is intended primarily for access or for human entrance or exit."

It can and has been argued the reference to a door can apply to personnel doors as well as cabinet doors. The use of door assembly and doorway assembly gives a more concrete definition and interpretation that the reference should pertain only to personnel doors.

The example that has arisen is a wet bar in a dwelling unit room, other than a kitchen. If the wet bar had an appliance garage cabinet with doors at counter top level, as 210.8(A)(6) does not apply outside kitchens, it would not be required to have GFCI protection per the cabinet door interpretation of the word door in 210.8. This unprotected receptacle(s) could service any number of devices to be utilized on this counter space that could pose a hazard when mixed with water.

Another example is the receptacle for a sink disposal. A duplex outlet installed for the purpose of servicing this receptacle could be installed as a half hot/half switched receptacle, or when utilizing a listed cord and plug pneumatic switch would be energized around the clock. Again, any number of appliances could utilize the unused unprotected receptacle.

A receptacle installed in an upper kitchen cabinet for the purpose of an electric can opener or radio that hangs below a cabinet would also be exempt from the requirements of 210.8(A)(6) and 210.8(A)(7) via the cabinet door interpretation of 210.8. A receptacle that supplies a refrigerator in a dwelling unit kitchen that is 6' or less from a sink, duplex or simplex, is required to be GFCI protected per 210.8(A)(7) as the refrigerator is not a permanent barrier. One could argue the receptacle for the radio or can opener is far more accessible than the refrigerator receptacle.So much so, the defined access per Art.100 of those two receptacles would fall under different accessibility definitions.

210.52 gives the required receptacle spacing per defined room usage to discourage occupants via receptacle availability from utilizing an appliance in the room other than the room in which it is receiving its power. That should be the determining factor of what is a doorway for the purpose of GFCI protection.

Submitter Information Verification

Submitter Full Name: Albin Kneggs
Organization: City of Dallas
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 07 14:59:35 EDT 2017

Copyright Assignment

Public Input No. 500-NFPA 70-2017 [Section No. 210.8 [Excluding any Sub-Sections]]

Ground-fault circuit-interrupter protection for personnel shall be provided as required in 210.8(A) through (E). The ground-fault circuit interrupter shall be installed in a readily accessible location.

Informational Note No. 1: See 215.9 for ground-fault circuit-interrupter protection for personnel on feeders.

Informational Note No. 2: See 422.5(A) for GFCI requirements for appliances.

For the purposes of this section, when determining distance from receptacles the distance shall be measured as the shortest path the cord of an appliance connected to the receptacle would follow without piercing a floor, wall, ceiling, or fixed barrier, or passing through a man door, doorway, or window.

Statement of Problem and Substantiation for Public Input

By using the word door it has been declared by national presenters that the receptacles below the sink are not required to be gfci protected. Measuring from the top edge of the sink, the cord would have to penetrate the "cabinet door"This once again leads to multiple shock hazards that have been previously eliminated by requiring gfci protection. Stainless steel trash compactors and other appliances now become a shock hazard. Metal kitchen faucets that are hooked up to a garbage disposal with 120v while standing on a tile floor become a shock hazard. Metal faucet piping, connected to the house copper piping that may have stray currents had additional safety protection by the gfci receptacle. I spent a mere 10 minutes googling people getting shocked from kitchen faucets. There is enough reading that should convince this code panel to re-establish the necessity of practical safeguarding human beings by including all receptacles within 6' of the sink and do not consider the cabinet door as a man door

Submitter Information Verification

Submitter Full Name: james dorsey

Organization: Douglas county

Street Address:

City:

State:

Zip:

Submittal Date: Sun Apr 09 17:30:23 EDT 2017

Public Input No. 3886-NFPA 70-2017 [New Section after 210.8(A)]

Exception to (1) through (10): Locking support and mounting receptacles utilized in combination with compatible attachment fittings shall not be required to be ground-fault circuit-interrupter protected.

Statement of Problem and Substantiation for Public Input

Locking support and mounting receptacles are located on ceilings or high up walls; and therefore, generally are not readily accessible. These receptacles utilized in combination with a compatible attachment fitting are load-make/load-break rated for disconnect. The faceplate prevents access to the outlet box. Work on the utilization equipment (changing bulbs, maintenance, cleaning) is done when the utilization equipment is disconnected, so that the risk of being shocked is greatly reduced and practically eliminated. Attachment fittings do not have cords attached to them. There is no cord to be damaged, that can create an electrical hazard. There is no equipment that personnel will be constantly handling. Once connected the utilization equipment may be considered to be similar to a hard-connected piece of equipment. The installation equipment may be considered as a semi-permanent installation and as such should be treated similar to a permanent installation.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3891-NFPA 70-2017 [New Section after 210.8(B)]	Similar subject.
Public Input No. 3897-NFPA 70-2017 [New Section after 210.8(E)]	Related subject.

Submitter Information Verification

Submitter Full Name: Michael Fontaine

Organization: National Electrical Safety Group, Inc.

Affilliation: SQL Technologies Corp.

Street Address:

City:

State:

Zip:

Submittal Date: Thu Sep 07 07:46:19 EDT 2017

Public Input No. 1496-NFPA 70-2017 [Section No. 210.8(A)]

(A) – **One-Family, Two-Family, and** Dwelling Units of Multifamily Dwelling .

All 125-volt, single-phase, 15- and 20-ampere receptacles installed in ~~the locations specified in 210.8(A) (1) through (10) shall have ground-fault circuit-interrupter protection for personnel.~~

- ~~Bathrooms~~
- ~~Garages, and also accessory buildings that have a floor located at or below grade level not intended as habitable rooms and limited to storage areas, work areas, and areas of similar use~~
- ~~Outdoors~~

  ~~*Exception to (3): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.*~~

- ~~Crawl spaces — at or below grade level~~

~~Unfinished portions or areas of the basement not intended as habitable rooms Exception to (5): A receptacle supplying only a permanently installed fire alarm or burglar alarm system shall not be required to~~ and outside of one-family, two-famly, and inside dwelling uits of multifamily dwellings shall have ground-fault circuit-interrupter protection ~~.~~

~~Informational Note: See 760.41(B) and 760.121(B) for power supply requirements for fire alarm systems.~~

~~Receptacles installed under the exception to 210.8(A) (5) shall not be considered as meeting the requirements of 210.52(G) .~~

- ~~Kitchens — where the receptacles are installed to serve the countertop surfaces~~
- ~~Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink~~
- ~~Boathouses~~
- ~~Bathtubs or shower stalls — where receptacles are installed within 1.8 m (6 ft) of the outside edge of the bathtub or shower stall~~
- ~~Laundry areas~~

for personnel.

Statement of Problem and Substantiation for Public Input

Guys... we are ready for this... lets require all 125-volt, single-phase, 15- and 20-ampere receptacles installed in and outside of one-family, two-famly, and inside dwelling uits of multifamily dwellings GFCI protected.

Submitter Information Verification

Submitter Full Name: Mike Holt

Organization: Mike Holt Enterprises Inc

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 01 11:09:23 EDT 2017

Copyright Assignment

Public Input No. 167-NFPA 70-2017 [Section No. 210.8(A)]

(A) Dwelling Units.

All 125-volt through 250 volt , single-phase, ~~15- and 20-ampere~~ _ receptacles installed in the locations specified in 210.8(A) (1) through (10) shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Garages, and also accessory buildings that have a floor located at or below grade level not intended as habitable rooms and limited to storage areas, work areas, and areas of similar use

(3) Outdoors

Exception to (3): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

(4) Crawl spaces — at or below grade level

(5)

Unfinished portions

or areas of the basement not intended as habitable

rooms

Exception to (5): A receptacle supplying only a permanently installed fire alarm or burglar alarm system shall not be required to have ground-fault circuit-interrupter protection.

Informational Note: See 760.41(B) and 760.121(B) for power supply requirements for fire alarm systems.

Receptacles installed under the exception to 210.8(A) ? (5) shall not be considered as meeting the requirements of 210.52(G).

(6) Kitchens — where the receptacles are installed to serve the countertop surfaces

(7) Sinks — where receptacles are installed within 1.8 m (6 ft)

from

the

top inside

edge of the

bowl of the

sink

(8) Boathouses

(9) Bathtubs or shower stalls — where receptacles are installed within 1.8 m (6 ft) of the outside edge of the bathtub or shower stall

(10) Laundry areas

Additional Proposed Changes

File Name	Description	Approved
Portsmouth_electrocution_Range.docx		✓

Statement of Problem and Substantiation for Public Input

this hazards is acknowledged in other than dwelling units and should be applied to any receptacles regardless of what is being supplied by the receptacle, even in a dwelling application. the limitation of ampacity is not realistic, and could be used as a means to avoid GFCI. there was an electrocution involving a 40 amp receptacle within six feet of a sink this tragedy could have been avoided if this section included 250 V receptacles. boathouse lifts are 250 Volts the same hazard exist as a 120 V circuit. Please follow link https://www.cpsc.gov/Recalls/2017/Following-Plumbers-Death-Electric-Ranges-Recalled-by-Arcelik-AS

Submitter Information Verification

Submitter Full Name: Alfio Torrisi

Organization: Master Electrician

Street Address:

City:

State:

Zip:

Submittal Date: Sat Feb 04 11:19:35 EST 2017

- o NEWS NOW

    - [Astronomy festival to feature search for extraterrestrials](#) ...
    - [Portsmouth has tentative deal to buy 'teepee' land](#) ...
    - [NH, UK Aerospace Consortia sign agreement](#) ...
    - [Astronomy festival to feature search for extraterrestrials](#) ...
    - [Portsmouth has tentative deal to buy 'teepee' land](#) ...
    - [NH, UK Aerospace Consortia sign agreement](#) ...

  - -

- PORTSMOUTH

Fatal accident in Portsmouth condo building under investigation

Electrocution is suspected

- Comment

  1

  1

-
-
-
- **By Elizabeth Dinan**
  edinan@seacoastonline.com

Posted Aug. 16, 2016 at 12:17 PM
Updated Aug 16, 2016 at 6:43 PM

PORTSMOUTH – Police are investigating an "untimely death" in the McIntosh Condominium building Tuesday morning that may have resulted from an apparent electrocution.

Deputy Fire Chief Carl Roediger said his department responded to the building at 8:13 a.m. for a call about a man in cardiac arrest. He said the man was deceased and there are "indications" that he may have been electrocuted. The deceased was later identified as David Dufresne Jr., 52, of Rochester.

"It looked like he was in the process of installing a dishwasher," Roediger said.

The deputy fire chief said a state medical examiner was called to the scene and the man's cause of death is inconclusive until that examiner makes a determination.

Police Sgt. Rich Webb said the fatality is being investigated by police detectives and preliminary findings indicate that the death was accidental.

In an email to city councilors Tuesday morning, City Manager John Bohenko said the work being performed by the deceased, "may have involved replacement of an outlet."

"No building permit was issued for this work, and had one been issued, the work would have been required to be performed by a licensed electrician," Bohenko wrote. "We have requested that our inspector be allowed to investigate the unit more closely when the police are finished with their work, to determine exactly what occurred, and to ensure the unit is safe."

 David Dufresne Jr.

- • **By Elizabeth Dinan**

edinan@seacoastonline.com

Posted Aug. 18, 2016 at 10:45 AM
Updated Aug 18, 2016 at 2:50 PM

PORTSMOUTH – Police have confirmed a Rochester plumber died of an accidental electrocution while working in the McIntosh condominium building on Fleet Street Tuesday and the federal Occupational Safety and Health Administration is investigating.

Detective Sgt. John Peracchi said the police investigation into the death of self-employed plumber David Dufresne Jr., 52, is complete. Further investigation will be conducted by OSHA, he said.

First responders were first notified about Dufresne's death on Aug. 18 at 8:13 a.m. by a 911 caller, Deputy Fire Chief Carl Roediger said Tuesday. According to the public police log, the fatal accident occurred on the sixth floor inside apartment number 2. Roediger said it appeared Dufresne was installing a dishwasher at the time.

Rose Ohar, OSHA's regional director, said her office opened an investigation after learning about Dufresne's death.

"Electrocution is one of our top hazards for fatalities around the country," she said. "So we're taking a close look."

Ohar said OSHA does not have jurisdiction over "sole proprietors," in other words private property, but is investigating anyway.

The public police log noted city inspectors were on scene at the 90 Fleet St. building Tuesday after police detectives cleared. Deputy City Manager Nancy Colbert Puff said Thursday that the city’s electrical inspector, John Plourde, returned to the scene Wednesday "to gain a better understanding as to what might have occurred."

"According to his observation, it appears that the deceased was in the process of installing a dishwasher, however, it also appears that the electrocution was not related to any electrical work being performed," she said. "Instead, he observed that the cord to the recently-installed (cooking) range was not installed per manufacturer’s recommended instructions. In the end, it appears that when the deceased was installing a copper line to the dishwasher, he made contact with the range, which did not have a ground fault path back to the overcurrent device, and ultimately resulted in his tragic passing."

Puff said the city "extends its deepest sympathy to the family of the deceased."

An obituary for Dufresne reports he was born in Portsmouth on Aug. 22, 1963. It notes he was a master plumber, an avid hunter and enjoyed fishing, boating and lobstering.

"David cared deeply for his family and friends," his survivors wrote. "He was a kind, loving, warm and generous man who considered everyone he met a friend for life. If a friend was in need, David made a point to drop everything and lend a hand."

Public Input No. 1801-NFPA 70-2017 [Section No. 210.8(A)]

(A) Dwelling Units.

All 125-volt, single-phase, 15- and 20-ampere receptacles installed in the locations specified in 210.8(A)(1) through (10) shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Garages, and also accessory buildings that have a floor located at or below grade level not intended as habitable rooms and limited to storage areas, work areas, and areas of similar use

(3) Outdoors

Exception to (3): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

(4) Crawl spaces — at or below grade level, where an exposed lamp is installed, and is not provided protection from damage.

(5) Unfinished portions or areas of the basement not intended as habitable rooms

Exception to (5): A receptacle supplying only a permanently installed fire alarm or burglar alarm system shall not be required to have ground-fault circuit-interrupter protection.

Informational Note: See 760.41(B) and 760.121(B) for power supply requirements for fire alarm systems.

Receptacles installed under the exception to 210.8(A)(5) shall not be considered as meeting the requirements of 210.52(G).

(6) Kitchens — where the receptacles are installed to serve the countertop surfaces

(7) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

(8) Boathouses

(9) Bathtubs or shower stalls — where receptacles are installed within 1.8 m (6 ft) of the outside edge of the bathtub or shower stall

(10) Laundry areas

Statement of Problem and Substantiation for Public Input

The electric shock hazard is from an exposed incandescent lamp that is exposed and broken by contact, exposing the energized lamp filament. Circuits for lighting and receptacles on construction sites are required to be kept separate. While we certainly don't want a person to be electrocuted, there are often other hazards to personnel in a crawl space, such as fall hazards such as tripping over concrete supports, falling into a deeper part of the crawl space and hitting your head, etc., black widow spiders, animals, etc.. There could also be a hazard of falling into energized electrical equipment such as an electric furnace that is opened and energized parts are exposed. Requiring additional circuits for the crawl space - such as one for lighting and one for receptacle use may not be reasonable, when a simpler solution is available. either guard the lamp with a cage or a globe, or use a recessed fixture installed in the floor joints above the crawl space. There, personnel are protected because the lamp is protected and less likely to be damaged.

Submitter Information Verification

Submitter Full Name: Michael Weitzel
Organization:
Street Address:
City:
State:
Zip:
Submittal Date: Sat Aug 05 12:12:43 EDT 2017

Copyright Assignment

I, Michael Weitzel, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Michael Weitzel, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 1875-NFPA 70-2017 [Section No. 210.8(A)]

(A) Dwelling Units.

All 125-volt,~~-~~ ~~single~~ and 250 -volt single- phase, 15- ~~and 20~~ thru - 50- ampere receptacles installed in the locations specified in 210.8(A)(1) through (10) shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Garages, and also accessory buildings that have a floor located at or below grade level not intended as habitable rooms and limited to storage areas, work areas, and areas of similar use

(3) Outdoors

Exception to (3): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

(4) Crawl spaces — at or below grade level

(5) Unfinished portions or areas of the basement not intended as habitable rooms

Exception to (5): A receptacle supplying only a permanently installed fire alarm or burglar alarm system shall not be required to have ground-fault circuit-interrupter protection.

Informational Note: See 760.41(B) and 760.121(B) for power supply requirements for fire alarm systems.

Receptacles installed under the exception to 210.8(A)(5) shall not be considered as meeting the requirements of 210.52(G).

(6) Kitchens — where the receptacles are installed to serve the countertop surfaces

(7) Kitchens--- where any applance fixed or portable in the kitchen is located , including, electic ranges, cooktops, ovens, diswashers, refrigerators, microwave, and disposals.

(8) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink, except for 210.8(A)(6)(7)

(9) Boathouses

(10) Bathtubs or shower stalls — where receptacles are installed within 1.8 m (6 ft) of the outside edge of the bathtub or shower stall

(11) Laundry areas, including 250 volt dryers

Statement of Problem and Substantiation for Public Input

Due to the electrocution in Portsmouth NH last August, I was the electrical inspector that did the investigation and found the cause to be a electrocution.
Due to the water and number of branch circuits in the kitchen, having all the receptacles in the kitchen area including 125 thru 250 volts 15 amp thru 50 amp to have ground fault devices to prevent electrical shock hazard.
I would also require the 250 volt dryer to be on a GFCI also for the same reason as stated above.
The 2017 has changed GFCI in other than dwelling, and I would consider dwelling units with small kids,

and elderly would be a big concern with shock hazards.
I have talked to Jeff Sargent of NFPA about the electrocution and he wrote an article in the NFPA Journal a while ago.
If there was a GFCI protection device at that dwelling unit in Portsmouth, the plumber that was installing a copper line to the dishwasher would be alive today.

Submitter Information Verification

Submitter Full Name:	John Plourde
Organization:	CITY OF PORTSMOUTH ELECTRICAL INSPECTION DEPARTMENT
Affilliation:	JP ELECTRICAL ENTERPRISES
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Mon Aug 07 17:03:19 EDT 2017

Public Input No. 1889-NFPA 70-2017 [Section No. 210.8(A)]

(A) Dwelling Units.

All 125-volt, single-phase, 15- and 20-ampere receptacles installed in the locations specified in 210.8(A)(1) through (10) shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Garages, and also accessory buildings that have a floor located at or below grade level not intended as habitable rooms and limited to storage areas, work areas, and areas of similar use

(3) Outdoors

Exception to (3): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

(4) Crawl spaces — at or below grade level

(5) Unfinished portions or areas of the basement not intended as habitable rooms

Exception to (5): A receptacle supplying only a permanently installed fire alarm or burglar alarm system shall not be required to have ground-fault circuit-interrupter protection.

Informational Note: See 760.41(B) and 760.121(B) for power supply requirements for fire alarm systems.

Receptacles installed under the exception to 210.8(A)(5) shall not be considered as meeting the requirements of 210.52(G).

(6) Kitchens — where the receptacles are installed to serve the countertop surfaces

(7) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

(8) Boathouses

(9) Bathtubs or shower stalls — where receptacles are installed within 1.8 m (6 ft) of the outside edge of the bathtub or shower stall

(10) Laundry areas

(11) Indoor wet locations

Statement of Problem and Substantiation for Public Input

2 places we run into this area in a residence and we are unable to enforce the safety measure of gfci protection. In our wealthy jurisdiction we see indoor dog washes and many floor receptacles in the finished basement. Both of these require gfci protection in other than dwelling but not in a residence. The predictable trend is to offer the same safety requirements in dwellings and commercial, this would offer consistency

Submitter Information Verification

Submitter Full Name: James Dorsey
Organization: Douglas County Electrical Insp
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 08 10:13:47 EDT 2017

Public Input No. 3104-NFPA 70-2017 [Section No. 210.8(A)]

(A) Dwelling Units.

All 125-volt, single-phase, 15- and 20-ampere receptacles installed in the locations specified in 210.8(A)(1) through (10) shall have ground-fault circuit-interrupter protection for personnel.The ground-fault circuit interrupter protection required in the locations specified in 210.8 (A)(1), (6) and (10) shall be provided by a receptacle ground-fault circuit interrupter.

(1) Bathrooms

(2) Garages, and also accessory buildings that have a floor located at or below grade level not intended as habitable rooms and limited to storage areas, work areas, and areas of similar use

(3) Outdoors

Exception to (3): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

(4) Crawl spaces — at or below grade level

(5) Unfinished portions or areas of the basement not intended as habitable rooms

Exception to (5): A receptacle supplying only a permanently installed fire alarm or burglar alarm system shall not be required to have ground-fault circuit-interrupter protection.

Informational Note: See 760.41(B) and 760.121(B) for power supply requirements for fire alarm systems.

Receptacles installed under the exception to 210.8(A)(5) shall not be considered as meeting the requirements of 210.52(G).

(6) Kitchens — where the receptacles are installed to serve the countertop surfaces

(7) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

(8) Boathouses

(9) Bathtubs or shower stalls — where receptacles are installed within 1.8 m (6 ft) of the outside edge of the bathtub or shower stall

(10) Laundry areas

Additional Proposed Changes

File Name	Description	Approved
PI_No_3104-NFPA_70-2017_actual_desired_submission_and_substantiation_text.docx	The attached file shows how the proposed text is intended to appear (with	✓

only the additional underlined sentence in the area "(A) Dwelling Units"). There are no other additions, deletions or changes.

Statement of Problem and Substantiation for Public Input

All GFCI's have a "push to test" button, and this "push to test" must be performed monthly. The GFCI providing the required protection specified in 210.8 must be installed in a readily accessible location. As defined in Article 100, the readily accessible requirement provides for reasonably unobstructed access to the GFCI, helping to ensure that the monthly test can be conducted without undue difficulty.

Although this requirement clearly serves the purpose of providing unobstructed access to the GFCI for someone with knowledge of the electrical system, it does little to ensure that the general public will understand how to respond when power is lost due to a GFCI trip. Previous studies indicate that much of the general public is uninformed with respect to the operation of the electrical system in their home. When asked what they do when an electrical appliance they are using fails to operate, a common response is that they simply try plugging the appliance into another receptacle. However, this is hazardous if the appliance has an electrical fault that tripped a GFCI. Plugging a faulty appliance into a receptacle on another circuit not GFCI protected exposes the user to a shock hazard.

All GFCI receptacles are provided with either a visual or audible signal, indicating that the GFCI has tripped. When a GFCI is located at the point of use and a trip occurs, even a user unfamiliar with the electrical system will recognize that the power loss is due to a GFCI trip. The trip indicator on a receptacle GFCI is designed to alert the user that a tripping event has occurred, thereby prompting the user to press the reset button on the GFCI. This results in a much safer installation, as a user is much less likely to attempt to continue to use a defective electrical product if that product results in repeated tripping of a GFCI. If the GFCI providing protection is not located at the point of use, it will remain a mystery to the uninformed user as to why the power has been cut off, prompting the user to use a defective electrical product on some other unprotected outlet. Users unfamiliar with the electrical system are unlikely to search for the source of a power outage (such as a tripped GFCI circuit breaker or GFCI receptacle) in a location other than the room that requires GFCI protection. If the source of power loss cannot be determined by a user unfamiliar with the electrical system, it is not uncommon to expect that extension cords run from areas that are not required to have GFCI protection will be used to bring power to a location where GFCI protection is required.

This proposal is limited to dwelling unit bathrooms, kitchens and laundry areas because these are the locations where the above-described conditions are most likely to occur.

Submitter Information Verification

Submitter Full Name: Stephen Rood

Organization: Legrand North America

Street Address:

City:

State:

Zip:

Submittal Date: Thu Aug 31 14:21:17 EDT 2017

Copyright Assignment

Public Input No. 3104-NFPA 70-2017 [Section No. 210.8(A)]

(A) Dwelling Units.

All 125-volt, single-phase, 15- and 20-ampere receptacles installed in the locations specified in 210.8(A)(1) through (10) shall have ground-fault circuit-interrupter protection for personnel. The ground-fault circuit interrupter protection required in the locations specified in 210.8 (A)(1), (6) and (10) shall be provided by a receptacle ground-fault circuit interrupter.

(1) Bathrooms

(2) Garages, and also accessory buildings that have a floor located at or below grade level not intended as habitable rooms and limited to storage areas, work areas, and areas of similar use

(3) Outdoors

Exception to (3): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22, as applicable.

(4) Crawl spaces — at or below grade level

(5) Unfinished portions or areas of the basement not intended as habitable rooms

Exception to (5): A receptacle supplying only a permanently installed fire alarm or burglar alarm system shall not be required to have ground-fault circuit-interrupter protection.

Informational Note: See 760.41(B) and 760.121(B) for power supply requirements for fire alarm systems.

Receptacles installed under the exception to 210.8(A)(5) shall not be considered as meeting the requirements of 210.52(G).

(6) Kitchens — where the receptacles are installed to serve the countertop surfaces

(7) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

(8) Boathouses

(9) Bathtubs or shower stalls — where receptacles are installed within 1.8 m (6 ft) of the outside edge of the bathtub or shower stall

(10) Laundry areas

Statement of Problem and Substantiation for Public Input

All GFCI's have a "push to test" button, and this "push to test" must be performed monthly. The GFCI providing the required protection specified in 210.8 must be installed in a readily accessible location. As defined in Article 100, the readily accessible requirement provides for reasonably unobstructed access to the GFCI, helping to ensure that the monthly test can be conducted without undue difficulty.

Although this requirement clearly serves the purpose of providing unobstructed access to the GFCI for someone with knowledge of the electrical system, it does little to ensure that the general public will understand how to respond when power is lost due to a GFCI trip. Previous studies indicate that much of the general public is uninformed with respect to the operation of the electrical system in their home. When asked what they do when an electrical appliance they are using fails to operate, a common response is that they simply try plugging the appliance into another receptacle. However, this is hazardous if the appliance has an electrical fault that tripped a GFCI. Plugging a faulty appliance into a receptacle on another circuit not GFCI protected exposes the user to a shock hazard.

All GFCI receptacles are provided with either a visual or audible signal, indicating that the GFCI has tripped. When a GFCI is located at the point of use and a trip occurs, even a user unfamiliar with the electrical system will recognize that the power loss is due to a GFCI trip. The trip indicator on a receptacle GFCI is designed to alert the user that a tripping event has occurred, thereby prompting the user to press the reset button on the GFCI. This results in a much safer installation, as a user is much less likely to attempt to continue to use a defective electrical product if that product results in repeated tripping of a GFCI. If the GFCI providing protection is not located at the point of use, it will remain a mystery to the uninformed user as to why the power has been cut off, prompting the user to use a defective electrical product on some other unprotected outlet. Users unfamiliar with the electrical system are unlikely to search for the source of a power outage (such as a tripped GFCI circuit breaker or GFCI receptacle) in a location other than the room that requires GFCI protection. If the source of power loss cannot be determined by a user unfamiliar with the electrical system, it is not uncommon to expect that extension cords run from areas that are not required to have GFCI protection will be used to bring power to a location where GFCI protection is required.

This proposal is limited to dwelling unit bathrooms, kitchens and laundry areas because these are the locations where the above-described conditions are most likely to occur.

Submitter Information Verification

Submitter Full Name: Stephen Rood

Organization: Legrand North America

Street Address:

City:

State:

Zip:

Submittal Date: Thu Aug 31 14:21:17 EDT 2017

Public Input No. 33-NFPA 70-2017 [Section No. 210.8(A)]

(A) Dwelling Units.

All 125-volt, single-phase, 15- and 20-ampere receptacles installed in the locations specified in 210.8(A) (1) through (10) shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Garages, and also accessory buildings that have a floor located at or below grade level not intended as habitable rooms and limited to storage areas, work areas, and areas of similar use

(3) Outdoors

Exception to (3): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

(4) Crawl spaces — at or below grade level

(5)

Unfinished portions

or areas of the basement not intended as habitable

rooms

Exception to (5): A receptacle supplying only a permanently installed fire alarm or burglar alarm system shall not be required to have ground-fault circuit-interrupter protection.

Informational Note: See 760.41(B) and 760.121(B) for power supply requirements for fire alarm systems.

Receptacles installed under the exception to 210.8(A) ? (5) shall not be considered as meeting the requirements of 210.52(G).

(6) Kitchens — where the receptacles are installed to serve the countertop surfaces

(7) Sinks — where receptacles are installed within 1.8 m (6 ft)

from

the

top inside

edge of the

bowl of the

sink

(8) Boathouses

(9) Bathtubs or shower stalls — where receptacles are installed within 1.8 m (6 ft) of the outside edge of the bathtub or shower stall

(10) Laundry areas - (Laundry area is defined as an area within 6 ft. of washer/dryer or laundry basin.)

Statement of Problem and Substantiation for Public Input

Clarity on definition and requirements for laundry in dwellings

Submitter Information Verification

Submitter Full Name: Dan Haruch
Organization: Brightwood Career Institute
Street Address:
City:
State:
Zip:
Submittal Date: Tue Jan 24 08:23:38 EST 2017

Public Input No. 3431-NFPA 70-2017 [Section No. 210.8(A)]

(A) Dwelling Units.

All 125-volt, single-phase, 15- and 20-ampere receptacles installed in the locations specified in 210.8(A)(1) through (10) shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Garages, and also accessory buildings that have a floor located at or below grade level not intended as habitable rooms and limited to storage areas, work areas, and areas of similar use

(3) Outdoors

Exception to (3): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

(4) Crawl spaces — at or below grade level

(5) Unfinished portions or areas of the basement not intended as habitable rooms, including sump pumps.

Exception to (5): A receptacle supplying only a permanently installed fire alarm or burglar alarm system shall not be required to have ground-fault circuit-interrupter protection.

Informational Note: See 760.41(B) and 760.121(B) for power supply requirements for fire alarm systems.

Receptacles installed under the exception to 210.8(A)(5) shall not be considered as meeting the requirements of 210.52(G).

(6) Kitchens — where the receptacles are installed to serve the countertop surfaces

(7) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

(8) Boathouses

(9) Bathtubs or shower stalls — where receptacles are installed within 1.8 m (6 ft) of the outside edge of the bathtub or shower stall

(10) Laundry areas

Statement of Problem and Substantiation for Public Input

The only changes proposed are to the first line of (5). "including sump pumps"
The sump pump should be included in this section to enhance the requirement. The circuits to sump pumps are normally in basements or crawl spaces. The manufacturers of sump pump also require them to be GFCI protected. There was a local proposal to provide an exemption for the sump pump to be GFCI protected because of nuisance tripping of the device. I spoke to two home builders in my area that construct nearly 1,000 homes per year to see if they have had any call backs regarding GFCI tripping on sump pumps and neither of them were aware of any problems, this requirement has been enforced for a number of years.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 06 07:48:28 EDT 2017

Public Input No. 3962-NFPA 70-2017 [Section No. 210.8(A)]

(A) Dwelling Units.

All 125-volt, single-phase, 15- and 20-ampere ~~receptacles installed in the locations specified in 210.8(A) (1) through (10) shall have~~ branch circuits supplying outlets installed in dwelling units, accessory buildings,garages, or boat houses shall be protected by a listed ground-fault circuit ~~-~~ interrupter protection for personnel.

- ~~Bathrooms~~
- ~~Garages, and also accessory buildings that have a floor located at or below grade level not intended as habitable rooms and limited to storage areas, work areas, and areas of similar use~~

~~Outdoors Exception to (3)~~

Exception No. 1 : Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

- ~~Crawl spaces — at or below grade level~~

~~Unfinished portions or areas of the basement not intended as habitable roomsException to (5)~~

Exception No. 2 : A receptacle supplying only a permanently installed fire alarm or burglar alarm system shall not be required to have ground-fault circuit-interrupter protection.

Informational Note: See 760.41(B) and 760.121(B) for power supply requirements for fire alarm systems.

~~Receptacles installed under the exception to 210.8(A) (5) shall not be considered as meeting the requirements of 210.52(G) .~~

- ~~Kitchens — where the receptacles are installed to serve the countertop surfaces~~
- ~~Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink~~
- ~~Boathouses~~
- ~~Bathtubs or shower stalls — where receptacles are installed within 1.8 m (6 ft) of the outside edge of the bathtub or shower stall~~
- ~~Laundry areas~~

Statement of Problem and Substantiation for Public Input

Because of changes made to the NEC the last few decades, electrocutions have been reduced significantly in residential dwellings. The issue is that this number is not yet zero.
This change would significantly increase the shock protection within residential electrical systems. All 15 and 20 amp conductors would be protected against short circuits, overloads, and ground faults (including people protection). The added ground fault protection has several benefits.

- Protects people remodeling or renovating existing structures.
- Protects DIY homeowners from shock hazards when doing their own electrical work (replacing a switch or outlet)
- Protects against electrical shock when fastening objects to interior and exterior walls.
- Reduces shock risk around damaged structures (Flood, Fire, Hurricane, Tornado, etc)

Real world justification

- Jacksonville Fire Department Firefighter Electrocuted At Incident Site

United States (Texas) - Jacksonville Fire Department Lt. David Glidewell received a medium strength electrical shock at a house fire on the 900 block of Fort Worth at around 7:30 p.m. Tuesday. Fire Marshall Dennis Tate said Glidewell was treated and released from ETMC-Jacksonville Tuesday evening and should be back to work Thursday. Tate estimated the strength of the shock at about 120 Volts. Fire Chief Paul White said some of the area emergency personnel have taken to calling him "Sparky" after the incident. "The paramedics from East Texas Medical Center started calling him Sparky," White said.
Tate said the home had a fire in an electrical box in a garage just outside of a brick wall. "It got a little water in it," Tate said. He said responding firefighters, Glidewell included, began cutting into the wall with saws to get to the fire, but he said Glidewell accidentally cut into a conduit with power still flowing through it.
"It just got him," Tate said. "Probably about a medium shock; it shocked him pretty good. He didn't lose consciousness, it just let him know he got into some electricity."
Glidewell was knocked onto his back and was sprawled out on the ground after being shocked, White said. He added Glidewell reported a tingling feeling in his digits.
White said it is standard practice to turn any meters or electrical boxes off before cutting, but noted this meter had become charged so fire fighters could not touch it. "I suspect lightning struck it or the meter shorted out," White said. He said the firefighters followed procedure as safely as they were able. "We have a lot of protection, but when you're standing in water and everything's wet, there's not much you can do," he said. "This was unique because we couldn't pull the meter. It was charged."
Tate said the fire itself resulted in a lot of smoke, but added the fire was in the walls and remained mostly hidden from view. White said the fire didn't result in high damage. Glidewell could not be reached for comment at press time.
Written by Jacksonville Daily Progress
Courtesy of YellowBrix

- C.T. firefighter electrocuted in cottage blaze!

January 8, 2010 (NewYorkInjuryNews.com - Injury News, Work Related Fire Fighter Deaths)
Legal news for Connecticut work-related firefighter death attorneys–A firefighter was electrocuted by an electrical wire while battling a blaze in Branford, Connecticut.
Branford, CT (NewYorkInjuryNews.com) – A two-cottage fire on Lanphiers Cove Road injured one firefighter in Branford Tuesday, January 5, 2010, according to New Haven Register.
A witness who saw the climbing flames from the town dock located at Branford Point reported it at 2:58 a.m. Responding firefighters arrived at the scene where one of the summer homes siding and exterior wall was already visibly damaged. One firefighter was crawling through water underneath the cottage when a live electrical wire struck the water and electrocuted him.
The firefighter, identified as John Massey Jr. was transported via ambulance to be treated by doctors and nurses at Yale-New Haven Hospital. Medical officials reported that Massey’s injuries were minor. The two cottages were unoccupied at the time of the blaze since both residencies were summerhouses.
The addresses of the properties damaged by the flames, water, and smoke were 23 and 24 Lanphiers Cove. Firefighters continue to look into what caused the fire. The United States Fire Administration (USFA) www.usfa.gov reported that there were 13.2 deaths per million people in the nation in 2006. In Connecticut, there was a reported 6.6, which is one of the lower death rates compared to the rest of the county.
Bridget Hom

Submitter Information Verification

Submitter Full Name: Kenneth Rempe
Organization: Siemens Industry Inc
Affilliation: American Circuit Breaker Manufacturers Association
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 07 10:39:43 EDT 2017

Copyright Assignment

I, Kenneth Rempe, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Kenneth Rempe, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 4042-NFPA 70-2017 [Section No. 210.8(A)]

(A) Dwelling Units.

All 125-volt, single-phase, 15- and 20-ampere receptacles installed in the locations specified in 210.8(A)(1) through (10) shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Garages, and also accessory buildings that have a floor located at or below grade level not intended as habitable rooms and limited to storage areas, work areas, and areas of similar use

(3) Outdoors

Exception to (3): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

(4) Crawl spaces — at or below grade level

(5) Unfinished portions or areas of the basement not intended as habitable rooms

Exception to (5): A receptacle supplying only a permanently installed fire alarm or burglar alarm system shall not be required to have ground-fault circuit-interrupter protection.

Informational Note: See 760.41(B) and 760.121(B) for power supply requirements for fire alarm systems.

Receptacles installed under the exception to 210.8(A)(5) shall not be considered as meeting the requirements of 210.52(G).

(6) Kitchens — where the receptacles are installed to serve the countertop surfaces

(7) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

(8) Boathouses

(9) Bathtubs or shower stalls — where receptacles are installed within 1.8 m (6 ft) of the outside edge of the bathtub or shower stall

(10) Laundry areas

Exception: Ground−fault circuit−interrupter protection shall not be required for a single receptacle providing power for sump or sewage pumps where an accessible ground−fault circuit−interrupter protected receptacle is located within 900 mm (3 ft) of the non−GFCI protected receptacle.

?

Statement of Problem and Substantiation for Public Input

Add new exception to the main requirement to allow a sump type pump to be plugged into a non-gfci protected receptacle to maintain reliability as had been allowed in the past, however require a GFCI protected general use receptacle within 3 feet to have a place to use power without plugging a splitter device into the non-gfci receptacle.

Submitter Information Verification

Submitter Full Name: Steven Froemming
Organization: City of Franklin
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 07 12:56:05 EDT 2017

Public Input No. 599-NFPA 70-2017 [Section No. 210.8(A)]

(A) Dwelling Units.

All 125-volt, single-phase, 15- and 20-ampere receptacles installed in the locations specified in 210.8(A)(1) through (10) shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Garages, and also accessory buildings that have a floor located at or below grade level not intended as habitable rooms and limited to storage areas, work areas, and areas of similar use

(3) Outdoors

Exception to (3): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

(4) Crawl spaces — at or below grade level

(5) ~~Unfinished portions or areas~~ Unfinished areas of the basement not intended as habitable rooms

Exception to (5): A receptacle supplying only a permanently installed fire alarm or burglar alarm system shall not be required to have ground-fault circuit-interrupter protection.

Informational Note: See 760.41(B) and 760.121(B) for power supply requirements for fire alarm systems.

Receptacles installed under the exception to 210.8(A)?(5) shall not be considered as meeting the requirements of 210.52(G).

(6) Kitchens — where the receptacles are installed to serve the countertop surfaces

(7) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

(8) Boathouses

(9) Bathtubs or shower stalls — where receptacles are installed within 1.8 m (6 ft) of the outside edge of the bathtub or shower stall

(10) Laundry areas

Statement of Problem and Substantiation for Public Input

Based on the conversations I have heard and or been a part of through various code discussion groups and forums, there is still confusion among installers and inspectors alike about the meaning of this rule. Is this rule intended to apply to finished areas of basements if they are not intended as habitable rooms? The literal wording is being interpreted as such. The rule is being interpreted as applying to two different parts of the basement- one area being the "unfinished portion", and the other area being "areas of the basement not intended as habitable rooms" even if the area is finished, such as a closet or storage area or some other finished room such as a play room, meditation room or exercise room, that may not meet all of the building code requirements for a habitable room but is nonetheless, "finished". I do not believe the intent of this rule is to apply the GFCI requirements to "finished" areas of the basement. I believe my proposed revision will remove some redundant wording and help clarify the intent of this rule as well as align better with the wording I have proposed for Section 210.8(A)(2).

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 600-NFPA 70-2017 [Section No. 210.8(A)]	GFCI protection for "unfinished areas"

Submitter Information Verification

Submitter Full Name: Russ Leblanc

Organization: Leblanc Consulting Services

Street Address:

City:

State:

Zip:

Submittal Date: Wed Apr 26 17:49:27 EDT 2017

Public Input No. 600-NFPA 70-2017 [Section No. 210.8(A)]

(A) Dwelling Units.

All 125-volt, single-phase, 15- and 20-ampere receptacles installed in the locations specified in 210.8(A)(1) through (10) shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Garages, and also accessory ~~buildings that have a floor~~ buildings where the floor is located at or below grade level, in unfinished areas not intended ~~as habitable rooms and limited to storage areas, work areas, and areas of similar use~~ as habitable rooms.

(3) Outdoors

Exception to (3): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

(4) Crawl spaces — at or below grade level

(5) Unfinished portions or areas of the basement not intended as habitable rooms

Exception to (5): A receptacle supplying only a permanently installed fire alarm or burglar alarm system shall not be required to have ground-fault circuit-interrupter protection.

Informational Note: See 760.41(B) and 760.121(B) for power supply requirements for fire alarm systems.

Receptacles installed under the exception to 210.8(A)?(5) shall not be considered as meeting the requirements of 210.52(G).

(6) Kitchens — where the receptacles are installed to serve the countertop surfaces

(7) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

(8) Boathouses

(9) Bathtubs or shower stalls — where receptacles are installed within 1.8 m (6 ft) of the outside edge of the bathtub or shower stall

(10) Laundry areas

Statement of Problem and Substantiation for Public Input

Based on the conversations I have heard and/or been a part of through various code discussion groups and forums, there is still confusion among installers and inspectors alike about the meaning of this rule. The literal wording requires GFCI protection for these receptacles throughout the entire garage or accessory building as long as the building has at least one floor "located at or below grade level". What about receptacles on the second floor of the garage or accessory building? Do they need GFCI protection too? Based on the literal wording, the answer is YES if there is a floor " located at or below grade level" !!!!!. I don't think that the intent of this rule is to require GFCI protection for these receptacles on the second floor, or other finished areas such as an exercise room or perhaps a home office on the second floor over the garage. I believe the intent of this rule is to apply GFCI protection to unfinished areas where the floor is located at or below grade level. My proposed revision will help clarify the intent and will align similarly with the wording in 210.8(A)(5).

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 599-NFPA 70-2017 [Section No. 210.8(A)]	GFCI protection for "unfinished area"

Submitter Information Verification

Submitter Full Name: Russ Leblanc
Organization: Leblanc Consulting Services
Street Address:
City:
State:
Zip:
Submittal Date: Wed Apr 26 18:21:19 EDT 2017

Public Input No. 46-NFPA 70-2017 [New Section after 210.8(A)]

TITLE OF NEW CONTENT

Type your content here ...

(11) Finished basements – where a concrete subfloor is without a nonconductive covering such as carpet, wood, composite or similar materials.

Statement of Problem and Substantiation for Public Input

Ground-fault circuit interrupter protection is presently required for 125 volt, 15 and 20 ampere receptacles installed in unfinished basements of one and two family dwellings. These unfinished areas expose the user of electrical equipment and devices to grounded surfaces and or surfaces in contact to the earth through concrete floors, masonry walls and steel columns embedded in concrete floors. Even with modern construction methods of placing basement concrete slabs over a layer of polyethylene, the concrete slab is still in contact to the earth thru contact with the masonry walls and steel columns.

Finished basement area floors that have a painted concrete floor or tiled areas with masonry grout in contact with a concrete floor or masonry walls are indirectly in contact with the earth. The receptacle outlets in these areas are frequently used for plugging in lamps, televisions and interactive games systems while the user may be on the floor without skin coverings such as shoes and socks, leg coverings and arm coverings. In the event of contact with the non-grounded blade of a plug while plugging the device into or unplugging the device to the receptacle outlet or a defective electric appliance will create a shock hazard without GFCI protection to de-energize the circuit. The user is at the same risk of shock hazard as in an unfinished basement.

Submitter Information Verification

Submitter Full Name: Darrell Zepp

Organization: Electrical Inspector

Street Address:

City:

State:

Zip:

Submittal Date: Wed Jan 25 07:29:50 EST 2017

Public Input No. 3673-NFPA 70-2017 [Sections 210.8(A), 210.8(B)]

Sections 210.8(A), 210.8(B)

(A) Dwelling Units.

All 125-volt, single-phase, 15- and 20-ampere receptacles installed in the locations specified in 210.8(A) (1) through (10) shall have ground-fault circuit-interrupter protection for personnel. The ground-fault circuit interrupter shall be the receptacle type.

Informational Note: The addition of auto-monitoring requirements to UL 943, Standard for Ground Fault Circuit Interrupters, that became effective on May 17, 2016 contains wo exemptions for circuit breaker type ground fault circuit interrupters due to constructional limitations. Listed receptacle type ground fault circuit interrupters are required to meet the two additional requirements without exception.

(1) Bathrooms

(2) Garages, and also accessory buildings that have a floor located at or below grade level not intended as habitable rooms and limited to storage areas, work areas, and areas of similar use

(3) Outdoors

Exception to (3): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

(4) Crawl spaces — at or below grade level

(5) Unfinished portions or areas of the basement not intended as habitable rooms

Exception to (5): A receptacle supplying only a permanently installed fire alarm or burglar alarm system shall not be required to have ground-fault circuit-interrupter protection.

Informational Note: See 760.41(B) and 760.121(B) for power supply requirements for fire alarm systems.

Receptacles installed under the exception to 210.8(A)(5) shall not be considered as meeting the requirements of 210.52(G).

(6) Kitchens — where the receptacles are installed to serve the countertop surfaces

(7) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

(8) Boathouses

(9) Bathtubs or shower stalls — where receptacles are installed within 1.8 m (6 ft) of the outside edge of the bathtub or shower stall

(10) Laundry areas

(B) Other Than Dwelling Units.

All single-phase receptacles rated 150 volts to ground or less, 50 amperes or less and three-phase receptacles rated 150 volts to ground or less, 100 amperes or less installed in the following locations shall have ground-fault circuit-interrupter protection for personnel. The ground-fault circuit interrupter shall be the receptacle type.

Informational Note: The addition of auto-monitoring requirements to UL 943, Standard for Ground Fault Circuit Interrupters, that became effective on May 17, 2016 contains wo exemptions for circuit breaker type ground fault circuit interrupters due to constructional limitations. Listed receptacle type ground fault circuit interrupters are required to meet the two additional requirements without exception.

(1) Bathrooms

(2) Kitchens

(3) Rooftops

Exception: Receptacles on rooftops shall not be required to be readily accessible other than from the rooftop.

(4) Outdoors

Exception No. 1 to (3) and (4): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

Exception No. 2 to (4): In industrial establishments only, where the conditions of maintenance and supervision ensure that only qualified personnel are involved, an assured equipment grounding conductor program as specified in 590.6(B)(3) shall be permitted for only those receptacle outlets used to supply equipment that would create a greater hazard if power is interrupted or having a design that is not compatible with GFCI protection.

(5) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

Exception No. 1 to (5): In industrial laboratories, receptacles used to supply equipment where removal of power would introduce a greater hazard shall be permitted to be installed without GFCI protection.

Exception No. 2 to (5): For receptacles located in patient bed locations of general care (Category 2) or critical care (Category 1) spaces of health care facilities other than those covered under 210.8(B) (1), GFCI protection shall not be required.

(6) Indoor wet locations

(7) Locker rooms with associated showering facilities

(8) Garages, service bays, and similar areas other than vehicle exhibition halls and showrooms

(9) Crawl spaces — at or below grade level

(10) Unfinished portions or areas of the basement not intended as habitable rooms

Additional Proposed Changes

File Name	Description	Approved

PI_3673.docx	The attached is the PI in word format. It appears TerraView marked up more changes than what I had submitted. I want to make sure the original is included for reference.	✓

Statement of Problem and Substantiation for Public Input

The updated UL 943 Standard for Ground-fault Circuit Interrupters that had went into effect in 2016 added new auto-monitoring requirements resulting in greatly improved GFCI safety and protection. The intent of the auto-monitoring function is to warn the users whenever the GFCI device's ability to protect is impaired or lost.

The original substantiation for the auto-monitoring requirements, and which components to test, came from the 2001 NEMA study titled GFCI Field Test Survey Report. Both the Consumer Product Safety Commission and Underwriters Laboratories participated in the study as well. However, two exceptions allowing circuit breaker type GFCIs to not provide warning when their SCR or trip coil fails open, had resulted in two levels of personnel protection. These two failure modes represent real life component failures. There are no differences between SCRs and trip coils used in circuit breaker and receptacle constructions, and they both can fail due to many environmental causes. As reported in the GFCI Field Test Survey, SCR and trip coil failures, representing 2 of the 7 identified causes of failure, were found in recovered circuit breaker GFCIs with "reset but No Trip" as the failure mode. It is important to remember that they represent complete loss of ground fault protection. These failed GFCI breakers can easily be reset and have the appearance of functioning normally (when in reality, only capable of providing overcurrent protection) thus creating a false sense of protection for the general public. For receptacle type GFCIs, such component failures will result in warning indications or reset lockout to encourage the users to take life-saving steps to replace a safety device that has reached the end of its life.

The introduction of GFCIs had resulted in significant decreases in electrocutions and death. The addition of auto-monitoring function to UL 943 will ensure further improvements upon that success. The exceptions currently permitted in UL 943 for circuit breaker GFCI have created two levels of safety and will result in unwanted and unacceptable loss of personnel protection. This proposal ensures the public is afforded the safest available personnel protection.

Submitter Information Verification

Submitter Full Name: Frank Tse

Organization: Leviton Manufacturing Company

Street Address:

City:

State:

Zip:

Submittal Date: Wed Sep 06 16:46:50 EDT 2017

Public Input #3673 – NFPA 70 (2020)

Proposal:

210.8 Ground-Fault Circuit-Interrupter Protection for Personnel.

Ground-fault circuit-interrupter protection for personnel shall be provided as required in 210.8(A) through (E). The ground-fault circuit interrupter shall be installed in a readily accessible location.

Informational Note No. 1: See 215.9 for ground-fault circuit interrupter protection for personnel on feeders.

Informational Note No. 2: See 422.5(A) for GFCI requirements for appliances.

For the purposes of this section, when determining distance from receptacles the distance shall be measured as the shortest path the cord of an appliance connected to the receptacle would follow without piercing a floor, wall, ceiling, or fixed barrier, or passing through a door, doorway, or window.

(A) Dwelling Units. All 125-volt, single-phase, 15- and 20-ampere receptacles installed in the locations specified in 210.8(A)(1) through (10) shall have ground-fault circuit interrupter protection for personnel. <u>The ground-fault circuit interrupter shall be the receptacle type.</u>

<u>Informational Note: The addition of auto-monitoring requirements to UL 943, Standard for Ground Fault Circuit Interrupters, that became effective on May 17, 2016 contains two exemptions for circuit breaker-type Ground Fault Circuit Interrupters due to constructional limitations. Listed receptacle type Ground Fault Circuit Interrupters are required to meet the two additional requirements without exemption.</u>

(B) Other Than Dwelling Units. All single-phase receptacles rated 150 volts to ground or less, 50 amperes or less and three phase receptacles rated 150 volts to ground or less, 100 amperes or less installed in the following locations shall have ground-fault circuit-interrupter protection for personnel. <u>The ground-fault circuit interrupter shall be the receptacle type.</u>

<u>Informational Note: The addition of auto-monitoring requirements to UL 943, Standard for Ground Fault Circuit Interrupters, that became effective on May 17, 2016 contains two exemptions for circuit breaker-type Ground Fault Circuit Interrupters due to constructional limitations. Listed receptacle type Ground Fault Circuit Interrupters are required to meet the two additional requirements without exemption.</u>

Public Input No. 4072-NFPA 70-2017 [New Section after 210.8(B)]

TITLE OF NEW CONTENT

-

Type your content here ... UNDER 210.8 (B) ADD (11) LAUNDRY AREAS

Statement of Problem and Substantiation for Public Input

LAUNDRY AREAS IN DWELLING REQUIRE GFCI PROTECTION FOR 15 AND 20 AMP 125 VOLT SINGLE PHASE CIRCUITS ALREADY, THERE IS NO DIFFERENCE IN THE HAZARD OUTSIDE OF A DWELLING UNIT

Submitter Information Verification

Submitter Full Name: RICHARD WOLFE
Organization: NDSEB
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 07 13:27:19 EDT 2017

Public Input No. 3891-NFPA 70-2017 [New Section after 210.8(B)]

Exception to (1) to (10): Locking support and mounting receptacles utilized in combination with compatible attachment fittings shall not be required to be ground-fault circuit-interrupter protected.

Statement of Problem and Substantiation for Public Input

Locking support and mounting receptacles are located on ceilings or high up walls; and therefore, generally are not readily accessible. These receptacles utilized in combination with a compatible attachment fitting are load-make/load-break rated for disconnect. The faceplate prevents access to the outlet box. Work on the utilization equipment (changing bulbs, maintenance, cleaning) is done when the utilization equipment is disconnected, so that the risk of being shocked is greatly reduced and practically eliminated. Attachment fittings do not have cords attached to them. There is no cord to be damaged, that can create an electrical hazard. There is no equipment that personnel will be constantly handling. Once connected the utilization equipment may be considered to be similar to a hard-connected piece of equipment. The installation equipment may be considered as a semi-permanent installation and as such should be treated similar to a permanent installation.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3886-NFPA 70-2017 [New Section after 210.8(A)]	Similar subject.

Submitter Information Verification

Submitter Full Name: Michael Fontaine

Organization: National Electrical Safety Group, Inc.

Affilliation: SQL Technologies Corp.

Street Address:

City:

State:

Zip:

Submittal Date: Thu Sep 07 08:08:23 EDT 2017

Public Input No. 1079-NFPA 70-2017 [Section No. 210.8(B)]

(B) Other Than Dwelling Units.

All single-~~phase receptacles~~ phase receptacles supplied by branch circuits rated 150 volts to ground or less, 50 amperes or less and three-~~phase receptacles rated~~ phase receptacles supplied by branch circuits rated 150 volts to ground or less, 100 amperes ~~or less installed in the following locations shall~~ or less shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Kitchens

(3) Rooftops

Exception: Receptacles on rooftops shall not be required to be readily accessible other than from the rooftop.

(4) Outdoors

Exception No. 1 to (3) and (4): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

Exception No. 2 to (4): In industrial establishments only, where the conditions of maintenance and supervision ensure that only qualified personnel are involved, an assured equipment grounding conductor program as specified in 590.6(B)(3) shall be permitted for only those receptacle outlets used to supply equipment that would create a greater hazard if power is interrupted or having a design that is not compatible with GFCI protection.

(5) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

Exception No. 1 to (5): In industrial laboratories, receptacles used to supply equipment where removal of power would introduce a greater hazard shall be permitted to be installed without GFCI protection.

Exception No. 2 to (5): For receptacles located in patient bed locations of general care (Category 2) or critical care (Category 1) spaces of health care facilities other than those covered under 210.8(B) (1), GFCI protection shall not be required.

(6) Indoor wet locations

(7) Locker rooms with associated showering facilities

(8) Garages, service bays, and similar areas other than vehicle exhibition halls and showrooms

(9) Crawl spaces — at or below grade level

(10) Unfinished portions or areas of the basement not intended as habitable rooms

Statement of Problem and Substantiation for Public Input

The current text references the rating of the receptacle. Receptacles are often rated by their phase to phase voltage. A receptacle rated 208 three phase would accordingly not required gfci protection as the rating of the receptacle is in excess of 150 volts with no to ground rating applicable. The proposed text takes the rating of the receptacle out of play and addresses the rating of the branch circuit supplying the receptacle.

Submitter Information Verification

Submitter Full Name: David Humphrey

Organization:

Street Address:

City:

State:

Zip:

Submittal Date: Mon Jun 26 14:09:51 EDT 2017

Public Input No. 1120-NFPA 70-2017 [Section No. 210.8(B)]

(B) Other Than Dwelling Units.

All receptacles supplied by single-phase ~~receptacles~~ branch circuits rated 150 volts to ground or less, 50 amperes or less and all receptacles supplied by three-phase ~~receptacles~~ branch circuits rated 150 volts to ground or less, 100 amperes or less installed in the following locations shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Kitchens

(3) Rooftops

Exception: Receptacles on rooftops shall not be required to be readily accessible other than from the rooftop.

(4) Outdoors

Exception No. 1 to (3) and (4): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

Exception No. 2 to (4): In industrial establishments only, where the conditions of maintenance and supervision ensure that only qualified personnel are involved, an assured equipment grounding conductor program as specified in 590.6(B)(3) shall be permitted for only those receptacle outlets used to supply equipment that would create a greater hazard if power is interrupted or having a design that is not compatible with GFCI protection.

(5) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

Exception No. 1 to (5): In industrial laboratories, receptacles used to supply equipment where removal of power would introduce a greater hazard shall be permitted to be installed without GFCI protection.

Exception No. 2 to (5): For receptacles located in patient bed locations of general care (Category 2) or critical care (Category 1) spaces of health care facilities other than those covered under 210.8(B) (1), GFCI protection shall not be required.

(6) Indoor wet locations

(7) Locker rooms with associated showering facilities

(8) Garages, service bays, and similar areas other than vehicle exhibition halls and showrooms

(9) Crawl spaces — at or below grade level

(10) Unfinished portions or areas of the basement not intended as habitable rooms

Statement of Problem and Substantiation for Public Input

Enforcement and readability of the main subsection text of the requirement.

Receptacles are listed and identified as having nominal or maximum voltage ratings but do not have identified voltage-to-ground ratings demonstrable by the installer or the manufacturer to the AHJ. While correlation with the limits of Class A GFCI protection of personnel requires applications not exceed 150 volts to ground, it is the rating of the branch circuit rather than of the receptacle that shall not exceed 150 volts to ground.

Submitter Information Verification

Submitter Full Name: Vince Baclawski
Organization: Nema
Street Address:
City:
State:
Zip:
Submittal Date: Fri Jul 07 13:43:28 EDT 2017

Public Input No. 1429-NFPA 70-2017 [Section No. 210.8(B)]

(B) Other Than Dwelling Units.

All single-phase receptacles rated 150 volts to ground or less, 50 amperes or less and three-phase receptacles rated 150 volts to ground or less, 100 amperes or less installed in the following locations shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Kitchens

(3) Rooftops

Exception: Receptacles on rooftops shall not be required to be readily accessible other than from the rooftop.

(4) Outdoors

Exception No. 1 to (3) and (4): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

Exception No. 2 to (4): In industrial establishments only, where the conditions of maintenance and supervision ensure that only qualified personnel are involved, an assured equipment grounding conductor program as specified in 590.6(B)(3) shall be permitted for only those receptacle outlets used to supply equipment that would create a greater hazard if power is interrupted or having a design that is not compatible with GFCI protection.

(5) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

Exception No. 1 to (5): In industrial laboratories, receptacles used to supply equipment where removal of power would introduce a greater hazard shall be permitted to be installed without GFCI protection.

Exception No. 2 to (5): For receptacles located in patient bed locations of general care (Category 2) or critical care (Category 1) spaces of health care facilities other than those covered under 210.8(B) (1), GFCI protection shall not be required.

(6) Indoor wet locations

(7) Locker rooms with associated showering facilities

(8) Garages, ***accessory buildings*** , service bays, and similar areas other than vehicle exhibition halls and showrooms

(9) Crawl spaces — at or below grade level

(10) Unfinished portions or areas of the basement not intended as habitable rooms

Statement of Problem and Substantiation for Public Input

We are protecting all receptacles in several locations throughout the "other than dwelling units" but the accessory structures (sheds, storage buildings, utility buildings, etc.) We could not say that these structures are similar to garages or service bays, therefore the need for this revision.

Submitter Information Verification

Submitter Full Name: Lorenzo Adam
Organization: City Of Mason
Street Address:
City:
State:
Zip:
Submittal Date: Fri Jul 28 17:08:17 EDT 2017

Copyright Assignment

I, Lorenzo Adam, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Lorenzo Adam, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 1984-NFPA 70-2017 [Section No. 210.8(B)]

(B) Other Than Dwelling Units.

All single-phase receptacles rated 150 volts to ground or less, 50 amperes or less and three-phase receptacles rated 150 volts to ground or less, 100 amperes or less installed in the following locations shall have ground-fault circuit-interrupter protection for personnel.

Exception to (1) through (10): Locking support and mounting receptacles utilized in combination with compatible attachment fittings shall not be required to be ground-fault circuit-interrupter protected.

(1) Bathrooms

(2) Kitchens

(3) Rooftops

Exception: Receptacles on rooftops shall not be required to be readily accessible other than from the rooftop.

(4) Outdoors

Exception No. 1 to (3) and (4): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

Exception No. 2 to (4): In industrial establishments only, where the conditions of maintenance and supervision ensure that only qualified personnel are involved, an assured equipment grounding conductor program as specified in 590.6(B)(3) shall be permitted for only those receptacle outlets used to supply equipment that would create a greater hazard if power is interrupted or having a design that is not compatible with GFCI protection.

(5) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

Exception No. 1 to (5): In industrial laboratories, receptacles used to supply equipment where removal of power would introduce a greater hazard shall be permitted to be installed without GFCI protection.

Exception No. 2 to (5): For receptacles located in patient bed locations of general care (Category 2) or critical care (Category 1) spaces of health care facilities other than those covered under 210.8(B) (1), GFCI protection shall not be required.

(6) Indoor wet locations

(7) Locker rooms with associated showering facilities

(8) Garages, service bays, and similar areas other than vehicle exhibition halls and showrooms

(9) Crawl spaces — at or below grade level

(10) Unfinished portions or areas of the basement not intended as habitable rooms

Statement of Problem and Substantiation for Public Input

Note to NFPA Staff: The only exception I added was the first one that applies to (1) through (10) yet all the existing exceptions appear underlined as well.
The locking support and mounting receptacles are generally located on the ceiling or high on the wall, and generally are not readily accessible. These receptacles utilized in combination with a compatible attachment fitting are load-make/load-break rated for disconnect. The faceplate prevents easy access to the outlet box. Additionally, work on the utilization equipment (changing bulbs, maintenance, cleaning) is done when the utilization equipment is disconnected, therefore the risk of being shocked is greatly reduced and practically eliminated. Additionally, the attachment fitting does not have a cord attached to it, therefore no cord to be potentially damaged to cause an electrical hazard. There is no portable equipment that personnel will be constantly handling. Once connected the utilization equipment may be considered similar to a hard-connected piece of equipment. The installation equipment may be considered as a semi-permanent installation and as such should be treated similar to a permanent installation.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 1980-NFPA 70-2017 [Section No. 210.8(A)]	Same topic for consideration

Submitter Information Verification

Submitter Full Name:	Amy Cronin
Organization:	Strategic Code Solutions Llc
Affilliation:	SQL Technologies (formerly Safety Quick Lighting and Fans Corp.)
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Wed Aug 09 13:18:53 EDT 2017

Public Input No. 20-NFPA 70-2017 [Section No. 210.8(B)]

(B) Other Than Dwelling Units.

All single-phase receptacles rated 150 volts to ground or less, 50 amperes or less and three-phase receptacles rated 150 volts to ground or less, 100 amperes or less installed in the following locations shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Kitchens

(3) Rooftops

~~Exception: Receptacles on rooftops shall not be required to be readily accessible other than from the rooftop~~

Additional requirements:

(a) *Rooftop receptacle GFCI devices should be readily accessible on the roof.*

(b) *Circuits serving rooftop receptacles should not have additional off-roof GFCI protection with clamping speeds or sensitivity that exceeds the specs of the rooftop GFCI devices on that circuit, thereby allowing the rooftop CFCI a chance to react first .*

(4) Outdoors

Exception No. 1 to (3) and (4): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

Exception No. 2 to (4): In industrial establishments only, where the conditions of maintenance and supervision ensure that only qualified personnel are involved, an assured equipment grounding conductor program as specified in 590.6(B)(3) shall be permitted for only those receptacle outlets used to supply equipment that would create a greater hazard if power is interrupted or having a design that is not compatible with GFCI protection.

(5) Sinks — where receptacles are installed within 1.8 m (6 ft)

from

the

top inside

edge of the

bowl of the

sink

Exception No. 1 to (5): In industrial laboratories, receptacles used to supply equipment where removal of power would introduce a greater hazard shall be permitted to be installed without GFCI protection.

Exception No. 2 to (5): For receptacles located in patient bed locations of general care

(Category 2)

or critical care

(Category 1) spaces

of health care facilities other than those covered under 210.8(B) (1), GFCI protection shall not be required.

(6) Indoor wet locations

(7) Locker rooms with associated showering facilities

(8) Garages, service bays, and similar areas other than vehicle exhibition halls and showrooms

(9) Crawl spaces — at or below grade level

(10) Unfinished portions or areas of the basement not intended as habitable rooms

Statement of Problem and Substantiation for Public Input

1.) The selection that I am recommending changes for should not be labeled as "Exception".
2.) The sentence that follows 'Exception:' is not grammatically correct.
3.) Should GFCI devices serving rooftop receptacles be dis-allowed in off-roof panels?

===

Intro:

I presume the "readily accessible" requirement for all GFCI units is intended to allow the end-user to be able to reset the device after the condition that tripped the device has been corrected.

Also, as best I can determine, the idea here is that the person on the roof who caused the GFCI to trip, should not have to exit the roof to re-set the device.

1.)
Assuming that I am correct in my assessments above, this section is not an "Exception" to the requirement for roof-top GFCI protection, because all roof-top receptacles are required to have protection, without exception.

Rather, this section is an additional requirement to rooftop receptacles situations.

Therefore, I recommend "Additional Reqirement:" instead.

You may, however, have some other equivelant expression more conventionally used in this document that can be used in lieu of my exact wording.

2.)
The existing sentence is not grammatically correct, which is to say that, as a result, its idea is, therefore, not crystal clear.

To illustrate what I mean, move the original word "not" to the beginning of the sentence, and replace it with the equivalent words, "It is not true that".

You will have a clear understanding of what the original sentence expresses when taken literally. Namely:

"It is not true that receptacles on rooftops shall be required to be readily accessible other than from the rooftop.

See what I mean? It is less than 'clear', falling short of what you are trying to convey.

Taken literally, the original sentence can be construed to mean that receptacles on the roof are not required to be readily accessible from an off-roof location. Or, in other words, for those individuals who are not on the roof, the receptacles do not have to be accessible to them.

:o) Not exactly a remarkable idea, and not of much value in a document geared for 'Safety first!'.

Hopefully you now see what I meant by the original being flawed in 'grammar'.

I hope you like my wording, which is simple and to the point, and has the additional benefit of not employing a double-negative like the original does-- always confusing those double-negatives are-- not that you would'nt agree, do you not? Or do you not not agree?

:o)

3.)
Possible additional requirement:

If I am correct in my assessment of this section's intent, which is that this section is simply meant to prevent the person on the roof from having to exit the roof before resuming their task, I wonder, therefore, if this section ought to also include a requirement that the circuit NEVER have GFCI protection down in an off-roof service panel/ sub-panel box.

(Admittedly I do not knowing enough to properly conclude, but ...) I base that question to you on the assumption that it is possible that an off-roof breaker box GFCI trip before the roof-top receptacle GCFI has a chance to trip. And if it is true that not all circuit panel GFCI devices 'always' allow the receptical GFCI device a chance to react first, it would be a logical corollary for you to specify that GFCI devices in off-roof breaker panels be dis-allowed for circuits serving rooftop receptacles.

Or, a the least, the off-roof same-circuit device should be a 'slave' (so to speak) to the on-roof device.

...If you follow what I am saying.

All in all, this is a wise idea you have here, I must say, particularly if Dad drops his corded electric drill in the accumulated snow as he is trying to get Rodolph and Santa anchored onto the ridge of the roof.

I know, I know. You are probably thinking more of flat-top commercial roofs with standing water. But the same applies, in that, the profanity, whether audible, or unspoken, when the power goes off, is an understandable reaction, and a roof should be a place for utter calmness, and concentration.

In conclusion, allow me to recommend the wording of an additional requirement, assuming you would agree that currently according, the possiblility that the off-roof breaker GFCI is not required to be 'slave' to the receptacle GFCI:

"Circuits serving rooftop receptacles should not have additional off-roof GFCI protection with clamping speeds or sensitivity that exceeds the specs of the rooftop GFCI devices on that circuit, thereby allowing the rooftop CFCI a chance to react first."

Outro:

Yeah. Admittedly, that last paragraph of mine is quite possibility not tehcnically precise'. I should have stayed at Rolla, the University of Rolla, Mo USA enginering school, (just between you and me, that is my greatest regret) then that paragraph might have had more accuracy, and 'zip'.

Please feel free to reword that at your leisure.

Me, I don't mind the length, though. I am a strong believer in clarity over any attempt at brevity that has any chance of being less than perfectly clear. All good kindergarten teachers would tell you, quite clamly and assuredly, that they know they have to be willing to repeat a new idea about 5-time, and in 5 different ways, and in full detail each time, if the want the idea to 'stick'.

All I ask of y'all is that you consider the 'in full detail' lesson of that childrens' story.

...Which is to say that, now-a-days, y'all should really start thinking about expanding your standard(s) expansively to include the reasoning behind every one of your recommendations, complete with examples which illustate the full gamat of possibilities which keep you, firemen (fire-persons), and other empathetic public officials awake at night as you envision the horrors you are hoping to mitigate, instead of y'all there at the shop being concerned about ink and paper, and the cost of same to old-school electricians who insist on it.

Quoting the movie 'Ghost Busters', "Print is dead."

I envision (and dream that) the NFPA 70 v. 2030 be five-fold its current size. (Even so, it would occupying no more room on my hard drive than a 10-minute video, if even that).

Clarity is king, and...

Independent improvisational decision making by the public in real world border-line complex situations needs you. It needs you to expain your rec's and stand's so that we know 'why', not just 'what' you want of us.

But that idea is something you might want 'limit the sharing of' with others in your organization, who like yourself are similarly enlightened individuals sincerely interested in a better world to come.

In other words, "Spread the word", especially to your younger colleagues-- but keep it out of the stock-holders' meeting, FOR SURE-- if you are truly interested, for our kids, in a better future, sooner than later.

===

"All the best; intended."

~ Christopher James Francis Rodgers

##

http://submittals.nfpa.org/TerraViewWeb/ViewerPage.jsp?id=70-2017.ditamap&toc=false&draft=true

201.8(5)(Rooftops)

+++ Original

Rooftops

Exception: Receptacles on rooftops shall not be required to be readily accessible other than from the rooftop.

+++ New (Note: Needs proper NFPA WYSIWYG formatting)

<h?>
Rooftops
</h?>

<p>
Additional requirements:
</p>

Rooftop receptacle GFCI devices should be readily accessible on the roof.

Circuits serving rooftop receptacles should not have additional off-roof GFCI protection with clamping speeds or sensitivity that exceeds the specs of the rooftop GFCI devices on that circuit, thereby allowing the rooftop CFCI a chance to react first.

###

Submitter Information Verification

Submitter Full Name: Christopher Rodgers
Organization: dba: Christopher James Francis Rodgers
Street Address:
City:
State:
Zip:
Submittal Date: Sat Jan 21 02:14:27 EST 2017

Public Input No. 2471-NFPA 70-2017 [Section No. 210.8(B)]

(B) Other Than Dwelling Units.

All single-phase receptacles rated ~~150 volts to ground or less, 50 amperes or less and three-phase receptacles rated 150 volts~~ 15 an 20 amperes and 150 volts to ground or ~~less, 100 amperes or less installed~~ less installed in the following locations shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Kitchens

(3) Rooftops

Exception: Receptacles on rooftops shall not be required to be readily accessible other than from the rooftop.

(4) Outdoors

Exception No. 1 to (3) and (4): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

Exception No. 2 to (4): In industrial establishments only, where the conditions of maintenance and supervision ensure that only qualified personnel are involved, an assured equipment grounding conductor program as specified in 590.6(B)(3) shall be permitted for only those receptacle outlets used to supply equipment that would create a greater hazard if power is interrupted or having a design that is not compatible with GFCI protection.

(5) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

Exception No. 1 to (5): In industrial laboratories, receptacles used to supply equipment where removal of power would introduce a greater hazard shall be permitted to be installed without GFCI protection.

Exception No. 2 to (5): For receptacles located in patient bed locations of general care (Category 2) or critical care (Category 1) spaces of health care facilities other than those covered under 210.8(B) (1), GFCI protection shall not be required.

(6) Indoor wet locations

(7) Locker rooms with associated showering facilities

(8) Garages, service bays, and similar areas other than vehicle exhibition halls and showrooms

(9) Crawl spaces — at or below grade level

(10) Unfinished portions or areas of the basement not intended as habitable rooms

Statement of Problem and Substantiation for Public Input

While I absolutely support the idea of protecting personnel from electric shock, the large expansion of GFCI requirements in the 2017 was not well substantiated. The requirement for SPGFCI is problematic because of cost and availability. Adding excessive requirements such up to 50 amps, and up to 100 amps for 3 phase receptacles in the NEC is discouraging to personnel who have to work with the result which a huge increased cost. Simply for one small example - a standard 2-pole circuit breaker costs around $ 12.00, while a 2-pole GFCI circuit breaker costs over $ 120.00, which is 10 times that amount. This cost for a GFCI circuit breaker is justified to protect a swimming pool pump, where personnel are much more vulnerable to electric shock. But requiring GFCI protection for a 240-volt single phase welder receptacle, or a 3-phase receptacles installed an indoor dry location is not justified. And, because of replacement requirements in Section 406.4 for existing installations are being steadily increased every Code cycle, existing installations are no longer 'grandfathered in'.

Additional GFCI requirements negatively affect maintenance departments of hospitals, universities, and businesses wherever the latest edition of the Code is adopted. The huge cost increase must be made up somewhere in their budgets. The continual increase in requirements is a real problem. Safety is paramount, but not so sacred that it should not be justified. In addition, where will the large 3-phase GFCI cabinet be located in an existing installation and still meet the Code requirements to be 'readily accessible'. This is clearly an installer or owner's problem, not a manufacturer's problem.

Also, there are times when electrical contractors can't 'pass on the cost', and get caught in a bind between compliance and a customer that doesn't understand why the same commercial job you did for them last year just increased so much with the new code being adopted. They are tempted to go with Brand X Electric or IB Cheap Electric, who doesn't pay as much attention to Codes and regulations, and you lose the job for doing the right thing when others aren't.

I urge CMP 2 to listen to even more to others - than those who strongly advocate increased GFCI requirements. You have a very important job. All aspects of the electrical industry, including the end users, and those trying to figure out how to pay the bill and comply with the Code are important, too. Thank you for your service on CMP 2.

Submitter Information Verification

Submitter Full Name: Michael Weitzel

Organization:

Street Address:

City:

State:

Zip:

Submittal Date: Fri Aug 18 15:09:12 EDT 2017

Public Input No. 324-NFPA 70-2017 [Section No. 210.8(B)]

(B) Other Than Dwelling Units.

All single-phase receptacles rated 150 volts to ground or less, 50 amperes or less and three-phase receptacles rated 150 volts to ground or less, 100 amperes or less installed in the following locations shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Kitchens

(3) Rooftops

Exception: Receptacles on rooftops shall not be required to be readily accessible other than from the rooftop.

(4) Outdoors

Exception No. 1 to (3) and (4): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

Exception No. 2 to (4): In industrial establishments only, where the conditions of maintenance and supervision ensure that only qualified personnel are involved, an assured equipment grounding conductor program as specified in 590.6(B)(3) shall be permitted for only those receptacle outlets used to supply equipment that would create a greater hazard if power is interrupted or having a design that is not compatible with GFCI protection.

(5) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

Exception No. 1 to (5): In industrial laboratories, receptacles used to supply equipment where removal of power would introduce a greater hazard shall be permitted to be installed without GFCI protection.

Exception No. 2 to (5): For receptacles located in patient bed locations of general care (Category 2) or critical care (Category 1) spaces of health care facilities other than those covered under 210.8(B) (1), GFCI protection shall not be required.

(6) Indoor wet locations

(7) Locker rooms with associated showering facilities

(8) Garages, service bays, and similar areas other than vehicle exhibition halls and showrooms

(9) Crawl spaces — at or below grade level

(10) Unfinished portions or areas of the basement not intended as habitable rooms

(11) Bathtubs and shower stalls - where receptacles are installed within 1.8 m (6 ft.) of the outside edge of the bathtub or shower stall

Statement of Problem and Substantiation for Public Input

This requirement mirrors that found in 210.8(A)(9) for dwelling units and 680.71 for hydro-massage bathtubs. This is a logical extension since sometimes bathtubs or shower stalls are NOT located in a locker room or an area that meets the NEC definition of a bathroom, and any receptacles in that area therefore would NOT require GFCI protection. Many of these areas may have tile or other conductive and possibly grounded floors. This presents a serious shock hazard to a person getting out of the shower or tub, who is soaking wet and is about to use a NON-GFCI protected receptacle!!! This new requirement will provide an increased level of safety.

Submitter Information Verification

Submitter Full Name: Russ Leblanc
Organization: Leblanc Consulting Services
Street Address:
City:
State:
Zip:
Submittal Date: Sat Mar 04 09:39:40 EST 2017

Public Input No. 3380-NFPA 70-2017 [Section No. 210.8(B)]

(B) Other Than Dwelling Units.

All single-phase receptacles rated 150 volts to ground or less, 50 amperes or less and three-phase receptacles rated 150 volts to ground or less, 100 amperes or less installed in the following locations shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Kitchens

(3) Rooftops

Exception: Receptacles on rooftops shall not be required to be readily accessible other than from the rooftop.

(4) Outdoors

Exception No. 1 to (3) and (4): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

Exception No. 2 to (4): In industrial establishments only, where the conditions of maintenance and supervision ensure that only qualified personnel are involved, an assured equipment grounding conductor program as specified in 590.6(B)(3) shall be permitted for only those receptacle outlets used to supply equipment that would create a greater hazard if power is interrupted or having a design that is not compatible with GFCI protection.

(5) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

Exception No. 1 to (5): In industrial laboratories, receptacles used to supply equipment where removal of power would introduce a greater hazard shall be permitted to be installed without GFCI protection.

Exception No. 2 to (5): For receptacles located in patient bed locations of general care (Category 2) or critical care (Category 1) spaces of health care facilities other than those covered under 210.8(B) (1), GFCI protection shall not be required.

(6) Indoor wet locations

(7) Locker rooms with associated showering facilities

(8) Garages, service bays, and similar areas other than vehicle exhibition halls and showrooms, not within the scope of Article 511 Commercial Garages, Repair, and Storage

(9) Crawl spaces — at or below grade level

(10) Unfinished portions or areas of the basement not intended as habitable rooms

Statement of Problem and Substantiation for Public Input

My change was to 210.8(B)(8) ", not within the scope of Article 511 Commercial Garages, Repair, and

Storage". This text is to make it clear 210.8(B)(8) does not apply to receptacles in commercial garages as covered by Article 511.

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 05 17:48:11 EDT 2017

Copyright Assignment

I, Mike Holt, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Mike Holt, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 3994-NFPA 70-2017 [Section No. 210.8(B)]

(B) Other Than Dwelling Units.

All single-phase receptacles rated 150 volts to ground or less, 50 amperes or less and three-phase receptacles rated 150 volts to ground or less, 100 amperes or less installed in the following locations shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Kitchens

(3) Rooftops

Exception: Receptacles on rooftops shall not be required to be readily accessible other than from the rooftop.

(4) Outdoors

Exception No. 1 to (3) and (4): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

Exception No. 2 to (4): In industrial establishments only, where the conditions of maintenance and supervision ensure that only qualified personnel are involved, an assured equipment grounding conductor program as specified in 590.6(B)(3) shall be permitted for only those receptacle outlets used to supply equipment that would create a greater hazard if power is interrupted or having a design that is not compatible with GFCI protection.

(5) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

Exception No. 1 to (5): In industrial laboratories, receptacles used to supply equipment where removal of power would introduce a greater hazard shall be permitted to be installed without GFCI protection.

Exception No. 2 to (5): For receptacles located in patient bed locations of general care (Category 2) or critical care (Category 1) spaces of health care facilities other than those covered under 210.8(B) (1), GFCI protection shall not be required.

(6) Countertops

(7) Indoor wet locations

(8) Locker rooms with associated showering facilities

(9) Garages, service bays, and similar areas other than vehicle exhibition halls and showrooms

(10) Crawl spaces — at or below grade level

(11) Unfinished portions or areas of the basement not intended as habitable rooms

Statement of Problem and Substantiation for Public Input

The only change proposed in this PI is to add (6) Countertops.
There are many installations that have countertops that are often wet on conductive surfaces that would not require GFCI protection since they do not fall under the provisions of 210.8(B)(2) or (5).
There are many ice cream stores and coffee houses that would fall under this concern.

Submitter Information Verification

Submitter Full Name: David Williams

Organization: Delta Charter Township

Street Address:

City:

State:

Zip:

Submittal Date: Thu Sep 07 11:51:00 EDT 2017

Public Input No. 619-NFPA 70-2017 [Section No. 210.8(B)]

(B) Other Than Dwelling Units.

All single-phase receptacles ~~rated 150 volts~~ with a nominal voltage of 150 volts to ground or less, and rated 50 amperes or less and three-phase receptacles ~~rated~~ with a nominal voltage of 150 volts to ground or less, and rated 100 amperes or less installed in the following locations shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Kitchens

(3) Rooftops

Exception: Receptacles on rooftops shall not be required to be readily accessible other than from the rooftop.

(4) Outdoors

Exception No. 1 to (3) and (4): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

Exception No. 2 to (4): In industrial establishments only, where the conditions of maintenance and supervision ensure that only qualified personnel are involved, an assured equipment grounding conductor program as specified in 590.6(B)(3) shall be permitted for only those receptacle outlets used to supply equipment that would create a greater hazard if power is interrupted or having a design that is not compatible with GFCI protection.

(5) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

Exception No. 1 to (5): In industrial laboratories, receptacles used to supply equipment where removal of power would introduce a greater hazard shall be permitted to be installed without GFCI protection.

Exception No. 2 to (5): For receptacles located in patient bed locations of general care (Category 2) or critical care (Category 1) spaces of health care facilities other than those covered under 210.8(B) (1), GFCI protection shall not be required.

(6) Indoor wet locations

(7) Locker rooms with associated showering facilities

(8) Garages, service bays, and similar areas other than vehicle exhibition halls and showrooms

(9) Crawl spaces — at or below grade level

(10) Unfinished portions or areas of the basement not intended as habitable rooms

Additional Proposed Changes

File Name	Description	Approved

.1493396298962	210.8B reword	✓

Statement of Problem and Substantiation for Public Input

Receptacles may be provided with a phase to phase rating only such as 20 ampere 250v. By basing the requirements of this section on the rating of the receptacle rather than the nominal voltage of the receptacle measured phase to ground many receptacles rated either 250 volt or 208 volt only may be effectively excluded from the requirements of this section.

The proposed text change is consistent with text in other code sections most notably Table 110.26(A)(1).

Submitter Information Verification

Submitter Full Name: David Humphrey
Organization: David G. Humphrey
Street Address:
City:
State:
Zip:
Submittal Date: Fri Apr 28 12:12:51 EDT 2017

Public Input No. 623-NFPA 70-2017 [Section No. 210.8(B)]

(B) Other Than Dwelling Units.

All single-phase receptacles rated 150 volts to ground or less, 50 amperes or less and three-phase receptacles rated 150 volts to ground or less, 100 amperes or less installed in the following locations shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Kitchens

(3) Rooftops

Exception: Receptacles on rooftops shall not be required to be readily accessible other than from the rooftop.

(4) Outdoors

Exception No. 1 to (3) and (4): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

Exception No. 2 to (4): In industrial establishments only, where the conditions of maintenance and supervision ensure that only qualified personnel are involved, an assured equipment grounding conductor program as specified in 590.6(B)(3) shall be permitted for only those receptacle outlets used to supply equipment that would create a greater hazard if power is interrupted or having a design that is not compatible with GFCI protection.

(5) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

Exception No. 1 to (5): In industrial laboratories, receptacles used to supply equipment where removal of power would introduce a greater hazard shall be permitted to be installed without GFCI protection.

Exception No. 2 to (5): For receptacles located in patient bed locations of general care (Category 2) or critical care (Category 1) spaces of health care facilities other than those covered under 210.8(B) (1), GFCI protection shall not be required.

(6) Indoor wet locations

(7) Locker rooms with associated showering facilities

(8) Garages, service bays, and similar areas other than vehicle exhibition halls and showrooms

(9) Crawl spaces — at or below grade level

(10) ~~Unfinished portions or~~ Unfinished areas of the basement not intended as habitable rooms

Statement of Problem and Substantiation for Public Input

Based on the conversations I have heard and or been a part of through various code discussion groups and forums, there is still confusion among installers and inspectors alike about the meaning of this rule. Is this rule intended to apply to finished areas of basements if they are not intended as habitable rooms? The literal wording is being interpreted as such. The rule is being interpreted as applying to two different parts of the basement- one area being the "unfinished portion", and the other area being "areas of the basement not intended as habitable rooms" even if the area is finished, such as a closet or storage area or some other finished room such as a play room, meditation room or exercise room, that may not meet all of the building code requirements for a habitable room but is nonetheless, "finished". I do not believe the intent of this rule is to apply the GFCI requirements to "finished" areas of the basement. I believe my proposed revision will remove some redundant wording and help clarify the intent of this rule as well as align better with the wording I have proposed for Section 210.8(A)(5).

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 599-NFPA 70-2017 [Section No. 210.8(A)]	GFCI protection in "unfinished areas"

Submitter Information Verification

Submitter Full Name: Russ Leblanc

Organization: Leblanc Consulting Services

Street Address:

City:

State:

Zip:

Submittal Date: Sat Apr 29 09:25:07 EDT 2017

Public Input No. 700-NFPA 70-2017 [Section No. 210.8(B)]

(B) Other Than Dwelling Units.

All single-phase receptacles rated 150 volts to ground or less, 50 amperes or less and three-phase receptacles rated 150 volts to ground or less, 100 amperes or less installed in the following locations shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Kitchens

(3) Rooftops

Exception: Receptacles on rooftops shall not be required to be readily accessible other than from the rooftop.

(4) Outdoors

Exception No. 1 to (3) and (4): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

Exception No. 2 to (4): In industrial establishments only, where the conditions of maintenance and supervision ensure that only qualified personnel are involved, an assured equipment grounding conductor program as specified in 590.6(B)(3) shall be permitted for only those receptacle outlets used to supply equipment that would create a greater hazard if power is interrupted or having a design that is not compatible with GFCI protection.

(5) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

Exception No. 1 to (5): In industrial laboratories, receptacles used to supply equipment where removal of power would introduce a greater hazard shall be permitted to be installed without GFCI protection.

Exception No. 2 to (5): For receptacles located in patient bed locations of general care (Category 2) or critical care (Category 1) spaces of health care facilities other than those covered under 210.8(B) (1), GFCI protection shall not be required.

(6) Indoor wet locations

(7) Locker rooms with associated showering facilities

(8) Garages, service bays, and similar areas other than vehicle exhibition halls and showrooms

(9) Crawl spaces — at or below grade level

(10) Unfinished portions or areas of the basement not intended as habitable rooms

(11) Laundry areas

Statement of Problem and Substantiation for Public Input

The laundry area hazard is exactly the same for "other than dwelling units" as it is for dwelling units. Many a condominium or apartment complex provides laundry areas so people can wash their clothes. These people do not deserve less protection simply because they don't live in a house.

PS - I'm not sure why the exceptions underlined. I have not changed any of the exceptions, not a word.

Submitter Information Verification

Submitter Full Name: Nick Sasso
Organization: State of Wyoming
Street Address:
City:
State:
Zip:
Submittal Date: Sat May 13 02:57:34 EDT 2017

Public Input No. 701-NFPA 70-2017 [Section No. 210.8(B)]

(B) Other Than Dwelling Units.

All single-phase receptacles rated 150 volts to ground or less, 50 amperes or less and three-phase receptacles rated 150 volts to ground or less, 100 amperes or less installed in the following locations shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Kitchens

(3) Rooftops

Exception: Receptacles on rooftops shall not be required to be readily accessible other than from the rooftop.

(4) Outdoors

Exception No. 1 to (3) and (4): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

Exception No. 2 to (4): In industrial establishments only, where the conditions of maintenance and supervision ensure that only qualified personnel are involved, an assured equipment grounding conductor program as specified in 590.6(B)(3) shall be permitted for only those receptacle outlets used to supply equipment that would create a greater hazard if power is interrupted or having a design that is not compatible with GFCI protection.

(5) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

Exception No. 1 to (5): In industrial laboratories, receptacles used to supply equipment where removal of power would introduce a greater hazard shall be permitted to be installed without GFCI protection.

Exception No. 2 to (5): For receptacles located in patient bed locations of general care (Category 2) or critical care (Category 1) spaces of health care facilities other than those covered under 210.8(B) (1), GFCI protection shall not be required.

(6) Indoor wet locations

(7) Locker rooms with associated showering facilities

(8) Garages, service bays, and similar areas other than vehicle exhibition halls and showrooms

(9) Crawl spaces — at or below grade level

(10) Unfinished portions or areas of the basement not intended as habitable rooms

(11) Janitor's mop sink - where receptacles are installed within 1.8 m (6 ft) from the mop sink

Additional Proposed Changes

File Name	Description	Approved
mopSink.jpg	mop sink - typical	✓

Statement of Problem and Substantiation for Public Input

Janitor's mop sink:

There is nothing in the code that clearly covers this, and contractors like to argue.

Due to people using this plumbing fixture, the concrete floors in these janitor closets usually have a puddle somewhere. As you know NEC considers concrete, brick, or tile to be a grounded surface. I feel that the GFCI protection is needed. Requiring GFCI protection for a duplex receptacle in this location will also not significantly impact any costs.

PS - I'm not sure why the exceptions underlined. I have not changed any of the exceptions, not a word.

Submitter Information Verification

Submitter Full Name: Nick Sasso

Organization: State of Wyoming

Street Address:

City:

State:

Zip:

Submittal Date: Sat May 13 03:01:02 EDT 2017

Public Input No. 888-NFPA 70-2017 [Section No. 210.8(B)]

(B) Other Than Dwelling Units.

All single-phase receptacles ~~rated~~ installed in circuits 150 volts to ground or less, 50 amperes or less and three-phase receptacles ~~rated~~ installed in circuits 150 volts to ground or less, 100 amperes or less installed in the following locations shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Kitchens

(3) Rooftops

Exception: Receptacles on rooftops shall not be required to be readily accessible other than from the rooftop.

(4) Outdoors

Exception No. 1 to (3) and (4): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

Exception No. 2 to (4): In industrial establishments only, where the conditions of maintenance and supervision ensure that only qualified personnel are involved, an assured equipment grounding conductor program as specified in 590.6(B)(3) shall be permitted for only those receptacle outlets used to supply equipment that would create a greater hazard if power is interrupted or having a design that is not compatible with GFCI protection.

(5) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

Exception No. 1 to (5): In industrial laboratories, receptacles used to supply equipment where removal of power would introduce a greater hazard shall be permitted to be installed without GFCI protection.

Exception No. 2 to (5): For receptacles located in patient bed locations of general care (Category 2) or critical care (Category 1) spaces of health care facilities other than those covered under 210.8(B) (1), GFCI protection shall not be required.

(6) Indoor wet locations

(7) Locker rooms with associated showering facilities

(8) Garages, service bays, and similar areas other than vehicle exhibition halls and showrooms

(9) Crawl spaces — at or below grade level

(10) Unfinished portions or areas of the basement not intended as habitable rooms

Statement of Problem and Substantiation for Public Input

This PI seeks to address the issue of difference between how receptacles are rated versus how this requirement is written. The requirement for protection is associated with the circuit not the rating of the product. This modification would establish that a receptacle rated 250V but applied in a lower voltage circuit would still require to be protected.

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich

Organization: Eaton Corporation

Street Address:

City:

State:

Zip:

Submittal Date: Sat Jun 03 15:25:02 EDT 2017

Public Input No. 1787-NFPA 70-2017 [Section No. 210.8(D)]

(D) Kitchen Dishwasher & Disposal Branch Circuit.

GFCI protection shall be provided for outlets that supply dishwashers and disposals installed in dwelling unit locations.

Statement of Problem and Substantiation for Public Input

I don't know if there is a problem and I probably don't have the substantiation necessary. Common sense tells me that as I wash dishes or have my hands in the sink with the disposal, I have a greater chance of being electrically hurt from the disposal then from a dishwasher. The attachment of the disposal to the sink is with a metal connector which can conduct the electrical problem straight into the water. I agree that is dishwashers need GFCI protection because of the possibility of touching a metal appliance and being shocked, the disposal provides a more substantial chance of shock.

Submitter Information Verification

Submitter Full Name: Roger Chick

Organization: Electrical Inspector BHGC Consultants

Affilliation: IAEI member

Street Address:

City:

State:

Zip:

Submittal Date: Fri Aug 04 17:57:53 EDT 2017

Public Input No. 1800-NFPA 70-2017 [Section No. 210.8(D)]

~~**(D)** Kitchen Dishwasher Branch Circuit.~~

~~GFCI protection shall be provided for outlets that supply dishwashers installed in dwelling unit locations.~~

Statement of Problem and Substantiation for Public Input

GFCI protection for a dishwasher should be provided by the manufacturer, not the end user. The product should be sound, and not be subject to possible failure when it leaves the factory. I am not aware of any other area of the NEC where this is permitted. The electrical industry out in the field sees this for what it is. The electrical contractor has to take responsibility for their installation. Why doesn't the manufacturer have to take responsibility for their product? This was the wrong message to send to manufacturers.

Possible future failure of an electrical product should be dealt with in a product standard.

Submitter Information Verification

Submitter Full Name: Michael Weitzel
Organization:
Street Address:
City:
State:
Zip:
Submittal Date: Sat Aug 05 12:00:25 EDT 2017

Public Input No. 1940-NFPA 70-2017 [Section No. 210.8(D)]

~~**(D)** Kitchen Dishwasher Branch Circuit.~~

~~GFCI protection shall be provided for outlets that supply dishwashers installed in dwelling unit locations.~~

-

Statement of Problem and Substantiation for Public Input

The GFCI requirements for dishwashers should be relocated to 422.5. A companion PI has been submitted to Panel 17 to include the requirements in 422.5.

The GFCI requirement for dishwashers first appeared in the 2014 NEC. Looking back at the substantiation that brought this requirement into Article 210, one quickly realizes the problem stated in the Pubic Input and Comment submitted by an appliance manufacturer was related to end of life problems with the appliance. In fact, because the problem was related to end of life failures with the product, CMP 2 rejected the public input stating the problem was product related and it should be addressed in the Product Standard.

At the first draft stage of the 2017 Cycle CMP 2 voted to move these requirements to Article 422. A task group was formed between Panel 17 and Panel 2 to coordinate the effort and ultimately 422.5 was rewritten to include the appliances that require GFCI protection and the methods of providing the GFCI protection. A job well done! During the Second Draft stage CMP 2 reversed their decision and kept the GFCI requirements for dishwashers in 210.8(D).

It is not the branch circuit or the outlet that presents the shock hazard, as was stated during the 2017 2nd Draft CMP 2 discussions, it is coming in contact with the equipment. Therefore any of the methods of providing the GFCI protection in 422.5 are more than sufficient. Additionally, to further state during those discussions “if there was no appliance present at the time of a final inspection there would be no guarantee the GFCI protection provided” was completely off base. In fact, if there was no appliance present at that time, it is all the more reason that GFCI protection would have to be provided for the branch circuit or at the outlet at the time of the inspection.

Finally, and most important, by having requirement located in Article 210 we are only providing shock protection for consumer’s part of the time. If a dishwashers installed prior to the addition of this requirement in Article 210 was replaced, there is no requirement to provide GFCI protection as a new branch circuit is not being installed.

Submitter Information Verification

Submitter Full Name: David Clements
Organization: Intl Assoc Elec Insp
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 09 09:09:57 EDT 2017

Copyright Assignment

I, David Clements, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am David Clements, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 2399-NFPA 70-2017 [Section No. 210.8(D)]

(D) Kitchen Dishwasher Branch Circuit.

GFCI protection shall be provided for ~~outlets~~ branch circuits that supply dishwashers installed in dwelling unit locations.

Statement of Problem and Substantiation for Public Input

the term " outlet" is taken literally some interpret if the dishwasher is wired direct then GFi protection is not required this I have seen in the field.

Submitter Information Verification

Submitter Full Name: Randy King

Organization: Rk Electric

Affilliation: miea

Street Address:

City:

State:

Zip:

Submittal Date: Thu Aug 17 18:23:52 EDT 2017

Public Input No. 4076-NFPA 70-2017 [Section No. 210.8(D)]

(D) Kitchen Dishwasher Branch Circuit.

GFCI protection shall be provided for ~~outlets~~ all circuits 125 volt . single-phase, 15-and 20-ampere outlets that supply dishwashers ~~installed in dwelling unit locations~~ .

Statement of Problem and Substantiation for Public Input

THERE IS NO DIFFERENCE IN THE HAZARDS OF GFCI PROTECTION ON A DISHWASHER INSTALLED IN A DWELLING OR COMMERCIAL LOCATION

Submitter Information Verification

Submitter Full Name: RICHARD WOLFE
Organization: NDSEB
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 07 13:34:01 EDT 2017

Public Input No. 4253-NFPA 70-2017 [Section No. 210.8(D)]

(D) Kitchen Dishwasher Branch Circuit.

~~GFCI protection shall be provided for outlets that supply dishwashers installed in dwelling unit locations~~ Outlets supplying dishwashwers in a dwelling unit, whether by receptacle or by direct connection, shall be provided with GFCI protection .

Statement of Problem and Substantiation for Public Input

After reading the current text in the 2017 NEC, many electrical contractors are under the impression that GFCI protection is only required if the dishwasher is plugged into a receptacle outlet because they don't understand the definition of the term "outlet" as defined in article 100. Inserting this text would eliminate a lot of confusion for electricians.

Submitter Information Verification

Submitter Full Name: Thomas Allen

Organization: Semper Fi Electric Inc

Street Address:

City:

State:

Zip:

Submittal Date: Thu Sep 07 17:25:42 EDT 2017

Public Input No. 587-NFPA 70-2017 [Section No. 210.8(D)]

(~~D~~ A)

(11) _ Kitchen Dishwasher Branch Circuit.

GFCI protection shall be provided for outlets that supply dishwashers installed in dwelling unit locations.

Statement of Problem and Substantiation for Public Input

There is already a first level subdivision regarding GFCI requirements for dwelling units in subdivision (A). It will be easier for the code user to only have to refer to subdivision (A) for these requirements.

Submitter Information Verification

Submitter Full Name: Tj Woods
Organization: Wyoming Electrical Jatc
Street Address:
City:
State:
Zip:
Submittal Date: Mon Apr 24 15:38:07 EDT 2017

Public Input No. 2508-NFPA 70-2017 [New Section after 210.8(D)]

Clothes Dryer Branch Circuits

GFCI protection shall be provided for four-wire receptacle outlets that supply clothes dryers

Statement of Problem and Substantiation for Public Input

In 1996, the Code was changed such that new installations for clothes dryers required a four-wire installation. This struck down the long-standing exception that allowed clothes dryers to re-bond the neutral to the frame such that a three-wire connection could be used.
Since that time, I have seen quite a few dryer installations where a four-wire cord was connected to the dryer but the bonding jumper was not removed in the dryer location. In reviewing the manufacturer's instructions, it is clear that the manufacturers don't understand the underlying issues. There are also NRTL listed cord sets that allow a person to connect a three wire dryer to a four wire receptacle.

By requiring GFCI protection for this circuit, any neutral to frame connections will not allow the GFCI to reset and the installation will have to be corrected.

Submitter Information Verification

Submitter Full Name: Eric Stromberg

Organization: Los Alamos National Laboratory

Affilliation: Self

Street Address:

City:

State:

Zip:

Submittal Date: Sat Aug 19 18:10:00 EDT 2017

Public Input No. 3897-NFPA 70-2017 [New Section after 210.8(E)]

Exception: Locking support and mounting receptacles utilized in combination with compatible attachment fittings shall not be required to be ground-fault circuit-interrupter protected. **Type your content here ...**

Statement of Problem and Substantiation for Public Input

Locking support and mounting receptacles utilized in combination with compatible attachment fittings are load-make/load-break rated for disconnect. The faceplate prevents access to the outlet box. A centerpiece can be installed, turning the faceplate into a coverplate. They are made so that the utilization equipment can be safely connected and disconnected. Work on the utilization equipment, such as changing bulbs, maintenance and cleaning is intended to be done when the utilization equipment is disconnected, therefore minimizing the risk of being shocked, if not practically eliminating it.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3886-NFPA 70-2017 [New Section after 210.8(A)]	Related subject.
Public Input No. 3891-NFPA 70-2017 [New Section after 210.8(B)]	Related subject.

Submitter Information Verification

Submitter Full Name: Michael Fontaine
Organization: National Electrical Safety Group, Inc.
Affilliation: SQL Technologies Corp.
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 07 08:23:06 EDT 2017

Public Input No. 2006-NFPA 70-2017 [Section No. 210.8(E)]

(E) Crawl Space Lighting Outlets.

GFCI protection shall be provided for lighting outlets not exceeding 120 volts installed in crawl spaces.

Exception: Locking support and mounting receptacles utilized in combination with compatible attachment fittings shall not be required to be ground-fault circuit-interrupter protected.

Statement of Problem and Substantiation for Public Input

These receptacles utilized in combination with a compatible attachment fitting are load-make/load-break rated for disconnect. The faceplate prevents easy access to the outlet box. A centerpiece can be installed for turning the faceplate into a coverplate. Additionally, work on the utilization equipment, such as changing bulbs, maintenance and cleaning is intended to be done when the utilization equipment is disconnected, therefore the risk of being shocked is greatly reduced, if not practically eliminated.

Submitter Information Verification

Submitter Full Name:	Amy Cronin
Organization:	Strategic Code Solutions Llc
Affilliation:	SQL Technologies (formerly Safety Quick Lighting and Fans Corp.)
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Wed Aug 09 14:11:48 EDT 2017

Public Input No. 2459-NFPA 70-2017 [Section No. 210.8(E)]

(E) Crawl Space Lighting Outlets.

GFCI protection shall be provided for lighting outlets not exceeding 120 volts installed in crawl spaces.

Exception: Where protection from damage is provided by a guard or globe manufactured for the purpose, or by other Approved means.

.

Statement of Problem and Substantiation for Public Input

If the GFCI device trips because an electrical cord or tool failure, the lighting installed on the same circuit will also be de-energized by the GFCI.
Protection for personnel provided by a metal guard, or glass or plastic type globe that is manufactured for the purpose is a better option, and should be permitted.
GFCI protection required for crawl space lighting may seem like a good idea to some, but when placed on the same circuit as a required GFCI protected receptacle outlet, introduces a number of hazards to personnel. One example is a trip or fall hazard. The hazard is increased of an electrical worker, HVAC worker, or homeowner tripping and stumbling over obstacles found in a crawlspace, or placing hands in a place where new hazards are introduced. Also included is the hazard of venomous spiders and snakes, or animals which may be found in some crawlspaces.
This thinking is consistent with Section 590.4(D) which states that receptacles on construction sites shall not be installed on any circuit that supplies temporary lighting. I was on a construction site years ago where this requirement was not followed, and it created a serious hazard where underground in a large, dark room with many trades working, hot surfaces and tripping hazards were in a abundance.

A new, additional GFCI-protected circuit dedicated to crawl space lighting is not what I propose. A required new, dedicated circuit is not warranted, and NEC CMP 2 should not consider adding that requirement, when the real objective of protecting personnel from electric shock can be addressed by a simple guard or globe that is readily available. Built into this PI is the clear option of the AHJ to accept other means of protection, such as installing a recessed can light up between the floor joints, thereby keeping the lamp out of harm's way.

Submitter Information Verification

Submitter Full Name: Michael Weitzel

Organization:

Street Address:

City:

State:

Zip:

Submittal Date: Fri Aug 18 13:54:51 EDT 2017

Copyright Assignment

I, Michael Weitzel, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Michael Weitzel, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 4312-NFPA 70-2017 [Section No. 210.8(E)]

(E) Crawl Space Lighting Outlets.

GFCI protection shall be provided for lighting outlets ~~not exceeding 120 volts~~ installed in crawl spaces.

Statement of Problem and Substantiation for Public Input

Though the vast majority of lighting systems operating in crawl spaces are 120 volts nominal; the hazard would still exist if another, higher, nominal voltage lighting system was used.

Thus the GFCI requirement should not be limited to just 120 volt nominal lighting systems.

Submitter Information Verification

Submitter Full Name: Matt Hermanson
Organization: A And A Electric Inc
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 07 20:00:09 EDT 2017

Public Input No. 440-NFPA 70-2017 [Section No. 210.8(E)]

(E) Crawl Space Lighting Outlets.

GFCI protection shall be provided for lighting outlets not exceeding 120 volts installed in crawl spaces at or below grade level .

Statement of Problem and Substantiation for Public Input

According to most dictionaries, attic spaces are crawl spaces. They don't have the same hazard, hence the language in 210.8A(4) and 210.8(B)(9). This input borrows that language.

Submitter Information Verification

Submitter Full Name: Ryan Jackson

Organization: Ryan Jackson

Street Address:

City:

State:

Zip:

Submittal Date: Fri Mar 31 13:48:21 EDT 2017

Public Input No. 773-NFPA 70-2017 [Section No. 210.8(E)]

(E) Crawl Space Lighting Outlets.

120 volts or less incandesent lamps shall be protected from breakage or GFCI protection shall be provided ~~for lighting outlets not exceeding 120 volts installed in crawl spaces~~ .

Additional Proposed Changes

File Name	Description	Approved
images-1.jpg	gaurds	✓
8b198dad-47c1-414f-8919-04681883dfba_1000.jpg	non incandescent lamps	✓
lights_cfls_hero.jpg	cfl	✓
images-1.jpg	flo	✓

Statement of Problem and Substantiation for Public Input

this hazard is not present in every lamp/lighting outlet installed in a crawl space and may also be mitigated by guarding the lamp. Under certain conditions losing your lighting in a crawl space due to tripling the GFI circuit may impose other unintended hazards.

Submitter Information Verification

Submitter Full Name: Alfio Torrisi
Organization: Master Electrician
Street Address:
City:
State:
Zip:
Submittal Date: Sat May 20 08:03:43 EDT 2017

Public Input No. 2280-NFPA 70-2017 [New Section after 210.8(E)]

(F) Electrically Operated Sink Disposers.

GFCI protection shall be provided for outlets that supply electrically operated sink disposers.

Statement of Problem and Substantiation for Public Input

The language clarifies that food waste disposals installed below sink basins both hardwired, and cord and plug connected would be required to have GFCI protection. A potential shock hazard exists when you are in close proximity to water for either a dwelling and/or non-dwelling installations.

Submitter Information Verification

Submitter Full Name: Dean Hunter

Organization: Minnesota Department of Labor

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 15 19:15:18 EDT 2017

Public Input No. 3923-NFPA 70-2017 [New Section after 210.8(E)]

Strutures Built on Flood Plains

GFCI protection shall be provided for branch circuits installed in structures which are built on land designated as a flood plain.

Statement of Problem and Substantiation for Public Input

Branch circuits feeding structures built on flood plains can produce stray currents in water as the structure and surrounding land is flooded. These stray currents can pose a risk to occupants or rescuers as they travel through and nearby the house.
An unfortunate example of electrocution due to flood waters is Andrew Pasek who was electrocuted by stray current while returning to his flooded home following tropical storm Harvey.

Submitter Information Verification

Submitter Full Name: Lanson Relyea
Organization: Eaton Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 07 09:19:17 EDT 2017

Public Input No. 3925-NFPA 70-2017 [New Section after 210.8(E)]

Strutures with Fire Sprinklers

GFCI protection shall be provided for branch circuits installed in areas protected by fire sprinklers.

Statement of Problem and Substantiation for Public Input

Branch circuits feeding circuits installed in areas protected by fire sprinklers can produce stray currents when the sprinkler system is activated. The spray from the sprinkler system can cover and penetrate all surfaces creating a conductive path for currents to flow outside the electrical system. These stray currents can pose a risk to occupants or rescuers.

Submitter Information Verification

Submitter Full Name: Lanson Relyea

Organization: Eaton Corporation

Street Address:

City:

State:

Zip:

Submittal Date: Thu Sep 07 09:21:32 EDT 2017

Public Input No. 1980-NFPA 70-2017 [Section No. 210.8(A)]

(A) Dwelling Units.

All 125-volt, single-phase, 15- and 20-ampere receptacles installed in the locations specified in 210.8(A)(1) through (10) shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Garages, and also accessory buildings that have a floor located at or below grade level not intended as habitable rooms and limited to storage areas, work areas, and areas of similar use

(3) Outdoors

Exception to (3): Receptacles that are not readily accessible and are supplied by a branch circuit dedicated to electric snow-melting, deicing, or pipeline and vessel heating equipment shall be permitted to be installed in accordance with 426.28 or 427.22 , as applicable.

(4) Crawl spaces — at or below grade level

(5) Unfinished portions or areas of the basement not intended as habitable rooms

Exception to (5): A receptacle supplying only a permanently installed fire alarm or burglar alarm system shall not be required to have ground-fault circuit-interrupter protection.

Informational Note: See 760.41(B) and 760.121(B) for power supply requirements for fire alarm systems.

Receptacles installed under the exception to 210.8(A)(5) shall not be considered as meeting the requirements of 210.52(G).

(6) Kitchens — where the receptacles are installed to serve the countertop surfaces

(7) Sinks — where receptacles are installed within 1.8 m (6 ft) from the top inside edge of the bowl of the sink

(8) Boathouses

(9) Bathtubs or shower stalls — where receptacles are installed within 1.8 m (6 ft) of the outside edge of the bathtub or shower stall

(10) Laundry areas

Exception to (1) through (10): Locking support and mounting receptacles utilized in combination with compatible attachment fittings shall not be required to be ground-fault circuit-interrupter protected.

Statement of Problem and Substantiation for Public Input

Note to NFPA Staff and CMP members: Terra underlined all the exceptions - the only addition was the last Exception (1) through (10).
The locking support and mounting receptacles are generally located on the ceiling or high on the wall, and generally are not readily accessible. These receptacles utilized in combination with a compatible attachment fitting are load-make/load-break rated for disconnect. The faceplate prevents easy access to the outlet box. Additionally, work on the utilization equipment (changing bulbs, maintenance, cleaning) is

done when the utilization equipment is disconnected, therefore the risk of being shocked is greatly reduced and practically eliminated. Additionally, the attachment fitting does not have a cord attached to it, therefore no cord to be potentially damaged to cause an electrical hazard. There is no portable equipment that personnel will be constantly handling. Once connected the utilization equipment may be considered similar to a hard-connected piece of equipment. The installation equipment may be considered as a semi-permanent installation and as such should be treated similar to a permanent installation.

Submitter Information Verification

Submitter Full Name:	Amy Cronin
Organization:	Strategic Code Solutions LLC
Affilliation:	SQL Technologies (formerly Safety Quick Lighting and Fans Corp)
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Wed Aug 09 13:14:33 EDT 2017

Copyright Assignment

I, Amy Cronin, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Amy Cronin, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 3926-NFPA 70-2017 [New Section after 210.8(E)]

Structures Built with Metal Framing

GFCI protection shall be provided for non-metallic sheathed cables installed through metal framing.

Statement of Problem and Substantiation for Public Input

Branch circuits traveling through metal framing (studs) can have their insulation compromised energizing the wall and any metal components in contact with the studs.

Submitter Information Verification

Submitter Full Name: Lanson Relyea

Organization: Eaton Corporation

Street Address:

City:

State:

Zip:

Submittal Date: Thu Sep 07 09:23:16 EDT 2017

Public Input No. 3902-NFPA 70-2017 [Section No. 210.70 [Excluding any Sub-Sections]]

Lighting outlets shall be installed where specified in 210.70(A), (B), and (C). Locking support and mounting receptacle outlets shall be recognized as lighting outlets.

Statement of Problem and Substantiation for Public Input

Locking support and mounting receptacle outlets are utilized to supply luminaires or fan/light combinations. The text is necessary to insure that these outlets are recognized as lighting outlets. It is needed to assure that there is no requirement to add lighting outlets in addition to the locking support and mounting receptacles, as they are lighting outlets.

Submitter Information Verification

Submitter Full Name:	Michael Fontaine
Organization:	National Electrical Safety Group, Inc.
Affilliation:	SQL Technologies Corp.
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Thu Sep 07 08:48:09 EDT 2017

Public Input No. 34-NFPA 70-2017 [Section No. 210.11(C)(2)]

(2) Laundry Branch Circuits.

In addition to the number of branch circuits required by other parts of this section, at least one additional 20-ampere branch circuit shall be provided to supply the laundry receptacle outlet(s) required by 210.52(F). This circuit shall have no other outlets. <u>and shall be in addition to outlet installed for washer and/or dryer.</u>

<u>*(Exception: Laundry area(s) contained within a closet with front access only where an outlet is installed for laundry appliance(s) shall be exempt from this additional outlet.)*</u>

Statement of Problem and Substantiation for Public Input

Clarity on definition and requirements for laundry in dwellings

Submitter Information Verification

Submitter Full Name: Dan Haruch

Organization: Brightwood Career Institute

Street Address:

City:

State:

Zip:

Submittal Date: Tue Jan 24 08:31:41 EST 2017

Public Input No. 1494-NFPA 70-2017 [Section No. 210.11(C)(3)]

(3) Bathroom Branch Circuits.

In addition to the number of branch circuits required by other parts of this section, at least one 120-volt, 20-ampere branch circuit shall be provided to supply the bathroom(s) receptacle outlet(s), required by 210 .52(D). Such circuits shall have no other outlets.

Exception: Where the 20-ampere circuit supplies a single bathroom, outlets for other equipment within the same bathroom shall be permitted to be supplied in accordance with 210.23(A)(1) and (A)(2).

Statement of Problem and Substantiation for Public Input

Edit to simply provide the reference on the required receptacle(s).

Submitter Information Verification

Submitter Full Name: Mike Holt

Organization: Mike Holt Enterprises Inc

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 01 10:57:11 EDT 2017

Public Input No. 1941-NFPA 70-2017 [Section No. 210.11(C)(3)]

(3) Bathroom Branch Circuits.

In addition to the number of branch circuits required by other parts of this section, at least one 120-volt, 20-ampere branch circuit shall be provided to supply the bathroom(s) receptacle outlet(s) required by 210 .52(D). Such circuits shall have no other outlets.

Exception: Where the 20-ampere circuit supplies a single bathroom, outlets for other equipment within the same bathroom shall be permitted to be supplied in accordance with 210.23(A)(1) and (A)(2).

Statement of Problem and Substantiation for Public Input

Enforcement officials have interpreted this requirement to mandate that any receptacle(s) installed in a bathroom, in addition to the receptacles required in 210.52(D), must be a 20 amp branch circuit. Example: If a cord and plug space heater receptacle is installed in a bathroom, in addition the receptacle(s) required by 210.52(D), a 15 amp branch circuit could be used as long as it met the other provisions of the NEC (i.e. GFCI, tamper resistant and etc.).

Submitter Information Verification

Submitter Full Name: David Clements

Organization: Intl Assoc Elec Insp

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 09 09:14:06 EDT 2017

Public Input No. 27-NFPA 70-2017 [Section No. 210.11(C)(3)]

(3) Bathroom Branch Circuits.

In addition to the number of branch circuits required by other parts of this section, at least one 120-volt, 20-ampere branch circuit shall be provided to

supply the

~~bathroom(s)~~

receptacle outlet(s)

~~. Such~~

specified by 210.52(D). Such circuits shall have no other outlets.

Exception: Where the 20-ampere circuit supplies a single bathroom, outlets for other equipment within the same bathroom shall be permitted to be supplied in accordance with 210.23(A)(1) and (A)(2).

Additional Proposed Changes

File Name	Description	Approved
picture_light.JPG	Picture light plugged into receptacle behind picture	✓

Statement of Problem and Substantiation for Public Input

The present wording creates a conflict for any appliance such as a towel warmer, dehumidifier, air conditioner or other cord-and-plug connected equipment installed in the bathroom that requires a maximum circuit of 15amps. I believe my proposal will help clarify the intent of this rule which is to require the receptacles next to the sink to be on a 20-amp circuit. Other receptacle outlets may be supplied by a 15-amp circuit as required or designed. Something else to consider, I have installed artwork and paintings on the bathroom walls of high-end condos where the customer wanted the items lit up with cord-and-plug connected picture lights. There would really be no need to have those picture light receptacles installed behind wall hung paintings to be on a 20-amp circuit as the literal wording presently requires. A 15-amp circuit would suffice for this lighting layout.This proposed revision will also provide some consistency with the wording in section 210.11(C)(1) and (2).

Submitter Information Verification

Submitter Full Name: Russ Leblanc

Organization: Leblanc Consulting Services

Street Address:

City:

State:

Zip:

Submittal Date: Sun Jan 22 09:12:30 EST 2017

Copyright Assignment

I, Russ Leblanc, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Russ Leblanc, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 2881-NFPA 70-2017 [Section No. 210.11(C)(3)]

(3) Bathroom Branch Circuits.

In addition to the number of branch circuits required by other parts of this section, at least one 120-volt, 20-ampere branch circuit shall be provided to supply the bathroom(s) receptacle outlet(s). Such circuits shall have no other outlets.

Exception:

(1) Where the 20-ampere circuit supplies a single bathroom, outlets for other equipment within the same bathroom shall be permitted to be supplied in accordance with 210.23(A)(1) and (A)(2).

(2) Bathroom receptacle outlet(s) not installed under exception (1) and used for lighting purposes shall be permitted provided they are connected to a general purpose circuit

Statement of Problem and Substantiation for Public Input

We often run into lighting under a vanity or inside a cabinet for low voltage accent lighting. These often require a receptacle for the power source. As I read the original section it appears to state that all receptacles in a bathroom must be on the bathroom circuit. In the case where one or more bathroom's are fed from a bathroom receptacle circuit, we would then be allowed to install receptacles not intended to be used for appliances as long as it is installed on a lighting circuit. This would eliminate more demand on the required bathroom receptacle circuit

Submitter Information Verification

Submitter Full Name: Dennis Alwon

Organization: Alwon Electric

Street Address:

City:

State:

Zip:

Submittal Date: Mon Aug 28 16:00:00 EDT 2017

Public Input No. 1492-NFPA 70-2017 [Section No. 210.11(C)(4)]

(4) Garage Branch Circuits.

In addition to the number of branch circuits required by other parts of this section, at least one 120-volt, 20-ampere branch circuit shall be installed to supply general purpose receptacle outlets in attached garages and in detached garages with electric power, required by 210 .52(G). This circuit shall have no other outlets.

Exception: This circuit shall be permitted to supply readily accessible outdoor receptacle outlets.

Statement of Problem and Substantiation for Public Input

Edit this rule to clarify that the dedicated 20A, 120V garage receptacle circuit is for general purpose receptacles, as required by 210.52(G).

Submitter Information Verification

Submitter Full Name: Mike Holt

Organization: Mike Holt Enterprises Inc

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 01 10:51:29 EDT 2017

Public Input No. 3371-NFPA 70-2017 [Section No. 210.11(C)(4)]

(4) Garage Branch Circuits.

In addition to the number of branch circuits required by other parts of this section, at least one 120-volt, 20-ampere branch circuit shall be installed to supply receptacle outlets in attached garages and in detached garages with electric power. This circuit shall have no other outlets.

Exception: This circuit shall be permitted to supply ~~readily accessible~~ outdoor receptacle outlets <u>located in the vacinity of the garage</u> .

Statement of Problem and Substantiation for Public Input

As currently worded, the branch circuit primarily dedicated to receptacle outlets in the garage could also supply any and all of the outdoor receptacles as long as those outdoor receptacles were by definition, "readily accessible." This could include an outdoor receptacle outlet located on the opposite side of the house from the garage (100 ft. away from the garage) as long is that receptacle outlet was "readily accessible."

As a visitor to CMP-2 as this section was being discussed during the 2017 NEC Code development process, I recall the committee discussing an exception for outdoor receptacle outlets that were "easily (conveniently) accessible from the garage itself so the installer would not have to install an additional branch circuit in the garage area just for these outdoor receptacle outlets. When the committee chose to use the term "readily accessible" to describe these outdoor receptacle outlets convenient to the garage, all of the outdoor receptacle outlets were encompassed into this exception (as long as they are readily accessible by definition).

Submitter Information Verification

Submitter Full Name: L. Keith Lofland

Organization: IAEI

Affilliation: Self

Street Address:

City:

State:

Zip:

Submittal Date: Tue Sep 05 17:22:25 EDT 2017

Public Input No. 3375-NFPA 70-2017 [Section No. 210.11(C)(4)]

(4) Garage Branch Circuits.

In addition to the number of branch circuits required by other parts of this section, at least one 120-volt, 20-ampere branch circuit shall be installed to supply receptacle outlets in attached garages and in detached garages with electric power. This circuit shall have no other outlets.

Exception: This circuit shall be permitted to supply ~~readily accessible~~ outdoor receptacle outlets accessible from the garage .

Statement of Problem and Substantiation for Public Input

As currently worded, the branch circuit primarily dedicated to receptacle outlets in the garage could also supply any and all of the outdoor receptacles as long as those outdoor receptacles were by definition, "readily accessible." This could include an outdoor receptacle outlet located on the opposite side of the house from the garage (100 ft. away from the garage) as long is that receptacle outlet was "readily accessible."

As a visitor to CMP-2 as this section was being discussed during the 2017 NEC Code development process, I recall the committee discussing an exception for outdoor receptacle outlets that were "easily (conveniently) accessible from the garage itself so the installer would not have to install an additional branch circuit in the garage area just for these outdoor receptacle outlets. When the committee chose to use the term "readily accessible" to describe these outdoor receptacle outlets convenient to the garage, all of the outdoor receptacle outlets were encompassed into this exception (as long as they are readily accessible by definition).

Submitter Information Verification

Submitter Full Name: L. Keith Lofland
Organization: IAEI
Affilliation: Self
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 05 17:36:03 EDT 2017

Public Input No. 3591-NFPA 70-2017 [Section No. 210.11(C)(4)]

(4) Garage Branch Circuits.

In addition to the number of branch circuits required by other parts of this section, at least one 120-volt, 20-ampere branch circuit shall be installed to supply receptacle outlets in attached garages and in detached garages with electric power. This circuit shall have no other outlets.

Exception: This circuit shall be permitted to supply readily accessible outdoor receptacle outlets.

This section has been revised over the past several code cycles to the betterment of the industry and to the benefit of the final homeowner. The revision in the 2014 NEC started with the requirement to have a receptacle located in each "car space" per 210.52 (G)(1) Garages. "The branch circuit supplying this receptacle(s) shall not supply outlets outside of the garage."

Then in 2017, the new section 210.11(C)(4) further required this receptacle circuit to be upgraded to a 20 ampere circuit to further accomodate the onset of electric vehicle charging systems (article 625). The last sentence of this section "Garage Branch Circuits" states: "This circuit shall have no other outlets." No ceiling lights, no outside lights, no hallway lights etc. etc. This is a very good step forward to meet these electrical vehicle charging requirements for the smaller electric vehicles and the hybrid cars. Of course the larger cars with bigger batteries will need dedicated, higher amperage charging stations. The Exception to allow outdoor receptacles to be installed on this valuable 20 ampere garage circuit is a mistake. Deleting this Exception would be a step forward for the garage circuit instead of the step backward that was taken for the 2017 NEC. Please delete the Exception.

Thank you for your Consideration

Ray Paulson

Chief Electrical Inspector - City of Hickman, Nebraska

2321 South 13th Street - Lincoln, Nebraska 68502

rpaulson@neb.rr.com (402)416-8899 cell phone

Statement of Problem and Substantiation for Public Input

By deleting the "Exception" to 210.11(C)(4), the 20 ampere branch circuit to the garage would not be compromised by the addition of "readily accessible outdoor receptacle outlets". We have made excellent improvements to the garage receptacle circuit, lets delete this backward step provided by this exception.

Submitter Information Verification

Submitter Full Name:	Raymond Paulson
Organization:	National Electrical Continuing Education (Currently Chief Electrical Inspector for City of Hickman, NE - but not representing the City of Hickman) Currently Secretary for the Nebraska Chapter of the IAEI, but not representing the NE Chapter.
Street Address:	
City:	
State:	

Zip:

Submittal Date: Wed Sep 06 14:26:12 EDT 2017

Copyright Assignment

Public Input No. 368-NFPA 70-2017 [Section No. 210.11(C)(4)]

(4) Garage Branch Circuits.

In addition to the number of branch circuits required by other parts of this section, at least one 120-volt, 20-ampere branch circuit shall be installed to the supply receptacle ~~outlets~~ outlets required by 210.52(G) in attached garages and in detached garages with electric power. This circuit shall have no other outlets.

Exception: This circuit shall be permitted to supply readily accessible outdoor receptacle outlets.

Statement of Problem and Substantiation for Public Input

Section 210.52(G)(1) was revised for the 2017 code to help clarify acceptable locations for the required receptacles in garages of one- and two-family dwellings. It is spelled out very clearly that for each attached garage, and each detached garage with electric power, at least one receptacle outlet must be installed in each vehicle bay and not more 5 ½ ft. above the floor. This revision means that receptacle outlets installed high on the walls, or on the ceiling for powering electric garage door openers will not be considered the “required” receptacles. What is not clarified is which circuit size is needed to supply the required receptacles. Does it need to be a 20-amp circuit or can it be a 15-amp circuit? Well, section 210.11(C)(4) was added for the 2017 code, which may help answer that question. It states “In addition to the number of branch circuits required by other parts of this section, at least one 120-volt, 20-ampere branch circuit shall be installed to supply receptacle outlets in attached garages and in detached garages with electric power. This circuit shall have no other outlets.” So, it seems as though the receptacles required by section 210.52(G) must be supplied by this 20-amp circuit. That is not necessarily the case however. Perhaps an installer could use a 20-amp circuit to supply some receptacles installed on the ceiling for powering the garage door openers. This 20-amp circuit would not have any other outlets except readily accessible outdoor receptacles. This arrangement would fulfill the literal requirements of 210.11(C)(4). A 15-amp circuit could then be used to supply the receptacles required by section 210.52(G)(1). This 15-amp circuit could also be used to supply lighting outlets and receptacle outlets inside and outside of the garage and elsewhere on the property. Is the intent of section 210.11(C)(4) to require the 20-amp circuit to supply power to the receptacles required by 210.11(C)(4)? The Public Inputs submitted during the last revision cycle seem to indicate that this was in fact the intent. I believe this revision will help clarify the intent of the requirement.

Submitter Information Verification

Submitter Full Name: Russ Leblanc

Organization: Leblanc Consulting Services

Street Address:

City:

State:

Zip:

Submittal Date: Sun Mar 26 07:35:50 EDT 2017

Copyright Assignment

I, Russ Leblanc, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Russ Leblanc, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 3737-NFPA 70-2017 [Section No. 210.11(C)(4)]

(4) Garage Branch Circuits.

In addition to the number of branch circuits required by other parts of this section, at least one 120-volt, 20-ampere branch circuit shall be installed to supply receptacle outlets in attached garages and in detached garages with electric power. This circuit shall have no other outlets.

Exception: This circuit shall be permitted to supply only readily accessible outdoor receptacle outlets on the exterior of garage walls .

Statement of Problem and Substantiation for Public Input

This exception as currently written would allow an outdoor receptacle outlet to be placed at any location that is readily accessible outdoors, whether or not attached to the garage. So could this also be the receptacle outlet for the house, or at a pedestal in the yard or at any outdoor location at the dwelling? Based on the text in the main requirement this branch circuit is to serve or supply the garage exclusively and if using the exception to put in an outdoor receptacle outlet it should be only limited to the exterior of the garage walls themselves.

Submitter Information Verification

Submitter Full Name: Darryl Hill
Organization: Wichita Electrical JATCIBEW 2
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 06 19:09:19 EDT 2017

Public Input No. 4006-NFPA 70-2017 [Section No. 210.11(C)(4)]

(4) Garage Branch Circuits.

In addition to the number of branch circuits required by other parts of this section, at least one 120-volt, 20-ampere branch circuit shall be installed to supply receptacle outlets in attached garages and in detached garages with electric power. This circuit shall have no other outlets.

Exception: This circuit shall be permitted to supply readily accessible outdoor receptacle outlets on the garage .

Statement of Problem and Substantiation for Public Input

This is to clarify if the garage circuit could also supply the 6-10 outdoor receptacles around the house or just for the garage outdoor receptacles.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 07 12:09:04 EDT 2017

Public Input No. 635-NFPA 70-2017 [Section No. 210.11(C)(4)]

(4) Garage Branch Circuits.

In addition to the number of branch circuits required by other parts of this section, at least one 120-volt, 20-ampere branch circuit shall be installed to supply receptacle outlets in attached garages and in detached garages with electric power. This circuit shall have no other outlets.

Exception 1 : This circuit shall be permitted to supply readily accessible outdoor receptacle outlets.

Exception 2: Detached garages supplied by an individual 20-ampere, 120-volt circuit, shall be permitted to be serve other outlets.

Statement of Problem and Substantiation for Public Input

This would allow an installer to feed a detached garage with a individual 20-ampere, 120-volt circuit and serve an interior light, exterior light and garage door operator receptacle which this code section would not allow. The current requirement would only allow a multi-wire branch circuit or a feeder to supply a detached garage to meet thie current requirement. A single circuit supplying a detached garage has been allowed for many years and the code states 90.1(B) that compliance therewith may result in an installation and proper maintenance that is essentially free from hazard, but not necessarily efficient, convenient or good service or future expansion of electrical use.

Submitter Information Verification

Submitter Full Name: Dewayne Jenkins

Organization:

Street Address:

City:

State:

Zip:

Submittal Date: Tue May 02 08:42:12 EDT 2017

Public Input No. 643-NFPA 70-2017 [Section No. 210.11(C)(4)]

(4) Garage Branch Circuits.

In addition to the number of branch circuits required by other parts of this section, at least one or more 120-volt, 20-ampere branch circuit(s) shall be installed to supply the receptacle outlets required by 210.52(G)(1) in attached garages and in detached garages with electric power. This circuit shall have no other outlets.

Exception: This circuit shall be permitted to supply readily accessible outdoor receptacle outlets.

Statement of Problem and Substantiation for Public Input

The reason that I submitted this public input was for clarification purposes.

I do understand that the wording in this section takes on similar format as section 210.11(C)(1), 210.11(C)(2), and 210.11(C)(3). However garages may need to be treated a bit differently because of the vehicle bays. Now, since a receptacle outlet must be installed in EACH vehicle bay per 210.52(G)(1), I believe this section needs to be clearer that if more than one required branch circuit gets installed, that they all be 20-ampere.

Imagine a garage with four vehicle bays. Contractors will argue that they can run a 20-ampere circuit to the first bay, and then a 15-ampere circuit to supply the rest of the bays. They (contractors) can make the argument that they have complied with the code language.

210.11(C)(1) is clear, because it uses the word "ALL" denoting "all receptacle outlets." This leaves no room for misinterpretation.
210.11(C)(2) is clear because it specifices, "the laundry receptacle outlet(s) required by 210.52(F)." This leaves no room for misinterpretation.
210.11(C)(3) is clear because it states, "the bathroom(s) receptacle outlet(s)." This leaves no room for misinterpretation.
210.11(C)(4) I feel is unclear, because it simply says, "receptacle outlets in attached garages..." This can mean all of them, or just some of them.

This new language would make it clear that if there is just one required branch circuit -or- more than one required branch circuit to power receptacle outlets being required by 210.52(G)(1), that they must all be 20-ampere. If the language is added, there would be no room for misinterpretation.

Submitter Information Verification

Submitter Full Name: Nick Sasso
Organization: State of Wyoming, www.electrical-code-expert.com
Street Address:
City:
State:
Zip:

Submittal Date: Wed May 03 22:29:33 EDT 2017

Copyright Assignment

I, Nick Sasso, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Nick Sasso, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 912-NFPA 70-2017 [Section No. 210.11(C)(4)]

(4) Garage Branch Circuits.

In addition to the number of branch circuits required by other parts of this section, at least one 120-volt, 20-ampere branch circuit shall be installed to supply receptacle outlets required in section 210.52(G)(1) for attached garages and in detached garages with electric power. This circuit shall have no other outlets.

Exception: This circuit shall be permitted to supply readily accessible outdoor receptacle outlets.

Statement of Problem and Substantiation for Public Input

This PI encourages CMP 2 to adopt the reference to section 210.52(G)(1) (see PI 1010 2017 renewal cycle) to clarify that only those receptacles required by said section are required to be supplied by a 20A branch circuit. The current language is currently interpreted in an inconsistent manner. If the intent of the language is not clear to installers and inspectors alike, then the language fails, Does CMP 2 wish all receptacles located in garages to be supplied by a 20 A 125 V circuit? If not the language can direct the users of this document to which receptacles must be supplied by a 20 A branch circuit and by default permit other outlets such as those for garage door openers, to be supplied from general lighting circuits. If the panel wishes that all receptacles in the garage be supplied by a 20 A branch circuit then I would direct the panels attention to my other PI which utilizes the word "all".

Submitter Information Verification

Submitter Full Name: Charles Palmieri
Organization: Town of Norwell
Street Address:
City:
State:
Zip:
Submittal Date: Wed Jun 07 08:48:21 EDT 2017

Public Input No. 913-NFPA 70-2017 [Section No. 210.11(C)(4)]

(4) Garage Branch Circuits.

In addition to the number of branch circuits required by other parts of this section, at least one 120-volt, 20-ampere branch circuit shall be installed to supply all receptacle outlets in attached garages and in detached garages with electric power. This circuit shall have no other outlets.

Exception: This circuit shall be permitted to supply readily accessible outdoor receptacle outlets.

Statement of Problem and Substantiation for Public Input

Please see my substantiation to PI 912. Although I am not in favor of all receptacles in a dwellings garage to be required to be supplied by a 120 V 20 A branch circuit I am offering this language for CMP 2 to work with. If the panel feels as I do that ancillary outlets may be adequately supplied by a 15 A circuit (such as door openers) then I would point you to the proposed language in PI 912.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 912-NFPA 70-2017 [Section No. 210.11(C)(4)]	

Submitter Information Verification

Submitter Full Name: Charles Palmieri
Organization: Town of Norwell
Street Address:
City:
State:
Zip:
Submittal Date: Wed Jun 07 09:15:54 EDT 2017

Public Input No. 1121-NFPA 70-2017 [Section No. 210.12(A)]

(A) Dwelling Units.

All 120-volt, single-phase, 15- and 20-ampere branch circuits supplying outlets or devices installed in dwelling unit ~~kitchens, family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, laundry areas, or similar rooms or areas~~ shall be protected by any of the means described in 210.12(A)(1) through (6):

(1) A listed combination-type arc-fault circuit interrupter, installed to provide protection of the entire branch circuit

(2) A listed branch/feeder-type AFCI installed at the origin of the branch-circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit. The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(3) A listed supplemental arc protection circuit breaker installed at the origin of the branch circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit where all of the following conditions are met:

   (4) <u>The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.</u>

   (5) <u>The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.</u>

   (6) <u>The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.</u>

(7) A listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet on the branch circuit in combination with a listed branch-circuit overcurrent protective device where all of the following conditions are met:

   (8) <u>The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.</u>

   (9) <u>The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.</u>

   (10) <u>The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.</u>

   (11) <u>The combination of the branch-circuit overcurrent device and outlet branch-circuit AFCI shall be identified as meeting the requirements for a system combination–type AFCI and shall be listed as such.</u>

(12) If RMC, IMC, EMT, Type MC, or steel-armored Type AC cables meeting the requirements of 250.118, metal wireways, metal auxiliary gutters, and metal outlet and junction boxes are installed for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

(13) Where a listed metal or nonmetallic conduit or tubing or Type MC cable is encased in not less than 50 mm (2 in.) of concrete for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

Exception: Where an individual branch circuit to a fire alarm system installed in accordance with 760.41(B) or 760.121(B) is installed in RMC, IMC, EMT, or steel-sheathed cable, Type AC or Type MC, meeting the requirements of 250.118, with metal outlet and junction boxes, AFCI protection shall be permitted to be omitted.

Informational Note No. 1: For information on combination-type and branch/feeder-type arc-fault circuit interrupters, see UL 1699-2011, *Standard for Arc-Fault Circuit Interrupters*. For information on outlet branch-circuit type arc-fault circuit interupters, see UL Subject 1699A, *Outline of Investigation for Outlet Branch Circuit Arc-Fault Circuit-Interrupters*. For information on system combination AFCIs, see UL Subject 1699C, *Outline of Investigation for System Combination Arc-Fault Circuit Interrupters*.

Informational Note No. 2: See 29.6.3(5) of *NFPA 72*-2013, *National Fire Alarm and Signaling Code*, for information related to secondary power-supply requirements for smoke alarms installed in dwelling units.

Informational Note No. 3: See 760.41(B) and 760.121(B) for power-supply requirements for fire alarm systems.

Statement of Problem and Substantiation for Public Input

AFCIs have been required in the Code since 1999. The initial requirement covered only bedroom receptacle outlets, giving installers an opportunity to gain experience with what was at that time a new product, and manufacturers to address any unforeseen problems with their designs. In the 2002 edition the requirement was expanded to include all bedroom outlets. In the 2008 edition the requirement was expanded once again to include bedrooms, family rooms, living rooms, parlors, libraries, dens, sun rooms, recreation rooms or similar rooms. Kitchen, laundry areas and devices located in the specified areas were added to the requirement in the 2014 edition. By the time the 2020 edition is published, the industry will have over 18 years of experience with the manufacture and installation of AFCIs and over 12 years of experience with combination type AFCIs.

All along CMP 2 has wisely chosen to take incremental steps in the expansion of the AFCI requirement. With the expanded requirment in the 2014 edition, there are a very few 120-volt single-phase 15- and 20-ampere branch circuits in a dwelling unit that do not require AFCI protection. The time has come to complete the arc-fault protection task by requiring AFCI protection on all 15- and 20-ampere 120-volt dwelling unit circuits.

Submitter Information Verification

Submitter Full Name: Vince Baclawski

Organization: Nema

Street Address:

City:

State:

Zip:

Submittal Date: Fri Jul 07 13:50:14 EDT 2017

Public Input No. 1390-NFPA 70-2017 [Section No. 210.12(A)]

(A) Dwelling Units.

All 120-volt, single-phase, 15- and 20-ampere branch circuits supplying outlets or devices installed in dwelling unit kitchens, family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, laundry areas, or similar rooms or areas shall be protected by any of the means described in 210.12(A)(1) through (6):

(1) A listed combination-type arc-fault circuit interrupter, installed to provide protection of the entire branch circuit

(2) A listed branch/feeder-type AFCI installed at the origin of the branch-circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit. The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(3) A listed supplemental arc protection circuit breaker installed at the origin of the branch circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit where all of the following conditions are met:

(4) <u>The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.</u>

(5) <u>The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.</u>

(6) <u>The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.</u>

(7) A listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet on the branch circuit in combination with a listed branch-circuit overcurrent protective device where all of the following conditions are met:

(8) <u>The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.</u>

(9) <u>The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.</u>

(10) <u>The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.</u>

(11) <u>The combination of the branch-circuit overcurrent device and outlet branch-circuit AFCI shall be identified as meeting the requirements for a system combination–type AFCI and shall be listed as such.</u>

(12) If RMC, IMC, EMT, Type MC, or steel-armored Type AC cables meeting the requirements of 250.118, metal wireways, metal auxiliary gutters, and metal outlet and junction boxes are installed for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

(13) Where a listed metal or nonmetallic conduit or tubing or Type MC cable is encased in not less than 50 mm (2 in.) of concrete for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

Exception <u>1</u> : Where an individual branch circuit to a fire alarm system installed in accordance with 760.41(B) or 760.121(B) is installed in RMC, IMC, EMT, or steel-sheathed cable, Type AC or Type MC, meeting the requirements of 250.118, with metal outlet and junction boxes, AFCI protection shall be permitted to be omitted.

Exception 2: AFCI protection shall not be required in Limited C are Facilities, as defined in Article 517.

Informational Note No. 1: For information on combination-type and branch/feeder-type arc-fault circuit interrupters, see UL 1699-2011, *Standard for Arc-Fault Circuit Interrupters*. For information on outlet branch-circuit type arc-fault circuit interupters, see UL Subject 1699A, *Outline of Investigation for Outlet Branch Circuit Arc-Fault Circuit-Interrupters*. For information on system combination AFCIs, see UL Subject 1699C, *Outline of Investigation for System Combination Arc-Fault Circuit Interrupters*.

Informational Note No. 2: See 29.6.3(5) of *NFPA 72*-2013, *National Fire Alarm and Signaling Code*, for information related to secondary power-supply requirements for smoke alarms installed in dwelling units.

Informational Note No. 3: See 760.41(B) and 760.121(B) for power-supply requirements for fire alarm systems.

Additional Proposed Changes

File Name	Description	Approved
afci_dwelling_unit_-_canada.pdf	Arc fault circuit interrupter in a dwelling unit	✓

Statement of Problem and Substantiation for Public Input

Electrical inspectors are having difficulty determining whether or not AFCI protection is required in limited care facilities (that may meet the definition of dwelling unit) such as some adult care centers and nursing homes. It is not. But when I pose the question to electrical inspectors, 9 out of 10 will say that they must require the AFCI protection if the "unit" has permanent provisions for cooking. This is incorrect. It creates confusion on the job and confusion with Architects and Engineers.

While AFCI protection has been expanded in the 2017 NEC to include guest rooms of hotels and also dormitory units, it was never the intent of the code to include limited care facilities. For limited care facilities, there are other life safety codes and standards come into play, to ensure occupant protection in the event of fire. These institutional facilities are usually required to have various different types of alarms and communication alert systems, and to be sprinkled. I have attached a business brief from our friends in Canada supporting my substantiation that limited care facilities are not required to have the AFCI protection. There has been very little discussion on this subject to date. Also, I believe that the existing exception helps to support my substantiation.

NOTE::
I'm not sure why so much of the text is underlined. Terra is acting up again. The only proposed change that I made is to have the Exception that exists now be relabeled as "Exception 1" and then to add "Exception 2: AFCI protection shall not be required in Limited Care Facilities, as defined in Article 517."

The reason for this change is for clarification purposes. It will help the electrical inspector in the course of his/her duties to avoid confusion.

Submitter Information Verification

Submitter Full Name: Nick Sasso
Organization: State of Wyoming

Affilliation: www.electrical-code-expert.com
Street Address:
City:
State:
Zip:
Submittal Date: Fri Jul 28 10:47:15 EDT 2017

Copyright Assignment

Bulletin 26-18-9
Arc fault circuit interrupter (AFCI) in a dwelling unit
Rule 26-724

Issued May 2016
Supersedes Bulletin 26-18-8

Scope

(1) Definitions
  (a) Dwelling unit
  (b) Cooking facility
(2) AFCI protection

(1) Definitions

(a) Dwelling unit

With the introduction of the AFCI, there has been confusion as to what is meant by “dwelling unit”.

A dwelling unit is one or more rooms, for the use of one or more persons, as a housekeeping unit with cooking, eating, living, and sleeping facilities.

Examples of dwelling units:
- single dwelling complete with cooking, eating, living, and sleeping facilities such as detached house, one unit of row housing or one unit of semi-detached, duplex, triplex or quadruplex
- an apartment unit complete with cooking, eating, living, and sleeping facilities
- a condominium unit complete with cooking, eating, living, and sleeping facilities
- a self-contained suite or unit in a motel or hotel complete with cooking, eating, living, and sleeping facilities
- a self-contained student dormitory unit consisting of cooking, eating, living, and sleeping facilities
- a self-contained unit in a long term care facility consisting of cooking, eating, living, and sleeping facilities
- a self-contained, housekeeping rental cabin

Examples of non-dwelling units:
- Institutional facility such as a hospital, nursing home, long term care facility, etc.
- prison
- facilities containing only living and sleeping facilities such as motel and hotel rooms, etc.

Rationale
The Ontario Electrical Safety Code (OESC) defines a "Dwelling unit "as one or more rooms for the use of one or more persons as a housekeeping unit with cooking, eating, living, and sleeping facilities".

(b) Cooking facility

A cooking facility shall have a range (electric or gas supply). Hot plates and microwaves do not constitute a cooking facility.

(2) AFCI Protection

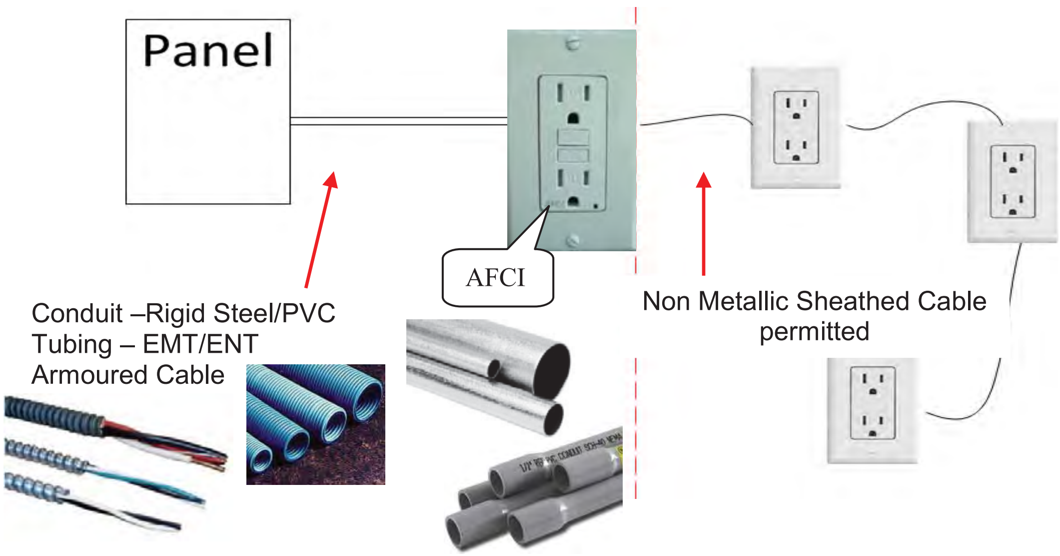
Background

Prior to the 2015 OESC, the only type of AFCI device mandated was the Branch AFCI breaker. Branch AFCI breakers only provide arcing protection against parallel faults and are no longer permitted by the OESC. The OESC now requires a **Combination type AFCI;** a device that provides both series and parallel arc fault protection to the entire branch circuit wiring, including cord sets and power supply cords connected to the outlets, against the unwanted effects of arcing. CAFI type breakers are marked as "Combination Type Arc-Fault Circuit-Interrupter" or "Combination Type AFCI".

In addition to combination type breakers, Outlet branch circuit (OBC) devices are now permitted when:

(i) the outlet branch circuit type AFCI is installed at the first outlet on the branch circuit; and

(ii) the wiring method for the portion of the branch circuit between the branch circuit overcurrent device and the first outlet is comprised of metal raceway, armoured cable or non-metallic conduit or tubing.



Rationale

Since OBC devices provide limited protection against arcing faults upstream of the OBC device (cannot interrupt parallel arcing faults), the increased wiring methods provide additional mechanical protection to the conductors from damage and also mitigates arcing faults from igniting adjacent combustibles.

Question 1

When a Branch circuit originates from a dwelling unit to feed receptacles not installed in or on the dwelling unit (i.e. landscape, garage or shed receptacle) is Arc Fault Protection required?

Answer 1

No, these branch circuits are not for the dwelling unit.

Question 2

For a branch circuit containing both lighting and receptacle outlets, is AFCI protection required?

Answer 2

Yes, unless exempted by Rule 26-724(f)

Question 3

Is AFCI protection required for receptacles not specifically exempted in rule 26-724, such as those for a dedicated microwave, dishwasher, or garbage disposal unit?

Answer 3

Yes.

Public Input No. 1497-NFPA 70-2017 [Section No. 210.12(A)]

(A) Dwelling Units.

All 120-volt, single-phase, 15- and 20-ampere branch circuits ~~supplying outlets or devices~~ installed in dwelling ~~unit kitchens, family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, laundry areas, or similar rooms or areas~~ units shall be protected by any of the means described in 210.12(A)(1) through (6):

(1) A listed combination-type arc-fault circuit interrupter, installed to provide protection of the entire branch circuit

(2) A listed branch/feeder-type AFCI installed at the origin of the branch-circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit. The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(3) A listed supplemental arc protection circuit breaker installed at the origin of the branch circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit where all of the following conditions are met:

(4) The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.

(5) The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.

(6) The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(7) A listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet on the branch circuit in combination with a listed branch-circuit overcurrent protective device where all of the following conditions are met:

(8) The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.

(9) The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.

(10) The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(11) The combination of the branch-circuit overcurrent device and outlet branch-circuit AFCI shall be identified as meeting the requirements for a system combination–type AFCI and shall be listed as such.

(12) If RMC, IMC, EMT, Type MC, or steel-armored Type AC cables meeting the requirements of 250.118, metal wireways, metal auxiliary gutters, and metal outlet and junction boxes are installed for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

(13) Where a listed metal or nonmetallic conduit or tubing or Type MC cable is encased in not less than 50 mm (2 in.) of concrete for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

Exception: Where an individual branch circuit to a fire alarm system installed in accordance with 760.41(B) or 760.121(B) is installed in RMC, IMC, EMT, or steel-sheathed cable, Type AC or Type MC, meeting the requirements of 250.118, with metal outlet and junction boxes, AFCI protection shall be permitted to be omitted.

Informational Note No. 1: For information on combination-type and branch/feeder-type arc-fault circuit interrupters, see UL 1699-2011, *Standard for Arc-Fault Circuit Interrupters*. For information on outlet branch-circuit type arc-fault circuit interupters, see UL Subject 1699A, *Outline of Investigation for Outlet Branch Circuit Arc-Fault Circuit-Interrupters*. For information on system combination AFCIs, see UL Subject 1699C, *Outline of Investigation for System Combination Arc-Fault Circuit Interrupters*.

Informational Note No. 2: See 29.6.3(5) of *NFPA 72*-2013, *National Fire Alarm and Signaling Code*, for information related to secondary power-supply requirements for smoke alarms installed in dwelling units.

Informational Note No. 3: See 760.41(B) and 760.121(B) for power-supply requirements for fire alarm systems.

Statement of Problem and Substantiation for Public Input

We are again ready for this change, let's require all 120-volt, single-phase, 15- and 20-ampere branch circuits supplying outlets or devices installed in dwelling to be AFCI protected. My entire home has dual rated GFCI/AFCIs and I don't have any problems.
Note: There is no proposed changes to any other part of this rule, but I see that other items were underlined.

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 01 11:13:15 EDT 2017

Public Input No. 1815-NFPA 70-2017 [Section No. 210.12(A)]

(A) Dwelling Units.

All 120-volt, single-phase, 15- and 20-ampere branch circuits supplying outlets or devices installed in dwelling unit kitchens, family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, laundry areas, or similar rooms or areas shall be protected by any of the means described in 210.12(A)(1) through (6):

(1) A listed combination-type arc-fault circuit interrupter, installed to provide protection of the entire branch circuit

(2) A listed branch/feeder-type AFCI installed at the origin of the branch-circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit. The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(3) A listed supplemental arc protection circuit breaker installed at the origin of the branch circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit where all of the following conditions are met:

(4) The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.

(5) The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.

(6) The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(7) A listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet on the branch circuit in combination with a listed branch-circuit overcurrent protective device where all of the following conditions are met:

(8) The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.

(9) The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.

(10) The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(11) The combination of the branch-circuit overcurrent device and outlet branch-circuit AFCI shall be identified as meeting the requirements for a system combination–type AFCI and shall be listed as such.

(12) If RMC, IMC, EMT, Type MC, or steel-armored Type AC cables meeting the requirements of 250.118, metal wireways, metal auxiliary gutters, and metal outlet and junction boxes are installed for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

(13) Where a listed metal or nonmetallic conduit or tubing or Type MC cable is encased in not less than 50 mm (2 in.) of concrete for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

Exception: Where an individual branch circuit to a fire alarm system installed in accordance with 760.41(B) or 760.121(B) is installed in RMC, IMC, EMT, or steel-sheathed cable, Type AC or Type MC, meeting the requirements of 250.118, with metal outlet and junction boxes, AFCI protection shall be permitted to be omitted.

Informational Note No. 1: ~~For information on combination-type and branch/feeder-type arc-fault circuit interrupters, see UL 1699-2011,~~ ~~*Standard for Arc-Fault Circuit Interrupters*~~ ~~. For information on outlet branch-circuit type arc-fault circuit interupters, see UL Subject 1699A,~~ ~~*Outline of Investigation for Outlet Branch Circuit Arc-Fault Circuit-Interrupters*~~ ~~. For information on system combination AFCIs, see UL Subject 1699C,~~ ~~*Outline of Investigation for System Combination Arc-Fault Circuit Interrupters*~~ ~~. Informational Note No. 2:~~ See 29.6.3(5) of *NFPA 72*-2013, *National Fire Alarm and Signaling Code*, for information related to secondary power-supply requirements for smoke alarms installed in dwelling units.

Informational Note No. ~~3~~ 2 : See 760.41(B) and 760.121(B) for power-supply requirements for fire alarm systems.

Statement of Problem and Substantiation for Public Input

The information in Note 1 is already found in Annex A. There is no reason to repeat it here.

Submitter Information Verification

Submitter Full Name: Ryan Jackson
Organization: Ryan Jackson
Street Address:
City:
State:
Zip:
Submittal Date: Sun Aug 06 18:26:05 EDT 2017

Copyright Assignment

Public Input No. 2980-NFPA 70-2017 [Section No. 210.12(A)]

(A) Dwelling Units.

All 120-volt, single-phase, 15- and 20-ampere branch circuits supplying outlets or devices installed in dwelling unit kitchens, family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, laundry areas, or similar rooms or areas shall be protected by any of the means described in 210.12(A)(1) through (6):

(1) A listed combination-type arc-fault circuit interrupter, installed to provide protection of the entire branch circuit

(2) A listed branch/feeder-type AFCI installed at the origin of the branch-circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit. The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(3) ~~A listed supplemental arc protection circuit breaker installed at the origin of the branch circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit where all of the following conditions are met:~~

(4) ~~The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.~~

(5) ~~The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.~~

(6) ~~The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.~~

(7) ~~A listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet on the branch circuit in combination with a listed branch-circuit overcurrent protective device where all of the following conditions are met:~~

(8) ~~The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.~~

(9) ~~The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.~~

(10) ~~The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.~~

(11) ~~The combination of the branch-circuit overcurrent device and outlet branch-circuit AFCI shall be identified as meeting the requirements for a system combination–type AFCI and shall be listed as such.~~

(12) If RMC, IMC, EMT, Type MC, or steel-armored Type AC cables meeting the requirements of 250.118, metal wireways, metal auxiliary gutters, and metal outlet and junction boxes are installed for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

(13) Where a listed metal or nonmetallic conduit or tubing or Type MC cable is encased in not less than 50 mm (2 in.) of concrete for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

Exception: Where an individual branch circuit to a fire alarm system installed in accordance with 760.41(B) or 760.121(B) is installed in RMC, IMC, EMT, or steel-sheathed cable, Type AC or Type MC, meeting the requirements of 250.118, with metal outlet and junction boxes, AFCI protection shall be permitted to be omitted.

Informational Note No. 1: For information on combination-type and branch/feeder-type arc-fault circuit interrupters, see UL 1699-2011, *Standard for Arc-Fault Circuit Interrupters*. For information on outlet branch-circuit type arc-fault circuit interupters, see UL Subject 1699A, *Outline of Investigation for Outlet Branch Circuit Arc-Fault Circuit-Interrupters*. For information on system combination AFCIs, see UL Subject 1699C, *Outline of Investigation for System Combination Arc-Fault Circuit Interrupters*.

Informational Note No. 2: See 29.6.3(5) of *NFPA 72*-2013, *National Fire Alarm and Signaling Code*, for information related to secondary power-supply requirements for smoke alarms installed in dwelling units.

Informational Note No. 3: See 760.41(B) and 760.121(B) for power-supply requirements for fire alarm systems.

Statement of Problem and Substantiation for Public Input

I may be wrong here but to my knowledge the devices listed in (3) and (4) do not exist on the market. These two methods have been an incredible cause of confusion especially number (4) . There are contractors and inspectors who believe you can run the distance stated without afci protection on the front side and just add an afci receptacle at the first outlet. I am a member of 2 national recognized forums and this issue comes up all the time and cause tremendous misunderstanding of what is being asked for here. If the manufacturers have not made these devices then why do we still have these two methods still in the code. If and when the manufacturers come out with these devices then we should add it to the NEC.

Submitter Information Verification

Submitter Full Name: Dennis Alwon

Organization: Alwon Electric

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 30 07:51:39 EDT 2017

Public Input No. 3228-NFPA 70-2017 [Section No. 210.12(A)]

(A) Dwelling Units.

All 120-volt, single-phase, 15- and 20-ampere branch circuits supplying outlets or devices installed in dwelling unit kitchens, family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, laundry areas, or similar rooms or areas shall be protected by any of the means described in 210.12(A)(1) through (6):

(1) A listed combination-type arc-fault circuit interrupter, installed to provide protection of the entire branch circuit

(2) A listed branch/feeder-type AFCI installed at the origin of the branch-circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit. The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(3) A listed supplemental arc protection circuit breaker installed at the origin of the branch circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit where all of the following conditions are met:

(4) The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.

(5) The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.

(6) The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(7) A listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet on the branch circuit in combination with a listed branch-circuit overcurrent protective device where all of the following conditions are met:

(8) The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.

(9) The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.

(10) The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(11) The combination of the branch-circuit overcurrent device and outlet branch-circuit AFCI shall be identified as meeting the requirements for a system combination–type AFCI and shall be listed as such.

(12) If RMC, IMC, EMT, Type MC, or steel-armored Type AC cables meeting the requirements of 250.118, metal wireways, metal auxiliary gutters, and metal outlet and junction boxes are installed for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

(13) Where a listed metal or nonmetallic conduit or tubing or Type MC cable is encased in not less than 50 mm (2 in.) of concrete for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

Exception: ~~Where~~ AFCI protection shall not be required for an individual branch circuit ~~to~~ supplying a fire alarm system installed in accordance with 760.41(B) or 760.121(B) ~~is~~ . The branch circuit shall be installed in ~~RMC, IMC, EMT, or steel-sheathed cable, Type AC or Type MC,~~ a metallic raceway, metallic auxillary gutter, steel-armored cable. Type MC or Type AC *systems* meeting the requirements of *250.118* ~~,~~ with ~~*metal outlet and junction boxes, AFCI protection shall be permitted to be omitted*~~ *metallic boxes, conduit bodies and enclosures* .

Informational Note No. 1: For information on combination-type and branch/feeder-type arc-fault circuit interrupters, see UL 1699-2011, *Standard for Arc-Fault Circuit Interrupters*. For information on outlet branch-circuit type arc-fault circuit interupters, see UL Subject 1699A, *Outline of Investigation for Outlet Branch Circuit Arc-Fault Circuit-Interrupters*. For information on system combination AFCIs, see UL Subject 1699C, *Outline of Investigation for System Combination Arc-Fault Circuit Interrupters*.

Informational Note No. 2: See 29.6.3(5) of *NFPA 72*-2013, *National Fire Alarm and Signaling Code*, for information related to secondary power-supply requirements for smoke alarms installed in dwelling units.

Informational Note No. 3: See 760.41(B) and 760.121(B) for power-supply requirements for fire alarm systems.

Additional Proposed Changes

File Name	Description	Approved
PC_655.pdf	70_PC655	✓

Statement of Problem and Substantiation for Public Input

NOTE: This Public Input appeared as “Reject but Hold” in Public Comment No. 655 of the (A2016) Second Draft Report for NFPA 70 and per the Regs. at 4.4.8.3.1.

Substantiation: The only thing not allowed is LTFMC and FMC both are made with steel and have the same strength as the armored cable and should be allowed. It would be valuable to have some flexibility in the field for an outdoor or indoor installations. You would only need to reference a metallic raceway and eliminate the laundry list. Metal outlet boxes and junction boxes is to narrow of an allowance, a more general statement covering most installation would be Metal boxes, conduit fittings and enclosures. The current language is confusing, “permitted to be omitted” and appears at the end of the paragraph. Say what this is for (no AFCI) and the give the requirements (Steel everything).

Submitter Information Verification

Submitter Full Name: CMP ON NEC-P02
Organization: Code-Making Panel 2
Street Address:
City:
State:
Zip:
Submittal Date: Mon Sep 04 13:16:49 EDT 2017

Copyright Assignment

I, CMP ON NEC-P02, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am CMP ON NEC-P02, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Comment No. 655-NFPA 70-2015 [Section No. 210.12(A)]

(A) Dwelling Units.

All 120-volt, single-phase, 15- and 20-ampere branch circuits supplying outlets or devices installed indwelling units shall be protected by any of the means described in 210.12(A)(1) through (6):

(1) A listed combination-type arc-fault circuit interrupter, installed to provide protection of the entire branch circuit

(2) A listed branch/feeder-type AFCI installed at the origin of the branch circuit in combination with a listed outlet branch-circuit-type arc-fault circuit interrupter installed at the first outlet box on the branch circuit. The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(3) A listed supplemental arc protection circuit breaker installed at the origin of the branch circuit in combination with a listed outlet branch-circuit-type arc-fault circuit interrupter installed at the first outlet box on the branch circuit where all of the following conditions are met:

(4) _ The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.

(5) _ The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.

(6) _ The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(7) A listed outlet branch-circuit-type arc-fault circuit interrupter installed at the first outlet on the branch circuit in combination with a listed branch-circuit overcurrent protective device where all of the following conditions are met:

(8) _ The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.

(9) _ The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.

(10) _ The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(11) If RMC, IMC, EMT, Type MC, or steel-armored Type AC cables meeting the requirements of 250.118, metal wireways, metal auxiliary gutters, and metal outlet and junction boxes are installed for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit-type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

(12) Where a listed conduit or tubing or Type MC cable is encased in not less than 50 mm (2 in.) of concrete for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit-type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

Exception:

~~Where~~
AFCI protection shall not be required for an individual branch circuit

~~to~~
supplying a fire alarm system installed in accordance with 760.41(B) or 760.121(B)

~~is~~
. The branch circuit shall be installed in

~~RMC, IMC, EMT, or metal wireways or auxiliary gutters or steel-sheathed~~
a metallic raceway, metallic auxiliary gutter, steel-armored cable, Type

~~AC~~
MC or Type

~~MC,~~
AC systems meeting the requirements of 250.118

, with

~~metal outlet and junction boxes, AFCI protection shall be permitted to be omitted~~
metallic boxes, conduit bodies, and enclosures .

Informational Note No. 1: For information on combination-type and branch/feeder-type arc-fault circuit interrupters, see UL 1699-2011, *Standard for Arc-Fault Circuit Interrupters*. For information on outlet branch-circuit type arc-fault circuit interrupters, see UL Subject 1699A, *Outline of Investigation for Outlet Branch Circuit Arc-Fault Circuit-Interrupters*. For information on system combination AFCIs, see UL Subject 1699C, *Outline of Investigation for System Combination Arc-Fault Circuit Interrupters*.

Informational Note No. 2: See 29.6.3(5) of *NFPA 72*-2013, *National Fire Alarm and Signaling Code*, for information related to secondary power-supply requirements for smoke alarms installed in dwelling units.

Informational Note No. 3: See 760.41(B) and 760.121(B) for power-supply requirements for fire alarm systems.

Statement of Problem and Substantiation for Public Comment

The only thing not allowed is LTFMC and FMC both are made with steel and have the same strength as the armored cable and should be allowed. It would be valuable to have some flexibility in the field for an outdoor or indoor installations. You would only need to reference a metallic raceway and eliminate the laundry list. Metal outlet boxes and junction boxes is to narrow of an allowance, a more general statement covering most installation would be Metal boxes, conduit fittings and enclosures. The current language is confusing, “permitted to be omitted” and appears at the end of the paragraph. Say what this is for (no AFCI) and the give the requirements (Steel everything).

Related Item

First Revision No. 329-NFPA 70-2015 [Section No. 210.12(A)]

Public Input No. 3596-NFPA 70-2014 [Section No. 210.12(A)]

Submitter Information Verification

Submitter Full Name: ALFIO TORRISI
Organization: Master
Street Address:
City:
State:
Zip:
Submittal Date: Mon Sep 14 19:31:48 EDT 2015

Committee Statement

Committee Action: Rejected but held
Resolution: This is new material that has not been subject to public comment but has merit.

Public Input No. 3343-NFPA 70-2017 [Section No. 210.12(A)]

(A) Dwelling ~~Units~~ Units or other similar habitable structures with sleeping accommodations .

All 120-volt, single-phase, 15- and 20-ampere branch circuits supplying outlets or devices installed in dwelling ~~unit kitchens~~ units or any other similar habitable structure with sleeping accomodations kitchens , family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, laundry areas, or similar rooms or areas shall be protected by any of the means described in 210.12(A)(1) through (6):

(1) A listed combination-type arc-fault circuit interrupter, installed to provide protection of the entire branch circuit

(2) A listed branch/feeder-type AFCI installed at the origin of the branch-circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit. The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(3) A listed supplemental arc protection circuit breaker installed at the origin of the branch circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit where all of the following conditions are met:

(4) The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.

(5) The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.

(6) The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(7) A listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet on the branch circuit in combination with a listed branch-circuit overcurrent protective device where all of the following conditions are met:

(8) The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.

(9) The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.

(10) The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(11) The combination of the branch-circuit overcurrent device and outlet branch-circuit AFCI shall be identified as meeting the requirements for a system combination–type AFCI and shall be listed as such.

(12) If RMC, IMC, EMT, Type MC, or steel-armored Type AC cables meeting the requirements of 250.118, metal wireways, metal auxiliary gutters, and metal outlet and junction boxes are installed for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

(13) Where a listed metal or nonmetallic conduit or tubing or Type MC cable is encased in not less than 50 mm (2 in.) of concrete for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

Exception: Where an individual branch circuit to a fire alarm system installed in accordance with 760.41(B) or 760.121(B) is installed in RMC, IMC, EMT, or steel-sheathed cable, Type AC or Type MC, meeting the requirements of 250.118, with metal outlet and junction boxes, AFCI protection *shall be permitted to be omitted.*

Informational Note No. 1: For information on combination-type and branch/feeder-type arc-fault circuit interrupters, see UL 1699-2011, *Standard for Arc-Fault Circuit Interrupters*. For information on outlet branch-circuit type arc-fault circuit interupters, see UL Subject 1699A, *Outline of Investigation for Outlet Branch Circuit Arc-Fault Circuit-Interrupters*. For information on system combination AFCIs, see UL Subject 1699C, *Outline of Investigation for System Combination Arc-Fault Circuit Interrupters*.

Informational Note No. 2: See 29.6.3(5) of *NFPA 72*-2013, *National Fire Alarm and Signaling Code*, for information related to secondary power-supply requirements for smoke alarms installed in dwelling units.

Informational Note No. 3: See 760.41(B) and 760.121(B) for power-supply requirements for fire alarm systems.

Statement of Problem and Substantiation for Public Input

There are many types of structures that are used like a dwelling unit but do not meet the definition of a "dwelling". They may not have sanitation (use an outhouse or nearby dwelling) or they may not have permanent cooking provisions (portable or cooking may happen at nearby structure). Examples are some cabins, cottages, hunting shacks, bunk houses, guest houses, ect. Many of these structures are occupied long term and the structure and occupants should be provided the same safety that an afci provides to a dwelling and its occupants. Some of these structures are only used occasionally or seasonally but there is no reason that the occupant should not have the same protections wherever they choose to stay for a time. If they are at home, a dormitory or at a hotel or motel the NEC already provides that protection.

Submitter Information Verification

Submitter Full Name: Wayne Jespersen

Organization:

Street Address:

City:

State:

Zip:

Submittal Date: Tue Sep 05 15:17:57 EDT 2017

Public Input No. 3386-NFPA 70-2017 [Section No. 210.12(A)]

(A) Dwelling Units.

All 120-volt, single-phase, 15- and 20-ampere branch circuits supplying outlets or devices installed in dwelling unit kitchens, family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, laundry areas, or similar rooms or areas shall be protected by any of the means described in 210.12(A)(1) through (6):

(1) A listed combination-type arc-fault circuit interrupter, installed to provide protection of the entire branch circuit

(2) A listed branch/feeder-type AFCI installed at the origin of the branch-circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit. The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(3) A listed supplemental arc protection circuit breaker installed at the origin of the branch circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit where all of the following conditions are met:

   (4) The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.

   (5) The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.

   (6) The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(7) A listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet on the branch circuit in combination with a listed branch-circuit overcurrent protective device where all of the following conditions are met:

   (8) The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.

   (9) The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.

   (10) The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

   (11) The combination of the branch-circuit overcurrent device and outlet branch-circuit AFCI shall be identified as meeting the requirements for a system combination–type AFCI and shall be listed as such.

(12) If RMC, IMC, EMT, Type MC, or steel-armored Type AC cables meeting the requirements of 250.118, metal wireways, metal auxiliary gutters, and metal outlet and junction boxes are installed for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

(13) Where a listed metal or nonmetallic conduit or tubing or Type MC cable is encased in not less than 50 mm (2 in.) of concrete for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

Exception: Where an individual branch circuit to a fire alarm system installed in accordance with 760.41(B) or 760.121(B) is installed in RMC, IMC, EMT, or steel-sheathed cable ~~,~~ of Type AC or Type MC, ~~meeting~~ and meets the requirements of 250.118~~, with~~ with metal outlet and junction boxes~~,~~ ; AFCI protection shall not be ~~permitted to be omitted~~ required .

Informational Note No. 1: For information on combination-type and branch/feeder-type arc-fault circuit interrupters, see UL 1699-2011, *Standard for Arc-Fault Circuit Interrupters*. For information on outlet branch-circuit type arc-fault circuit interupters, see UL Subject 1699A, *Outline of Investigation for Outlet Branch Circuit Arc-Fault Circuit-Interrupters*. For information on system combination AFCIs, see UL Subject 1699C, *Outline of Investigation for System Combination Arc-Fault Circuit Interrupters*.

Informational Note No. 2: See 29.6.3(5) of *NFPA 72*-2013, *National Fire Alarm and Signaling Code*, for information related to secondary power-supply requirements for smoke alarms installed in dwelling units.

Informational Note No. 3: See 760.41(B) and 760.121(B) for power-supply requirements for fire alarm systems.

Statement of Problem and Substantiation for Public Input

This proposal is simply editorial. I am proposing no changes in content of the Exception, only a re-write for the following reasons.

The comma after the phrase, "or steel sheathed cable," in the existing text makes the phrase "steel sheathed cable" a statement all alone, it detaches from its intended "Type AC or Type MC". I see in ROP 2-182 of the 2010 revision cycle, that in the Panel Statement, the intention was to require the MC cable to be "steel sheathed MC cable" not because of crush resistance, but for arcing events.

Also the term, "shall be permitted to be omitted" I propose to be changed to "shall not be required" this is more consistent with existing mandatory rules. If all conditions are met, then an AFCI would not be required. A permissive statement could be removed form the exception.

Submitter Information Verification

Submitter Full Name: Richard Janoski
Organization: [Not Specified]
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 05 18:13:16 EDT 2017

Public Input No. 3684-NFPA 70-2017 [Section No. 210.12(A)]

(A) Dwelling Units.

All 120-volt, single-phase, 15- and 20-ampere branch circuits supplying outlets or devices installed in dwelling unit kitchens, family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, laundry areas, or similar rooms or areas shall be protected by ~~any~~ one of the means described in 210.12 (A)(1) ~~through (6):~~

- ~~A listed combination-type arc-fault circuit interrupter, installed to provide protection of the entire branch circuit~~
- ~~A listed branch/feeder-type AFCI installed at the origin of the branch-circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit. The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.~~
- ~~A listed supplemental arc protection circuit breaker installed at the origin of the branch circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit where all of the following conditions are met:~~

  (1) ~~The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.~~

  (2) ~~The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.~~

  (3) ~~The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.~~

- ~~A listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet on the branch circuit in combination with a listed branch-circuit overcurrent protective device where all of the following conditions are met:~~

  (1) ~~The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.~~

  (2) ~~The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.~~

  (3) ~~The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.~~

  (4) ~~The combination of the branch-circuit overcurrent device and outlet branch-circuit AFCI shall be identified as meeting the requirements for a system combination–type AFCI and shall be listed as such.~~

~~If~~ and one of the means described in 210.12 (A)(2)

(1):

a) RMC, IMC, EMT, Type MC, or steel-armored Type AC cables meeting the requirements of 250.118, metal wireways, metal auxiliary gutters, and metal outlet and junction boxes are installed for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet

~~, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.Where a listed metal or~~

.; OR

b) listed nonmetallic conduit or tubing

~~or Type MC cable~~

is encased in not less than

~~50 mm~~

50 mm (

~~2 in~~

2 in .) of concrete for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet,

~~it shall be permitted to install a listed~~

(2):

a) A listed combination-type arc-fault circuit interrupter, installed at the origin of the branch circuit; OR

b) A listed outlet branch-circuit type

~~AFCI~~

arc-fault circuit interrupter installed at the first outlet

~~to provide protection for the remaining portion of the~~

on the branch circuit

~~.~~

Exception: Where an individual branch circuit to a fire alarm system installed in accordance with 760.41(B) or 760.121(B) is installed in RMC, IMC, EMT, or steel-sheathed cable, Type AC or Type MC, meeting the requirements of 250.118, with metal outlet and junction boxes, AFCI protection shall be permitted to be omitted.

Informational Note No. 1: For information on combination-type and branch/feeder-type arc-fault circuit interrupters, see UL 1699-2011, *Standard for Arc-Fault Circuit Interrupters*. For information on outlet branch-circuit type arc-fault circuit interupters, see UL Subject 1699A, *Outline of Investigation for Outlet Branch Circuit Arc-Fault Circuit-Interrupters*. For information on system combination AFCIs, see UL Subject 1699C, *Outline of Investigation for System Combination Arc-Fault Circuit Interrupters*.

Informational Note No. 2: See 29.6.3(5) of *NFPA 72*-2013, *National Fire Alarm and Signaling Code*, for information related to secondary power-supply requirements for smoke alarms installed in dwelling units.

Informational Note No. 3: See 760.41(B) and 760.121(B) for power-supply requirements for fire alarm systems.

Additional Proposed Changes

File Name	Description	Approved
PI_3684.docx	The attached is the proposal in word format. This is provided for reference just in case TerraView made more changes than intended.	✓

Statement of Problem and Substantiation for Public Input

During the NEC 2017 revision cycles, FR329, which sought to expand the permissible methods for providing AFCI protection, failed due to perception, by some, that combination type AFCIs represent “the benchmark” protection, for the home run portions of the branch circuits, that is not equaled by the proposed alternate method with outlet-branch type AFCIs. However, when comparing all methods currently permitted, combination type AFCIs do not actually provide the BEST arc and fire protection for the home run and therefore should not have been designated the “benchmark” for home run arc protection. The methods described in (5) and (6), armed cables and conduits, actually provide 100% arc and fire protection for the home run. They are the actual real-life BENCHMARKs for arc and fire protection for the home run, since they will prevent all of the physical damages that are normally the causes of arcing. Combination type AFCIs can only “mitigate” arcing conditions that eventually lead to fires, with a theoretical success rate in the 80% range.

Comparing the most recent 2017 NFPA electrical fires report to the 2009 report, the number of electrical fires attributed to “branch circuit wiring” has seen an increase of 155%, from annual average of 1,440 (2003-2006, AFCIs were mandated in 2002) to 2,230 (2010-2014). With over 15 years of install history already and complete lack of statistical evidence to show improvements in branch circuit wiring fires to support the manufacturers’ claims, we can no longer continue to accept/endorse the combination AFCI as the “benchmark” in home run branch circuit arc protection. We must look for a better and more reliable method.

As we can all agree on: prevention is the best cure. We must redirect our focus away from “how to minimize fires after arcing has started”, instead, we must turn our focus to “how can we best prevent arcing to occur in the first place?”

This proposed change to require the highest level of arc fault and fire protection for the home run conductors is in line with at least one other proposal that seeks to expand AFCI protection to all branch circuits in dwelling units. If it is ARC PROTECTION that the code is trying to improve, then this proposal must be part of the 2020 code update.

Additionally, and due to the discontinuation of branch/feeder type AFCIs and the continuing lack of availability of Supplemental type AFCIs, this proposal deletes those references and simplifying the requirements to reflect the actual options available to the public.

Submitter Information Verification

Submitter Full Name: Frank Tse

Organization: Leviton Manufacturing Company

Street Address:

City:

State:

Zip:

Submittal Date: Wed Sep 06 17:09:46 EDT 2017

Public Input #3684 – NFPA 70 (2020)

Proposal:

210.12 Arc-Fault Circuit-Interrupter Protection. Arc-fault circuit-interrupter protection shall be provided as required in 210.12(A), (B), and (C). The arc-fault circuit interrupter shall be installed in a readily accessible location.

(A) Dwelling Units. All 120-volt, single-phase, 15- and 20-ampere branch circuits supplying outlets or devices installed in dwelling unit kitchens, family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, laundry areas, or similar rooms or areas shall be protected by ~~any of the means described in 210.12(A)(1) through (6):~~

~~(1) A listed combination-type arc-fault circuit interrupter, installed to provide protection of the entire branch circuit~~

~~(2) A listed branch/feeder-type AFCI installed at the origin of the branch-circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit. The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.~~

~~(3) A listed supplemental arc protection circuit breaker installed at the origin of the branch circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit where all of the following conditions are met:~~

~~a. The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.~~

~~b. The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.~~

~~c. The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.~~

~~(4) A listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet on the branch circuit in combination with a listed branch-circuit overcurrent protective device where all of the following conditions are met:~~

~~a. The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.~~

~~b. The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.~~

~~c. The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.~~
~~d. The combination of the branch-circuit overcurrent device and outlet branch-circuit AFCI shall be identified as meeting the requirements for a system combination–type AFCI and shall be listed as such.~~
~~(5) If RMC, IMC, EMT, Type MC, or steel-armored Type AC cables meeting the requirements of 250.118, metal wireways, metal auxiliary gutters, and metal outlet and junction boxes are installed for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.~~
~~(6) Where a listed metal or nonmetallic conduit or tubing or Type MC cable is encased in not less than 50 mm (2 in.) of concrete for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branchcircuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.~~

one of the means described in 210.12 (A)(1) and one of the means described in 210.12 (A)(2)

(1):

a) RMC, IMC, EMT, Type MC, or steel-armored Type AC cables meeting the requirements of 250.118, metal wireways, metal auxiliary gutters, and metal outlet and junction boxes are installed for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet; OR

b) listed nonmetallic conduit or tubing is encased in not less than 50 mm (2 in.) of concrete for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet.

(2):

a) A listed combination-type arc-fault circuit interrupter, installed at the origin of the branch circuit; OR

b) A listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet on the branch circuit.

Exception: Where an individual branch circuit to a fire alarm system installed in accordance with 760.41(B) or 760.121(B) is installed in RMC, IMC, EMT, or steel-sheathed cable, Type AC or Type MC, meeting the requirements of 250.118, with metal outlet and junction boxes, AFCI protection shall be permitted to be omitted.

Public Input No. 3692-NFPA 70-2017 [Section No. 210.12(A)]

(A) Dwelling Units.

All 120-volt, single-phase, 15- and 20-ampere branch circuits supplying outlets or devices installed in dwelling unit kitchens, family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, laundry areas, or similar rooms or areas shall be protected by any of the means described in 210.12(A)(1) through (6):

(1) A listed combination-type arc-fault circuit interrupter, installed to provide protection of the entire branch circuit

(2) A listed branch/feeder-type AFCI installed at the origin of the branch-circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit. The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(3) A listed supplemental arc protection circuit breaker installed at the origin of the branch circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit where all of the following conditions are met:

(4) <u>The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.</u>

(5) <u>The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.</u>

(6) <u>The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.</u>

(7) ~~A listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet on the branch circuit in combination with a listed branch-circuit overcurrent protective device where all of the following conditions are met:~~

(8) ~~The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.~~

(9) ~~The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.~~

(10) ~~The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.~~

(11) ~~The combination of the branch-circuit overcurrent device and outlet branch-circuit AFCI shall be identified as meeting the requirements for a system combination–type AFCI and shall be listed as such.~~

(12)

(13) If RMC, IMC, EMT, Type MC, or steel-armored Type AC cables meeting the requirements of 250.118, metal wireways, metal auxiliary gutters, and metal outlet and junction boxes are installed for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

(14) Where a listed metal or nonmetallic conduit or tubing or Type MC cable is encased in not less than 50 mm (2 in.) of concrete for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

Exception: Where an individual branch circuit to a fire alarm system installed in accordance with 760.41(B) or 760.121(B) is installed in RMC, IMC, EMT, or steel-sheathed cable, Type AC or Type

MC, meeting the requirements of 250.118, with metal outlet and junction boxes, AFCI protection shall be permitted to be omitted.

Informational Note No. 1: For information on combination-type and branch/feeder-type arc-fault circuit interrupters, see UL 1699-2011, *Standard for Arc-Fault Circuit Interrupters*. For information on outlet branch-circuit type arc-fault circuit interupters, see UL Subject 1699A, *Outline of Investigation for Outlet Branch Circuit Arc-Fault Circuit-Interrupters*. For information on system combination AFCIs, see UL Subject 1699C, *Outline of Investigation for System Combination Arc-Fault Circuit Interrupters*.

Informational Note No. 2: See 29.6.3(5) of *NFPA 72*-2013, *National Fire Alarm and Signaling Code*, for information related to secondary power-supply requirements for smoke alarms installed in dwelling units.

Informational Note No. 3: See 760.41(B) and 760.121(B) for power-supply requirements for fire alarm systems.

Statement of Problem and Substantiation for Public Input

Greetings CMP 2,

Let's stop the games between the Circuit Breaker folks and Device folks with the removal of an allowance for AFCI protection that still has yet to exist. In doing research on this allowable method of protection I am not able to find a single document or product that is system-combination listed between a standard CB and an AFCI OBC Device. While I know some company is in the market to be a player in both the receptacle and CB market I have yet to see one come to market now for 3 NEC Cycles. Without evidence that such a system-combination exists the allowance should be removed. The evidence you seek is in the fact none are on the market as of this Public Input.

Submitter Information Verification

Submitter Full Name: Paul Abernathy
Organization: Encore Wire Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 06 17:18:27 EDT 2017

Public Input No. 3744-NFPA 70-2017 [Section No. 210.12(A)]

(A) Dwelling Units.

All 120-volt, single-phase, 15- and 20-ampere branch circuits supplying outlets or devices installed in dwelling unit ~~kitchens~~ , family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, ~~laundry areas~~ , or similar rooms or areas shall be protected by any of the means described in 210.12(A)(1) through (6):

(1) A listed combination-type arc-fault circuit interrupter, installed to provide protection of the entire branch circuit

(2) A listed branch/feeder-type AFCI installed at the origin of the branch-circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit. The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(3) A listed supplemental arc protection circuit breaker installed at the origin of the branch circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit where all of the following conditions are met:

(4) The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.

(5) The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.

(6) The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(7) A listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet on the branch circuit in combination with a listed branch-circuit overcurrent protective device where all of the following conditions are met:

(8) The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.

(9) The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.

(10) The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(11) The combination of the branch-circuit overcurrent device and outlet branch-circuit AFCI shall be identified as meeting the requirements for a system combination–type AFCI and shall be listed as such.

(12) If RMC, IMC, EMT, Type MC, or steel-armored Type AC cables meeting the requirements of 250.118, metal wireways, metal auxiliary gutters, and metal outlet and junction boxes are installed for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

(13) Where a listed metal or nonmetallic conduit or tubing or Type MC cable is encased in not less than 50 mm (2 in.) of concrete for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

Exception: Where an individual branch circuit to a fire alarm system installed in accordance with 760.41(B) or 760.121(B) is installed in RMC, IMC, EMT, or steel-sheathed cable, Type AC or Type MC, meeting the requirements of 250.118, with metal outlet and junction boxes, AFCI protection shall be permitted to be omitted.

Informational Note No. 1: For information on combination-type and branch/feeder-type arc-fault circuit interrupters, see UL 1699-2011, *Standard for Arc-Fault Circuit Interrupters*. For information on outlet branch-circuit type arc-fault circuit interupters, see UL Subject 1699A, *Outline of Investigation for Outlet Branch Circuit Arc-Fault Circuit-Interrupters*. For information on system combination AFCIs, see UL Subject 1699C, *Outline of Investigation for System Combination Arc-Fault Circuit Interrupters*.

Informational Note No. 2: See 29.6.3(5) of *NFPA 72*-2013, *National Fire Alarm and Signaling Code*, for information related to secondary power-supply requirements for smoke alarms installed in dwelling units.

Informational Note No. 3: See 760.41(B) and 760.121(B) for power-supply requirements for fire alarm systems.

Statement of Problem and Substantiation for Public Input

In 1999 AFCI's were first introduced into the NEC based on residential fire data that indicated that there were a significant number of residential fires that could be attributed to electrical failures. After extensive debate, CMP 2 agreed that AFCI protection may help reduce the number of electrical fires and proceeded cautiously to add AFCI protection to the NEC by limiting the AFCI requirement to dwelling unit bedrooms. CMP 2 gradually expanded the areas in dwelling units that required AFCI protection in subsequent editions of the NEC.

The demonstration of the effectiveness of AFCI's to mitigate arcing and prevent fires has essentially relied on laboratory tests of arc interruption in a controlled setting and a limited number of anecdotal reports describing how an AFCI may have prevented a fire by interrupting an existing or potential arcing condition.

While AFCI's do undoubtedly provide arc mitigation, new residential fire reports show that, from 2002 to 2015, the number of residential fires due to electrical failures has remained flat, that is, the number of residential fires has not decreased and, in fact, has slightly increased in the later years covered in the reports.

The NFPA Research Report , Home Structure Fires, dated September 2016, shows essentially no decrease in the number of fires from 2002 to 2014.

The NFPA Research Report titled Electrical Fires, dated March 2017 and the FEMA report covering Residential Building Fire Trends (2006-2015) both contain similar results showing that the number of residential fires due to electrical failures has shown no significant decrease in the period 2002 to 2015.

These reports suggest that there my be a number of factors that have yet to be understood that are contributing to electrical system malfunctions that cause residential fires.

Although AFCI's provide a level of arc mitigation, there appears to be other factors contributing to electrical failures that cause fires. AFCI protection alone does not appear to be significantly reducing the number of residential fires.

This proposal recommends that CMP 2 return to the 2011 AFCI requirements by deleting kitchens and laundry areas from 210.12(A). CMP2 should delay further expansion of AFCI requirements until there is a better understanding of the causes associated with residential fires due to malfunctions in the electrical infrastructure.

Although it may not be within the purview of CMP 2 to undertake the broad task of determining the many factors that contribute to residential fires due to electrical failures, simply expanding AFCI protection without a clear indication that this protection is contributing to the reduction in residential fires is not an effective method of addressing the residential fire problem.

Perhaps CMP2 could recommend that the NFPA Fire Protection Research Foundation undertake the task of defining the specific causes of residential fires. The Research Foundation has access to reports that will help determine a more precise definition of the residential fire problem, such as, fires in old vs. new construction, failures in the infrastructure (cabling, receptacles, lighting, etc.) vs. plug and cord connected products. Such an analysis will aide in the development of a more targeted approach in taking action to decrease the number of residential fires due to electrical malfunction.

Submitter Information Verification

Submitter Full Name: Daniel Kissane
Organization:
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 06 19:40:09 EDT 2017

Copyright Assignment

I, Daniel Kissane, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Daniel Kissane, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 3813-NFPA 70-2017 [Section No. 210.12(A)]

(A) Dwelling Units.

All 120-volt, single-phase, 15- and 20-ampere branch circuits supplying outlets or devices installed in dwelling unit ~~kitchens,~~ family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, ~~laundry areas,~~ or similar rooms or areas shall be protected by any of the means described in 210.12(A)(1) through (6):

(1) A listed combination-type arc-fault circuit interrupter, installed to provide protection of the entire branch circuit

(2) A listed branch/feeder-type AFCI installed at the origin of the branch-circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit. The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(3) A listed supplemental arc protection circuit breaker installed at the origin of the branch circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit where all of the following conditions are met:

(4) The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.

(5) The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.

(6) The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(7) A listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet on the branch circuit in combination with a listed branch-circuit overcurrent protective device where all of the following conditions are met:

(8) The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.

(9) The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.

(10) The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(11) The combination of the branch-circuit overcurrent device and outlet branch-circuit AFCI shall be identified as meeting the requirements for a system combination–type AFCI and shall be listed as such.

(12) If RMC, IMC, EMT, Type MC, or steel-armored Type AC cables meeting the requirements of 250.118, metal wireways, metal auxiliary gutters, and metal outlet and junction boxes are installed for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

(13) Where a listed metal or nonmetallic conduit or tubing or Type MC cable is encased in not less than 50 mm (2 in.) of concrete for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

Exception: Where an individual branch circuit to a fire alarm system installed in accordance with 760.41(B) or 760.121(B) is installed in RMC, IMC, EMT, or steel-sheathed cable, Type AC or Type MC, meeting the requirements of 250.118, with metal outlet and junction boxes, AFCI protection shall be permitted to be omitted.

Informational Note No. 1: For information on combination-type and branch/feeder-type arc-fault circuit interrupters, see UL 1699-2011, *Standard for Arc-Fault Circuit Interrupters*. For information on outlet branch-circuit type arc-fault circuit interupters, see UL Subject 1699A, *Outline of Investigation for Outlet Branch Circuit Arc-Fault Circuit-Interrupters*. For information on system combination AFCIs, see UL Subject 1699C, *Outline of Investigation for System Combination Arc-Fault Circuit Interrupters*.

Informational Note No. 2: See 29.6.3(5) of *NFPA 72*-2013, *National Fire Alarm and Signaling Code*, for information related to secondary power-supply requirements for smoke alarms installed in dwelling units.

Informational Note No. 3: See 760.41(B) and 760.121(B) for power-supply requirements for fire alarm systems.

Additional Proposed Changes

File Name	Description	Approved
Public_Input_No._3813_confirmation_of_only_areas_to_be_changed.docx	File depicts only two desired areas of change ("kitchens" and "laundry areas" to be deleted; TerraView inadvertently underlined additional text that was not added.	✓

Statement of Problem and Substantiation for Public Input

GFCI receptacles have contributed significantly to reducing deaths due to electrical shock. In just 25 years after GFCIs were introduced, accidental electrocutions in the United States were cut by more than half, even though electricity use more than doubled. 1(ESFi) There is a clear relationship between the reduction in electrocutions and the increased use of GFCI's. CMP2 recognized the effectiveness of GFCI's in preventing electrical shock and has continually expanded the National Electrical Code (NEC) requirements for GFCI's to and within areas where a shock hazard exists.

Conversely, since AFCI's were first required (effective 2002) for bedroom branch circuits in the 1999 NEC, AFCI requirements have been expanded twice (for 2008 and for 2014) without statistical validation. Since 2002, there have only been three years where the total number of electrical fires was slightly less than it was in 2002. 2(NFPA) In addition, the number of residential building electrical malfunction fires has remained relatively unchanged from 2009 – 2015. 3(FEMA) There is no known data indicating that the expansion of AFCI requirements in the NEC has resulted in the reduction of residential fires due to electrical malfunctions. Expanding the requirements for AFCI's to additional branch circuits has not effectively addressed the problem of residential fires due to electrical system failures.

AFCI technology is promising, but more direct evidence is needed. Without it, further Code expansion is an unnecessary mandate that will drive $200 - $300 million of added costs into home construction and renovation. Simultaneously, new kitchen and laundry appliances are rapidly being introduced that are causing unwanted AFCI tripping.

Therefore, we request a roll-back as proposed of the 2017 NEC to eliminate the requirement for AFCI protection on kitchen and laundry room circuits, as well as no further expansion in the NEC for AFCIs until more conclusive data on performance and unwanted tripping is available.

1.”Know the Dangers in Your Older Home”, February 2015 (page 5), Electrical Safety Foundation International
2 “Electrical Fires”, March 2017, Section 4 - Home Fires Involving Wiring and Related Equipment (line graph on page 47, table on page 50), NFPA Research
3 “Residential Building Electrical Malfunction Fire Trends”, May 2017 (upper left hand line graph on page 9), Federal Emergency Management Agency: Fire Estimate Summary

Submitter Information Verification

Submitter Full Name: Stephen Rood
Organization: Legrand North America
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 06 22:48:20 EDT 2017

Public Input No. 3813-NFPA 70-2017 – confirmation of only desired areas of change:

- The only two areas to be changed are the words “kitchens” and “laundry areas”; they are to be deleted from the “(A) Dwelling Units” paragraph as indicated below.

- No other changes (TerraView inadvertently underlined additional text that was not added).

210.12 (A) Dwelling Units. All 120-volt, single-phase, 15- and 20-ampere branch circuits supplying outlets or devices installed in dwelling unit ~~kitchens,~~ family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, ~~laundry areas,~~ or similar rooms or areas shall be protected by any of the means described in 210.12(A)(1) through (6):

1. A listed combination-type arc-fault circuit interrupter, installed to provide protection of the entire branch circuit
2. A listed branch/feeder-type AFCI installed at the origin of the branch-circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit. The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.
3. A listed supplemental arc protection circuit breaker installed at the origin of the branch circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit where all of the following conditions are met:
    a. The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.
    b. The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.
    c. The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.
4. A listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet on the branch circuit in combination with a listed branch-circuit overcurrent protective device where all of the following conditions are met:
    a. The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.
    b. The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.
    c. The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

    d. The combination of the branch-circuit overcurrent device and outlet branch-circuit AFCI shall be identified as meeting the requirements for a system combination–type AFCI and shall be listed as such.
5. If RMC, IMC, EMT, Type MC, or steel-armored Type AC cables meeting the requirements of 250.118, metal wireways, metal auxiliary gutters, and metal outlet and junction boxes are installed for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.
6. Where a listed metal or nonmetallic conduit or tubing or Type MC cable is encased in not less than 50 mm (2 in.) of concrete for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

Exception: Where an individual branch circuit to a fire alarm system installed in accordance with 760.41(B) or 760.121(B) is installed in RMC, IMC, EMT, or steel-sheathed cable, Type AC or Type MC, meeting the requirements of 250.118, with metal outlet and junction boxes, AFCI protection shall be permitted to be omitted.

Informational Note No. 1: For information on combination-type and branch/feeder-type arc-fault circuit interrupters, see UL 1699-2011, *Standard for Arc-Fault Circuit Interrupters*. For information on outlet branch-circuit type arc-fault circuit interupters, see UL Subject 1699A, *Outline of Investigation for Outlet Branch Circuit Arc-Fault Circuit-Interrupters*. For information on system combination AFCIs, see UL Subject 1699C, *Outline of Investigation for System Combination Arc-Fault Circuit Interrupters*.

Informational Note No. 2: See 29.6.3(5) of *NFPA 72*-2013, *National Fire Alarm and Signaling Code*, for information related to secondary power-supply requirements for smoke alarms installed in dwelling units.

Informational Note No. 3: See 760.41(B) and 760.121(B) for power-supply requirements for fire alarm systems.

Public Input No. 3899-NFPA 70-2017 [Section No. 210.12(A)]

<u>**(A)**</u> Dwelling Units.

All 120-volt, single-phase, 15- and 20-ampere branch circuits supplying outlets or devices installed in dwelling ~~unit kitchens, family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, laundry areas, or similar rooms or areas~~ units shall be protected by any of the means described in 210.12(A)(1) through (6):

(1) A listed combination-type arc-fault circuit interrupter, installed to provide protection of the entire branch circuit

(2) A listed branch/feeder-type AFCI installed at the origin of the branch-circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit. The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(3) A listed supplemental arc protection circuit breaker installed at the origin of the branch circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit where all of the following conditions are met:

 (4) The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.

 (5) The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.

 (6) The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(7) A listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet on the branch circuit in combination with a listed branch-circuit overcurrent protective device where all of the following conditions are met:

 (8) The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.

 (9) The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.

 (10) The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

 (11) The combination of the branch-circuit overcurrent device and outlet branch-circuit AFCI shall be identified as meeting the requirements for a system combination–type AFCI and shall be listed as such.

(12) If RMC, IMC, EMT, Type MC, or steel-armored Type AC cables meeting the requirements of 250.118, metal wireways, metal auxiliary gutters, and metal outlet and junction boxes are installed for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

(13) Where a listed metal or nonmetallic conduit or tubing or Type MC cable is encased in not less than 50 mm (2 in.) of concrete for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

Exception: Where an individual branch circuit to a fire alarm system installed in accordance with 760.41(B) or 760.121(B) is installed in RMC, IMC, EMT, or steel-sheathed cable, Type AC or Type MC, meeting the requirements of 250.118, with metal outlet and junction boxes, AFCI protection shall be permitted to be omitted.

Informational Note No. 1: For information on combination-type and branch/feeder-type arc-fault circuit interrupters, see UL 1699-2011, *Standard for Arc-Fault Circuit Interrupters*. For information on outlet branch-circuit type arc-fault circuit interupters, see UL Subject 1699A, *Outline of Investigation for Outlet Branch Circuit Arc-Fault Circuit-Interrupters*. For information on system combination AFCIs, see UL Subject 1699C, *Outline of Investigation for System Combination Arc-Fault Circuit Interrupters*.

Informational Note No. 2: See 29.6.3(5) of *NFPA 72*-2013, *National Fire Alarm and Signaling Code*, for information related to secondary power-supply requirements for smoke alarms installed in dwelling units.

Informational Note No. 3: See 760.41(B) and 760.121(B) for power-supply requirements for fire alarm systems.

Statement of Problem and Substantiation for Public Input

The goal of the NEC should be to have all conductors within a residential electrical system protected by the latest technology available. Current technologies available are the traditional overload and short circuit protection provided by traditional thermal/magnetic circuit breakers along with the newer GFCI and AFCI technologies.
As every AHJ and fire inspector knows the bottom line is things can and will happen to the branch circuits throughout its product lifecycle. The conductors could have been damaged during installation or damaged due to remodeling projects. These damaged conductors continue to operate for years without noticeable effects until the insulations system is compromised to the point a persistent arcing fault occurs. This arcing fault as shown in many fire reports is a fire danger risking life and property.
In 2017 kitchens and laundry rooms were added to this requirement. It is now time to expand combination AFCI protection to the rest of the 15 and 20 amp circuits in homes. This will be another step in bringing down the fire rate due to electrical arcing within residential dwellings.

Submitter Information Verification

Submitter Full Name: Kenneth Rempe
Organization: Siemens Industry Inc
Affilliation: American Circuit Breaker Manufacturers Association
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 07 08:34:45 EDT 2017

Public Input No. 4187-NFPA 70-2017 [Section No. 210.12(A)]

(A) Dwelling Units.

All 120-volt, single-phase, 15- and 20-ampere branch circuits supplying outlets or devices installed in dwelling unit kitchens, family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, laundry areas, or similar rooms or areas shall be protected by any of the means described in 210.12(A)(1) through (6):

(1) A listed combination-type arc-fault circuit interrupter, installed to provide protection of the entire branch circuit

(2) A listed branch/feeder-type AFCI installed at the origin of the branch-circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit. The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(3) A listed supplemental arc protection circuit breaker installed at the origin of the branch circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit where all of the following conditions are met:

(4) The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.

(5) The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.

(6) The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(7) A listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet on the branch circuit in combination with a listed branch-circuit overcurrent protective device where all of the following conditions are met:

(8) The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.

(9) The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.

(10) The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(11) The

~~combination of the branch-circuit overcurrent device and outlet branch-circuit AFCI shall be identified as meeting the requirements for a system combination–type AFCI and shall be listed as such~~

a. .

(12) If RMC, IMC, EMT, Type MC, or steel-armored Type AC cables meeting the requirements of 250.118, metal wireways, metal auxiliary gutters, and metal outlet and junction boxes are installed for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

(13) Where a listed metal or nonmetallic conduit or tubing or Type MC cable is encased in not less than 50 mm (2 in.) of concrete for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

Exception: Where an individual branch circuit to a fire alarm system installed in accordance with 760.41(B) or 760.121(B) is installed in RMC, IMC, EMT, or steel-sheathed cable, Type AC or Type MC, meeting the requirements of 250.118, with metal outlet and junction boxes, AFCI protection shall be permitted to be omitted.

Informational Note No. 1: For information on combination-type and branch/feeder-type arc-fault circuit interrupters, see UL 1699-2011, *Standard for Arc-Fault Circuit Interrupters*. For information on outlet branch-circuit type arc-fault circuit interupters, see UL Subject 1699A, *Outline of Investigation for Outlet Branch Circuit Arc-Fault Circuit-Interrupters*. For information on system combination AFCIs, see UL Subject 1699C, *Outline of Investigation for System Combination Arc-Fault Circuit Interrupters*.

Informational Note No. 2: See 29.6.3(5) of *NFPA 72*-2013, *National Fire Alarm and Signaling Code*, for information related to secondary power-supply requirements for smoke alarms installed in dwelling units.

Informational Note No. 3: See 760.41(B) and 760.121(B) for power-supply requirements for fire alarm systems.

Additional Proposed Changes

File Name	Description	Approved
AFCI_Consortium_Proposal_-_Remove_A4d.docx	Copy of the full proposal	✓
Arc_Fault_Attenuation_Test_Report_9-5-17.docx	Test Report - Cable Attenuation	✓
10-01-2014_letter_from_UL_to_STP_1699_002_.pdf	UL email	✓
Damage_Degradation_Breakdown_Voltage_NM_Cables.pdf	UL Report	✓

Statement of Problem and Substantiation for Public Input

This proposal and rationale has been submitted additionally as an uploaded attachment because the TerraView editing capabilities were not sufficient to capture the editorials correctly.

While it is required for the OBC AFCI receptacle to be listed onto itself and for the branch circuit overcurrent protective device to be listed onto itself, it is not possible to meet the code requirement 210.12(A)(4)(d) since the standard for a listed SYSTEM COMBINATION of the branch-circuit overcurrent device and outlet branch-circuit AFCI does not exist. This requirement 210.12(A)(4)(d) needs to be removed from the NEC.

The standard set forth in 210.12(A)(4)(d) mandating that such a combination device meet the requirements for a system combination-type AFCI "and shall be listed as such" is unenforceable because there currently exists no listing standard for system combination-type AFCIs. The expectation was that UL 1699C would supply the listing standard to certify the combination-type AFCI devices contemplated by section (A)(4)(d). This expectation is reflected in the informational note which directs those relying on (A)(4)(d)'s listing requirement to consult UL 1699C. However, UL 1699C was never finalized, never adopted, and ultimately, withdrawn by UL. (On this score, two NEC code cycles have passed without the development of UL 1699C and there is no activity in progress to create such a listing standard). See the attached email from UL dated 10-1-2014 indicating that they will not pursue the development of this standard. NEMA's Code Panel 2 acknowledged as much as far back as November 2015 during NFPA code development proceedings on 210.12(A) for the 2017 Code cycle when it voted to delete section (A)(4)(d) – including reference to UL 1699C in the informational note – because "the document [UL 1699C] has been withdrawn."

In short, 210.12(A)(4)(d) cannot be enforced because the mechanism necessary to enforce the listing requirement for system combination-type AFCIs – namely, UL 1699C – literally does not exist. Removal of 210.12(A)(4)(d) is required not only as a matter of common sense but also as matter of maintaining the integrity of NFPA's own code development process. In this regard, the NEC Style Manual (Section 3.2.1) instructs that "The NEC shall not contain references or requirements that are unenforceable or vague." Additionally, Section 3.3.7.4 of the Regulations Governing the Development of NFPA Standards, states that reference to publications by other organizations "shall" only be included in an NFPA standard if such reference is "adequate and appropriate" and is available/on file at NFPA Headquarters. Here, UL 1699C does not exist, is not available for reference at NFPA Headquarters, and, as such, is not adequate or appropriate for purposes identified in this section.

On the merits, additional supporting reasons for eliminating the system combination listing requirement of clause (4)(d) are discussed below.

1. AFCI Receptacles being located closer than a circuit breaker to the more probable source of arcing are more sensitive to unsafe arcing and can better distinguish between an operational arc and an unsafe arc. See test report.
2. A UL report has been issued discussing the low probability of an arc igniting on the home run.
3. A UL report has been issued discussing that standard Circuit Breakers afford a certain degree of parallel arc protection.

There has been much debate over the arc fault protection of a branch circuit home run. Circuit breakers have self-proclaimed better parallel arc protection of the home run. There have been many arguments to the contrary. Item 1 above is intended to present the argument that AFCI Receptacles afford better overall protection of the branch circuit due to their nearness to the more probable sources of arc faults. This argument asserts that the more probable source of an arc fault is the device or cord plugged into the receptacle.

The arc fault receptacle has a front row seat to the arcing event while the AFCI Breaker is dozens or hundreds of feet upstream and partially blind as the attached report will demonstrate.

In addition to the previous code cycle cited UL research report titled "Effectiveness of Circuit Breakers in Mitigating Parallel Arcing Faults in the Home Run" which provided significant statistical assurance (99%) that the "home run" portion of the branch circuit is protected from parallel arcing faults, UL issued another research (copy attached) report titled “Influence of Damage and Degradation on Breakdown Voltage of NM Cables” that had the following conclusion:

“In summary, the work described here shows that damage and degradation of a residential NM cable can lead to an arcing event, through voltage surges that break down the cable insulation and ignite arcing. However, THE TEST RESULTS ALSO INDICATE THAT THE BREAKDOWN EVENT IS UNLIKELY TO INITIATE ARCING THAT IS SUSTAINED LONG ENOUGH TO IGNITE THE CABLE INSULATION OR SURROUNDING MATERIALS. In this study, arcing for hammer-damaged cable exhibited arcing during less than 10% of the surge events, and exhibited arcing that lasted over a single half-cycle. THE ARCING OBSERVED IN THIS STUDY IS MUCH SHORTER THAN WHAT IS REQUIRED FOR AN AFCI TO REACT TO THE EVENT (EIGHT ARCING HALF-CYCLES WITHIN 0.5 SECONDS, PER UL1699); HOWEVER, THE ENERGY RELEASED IN THAT SHORT EVENT IS NOT EXPECTED TO IGNITE THE CABLE INSULATION.” *

*The above paragraph is from page 58 & 59 of the UL report with emphasis added.

Conclusions that can be drawn from these two UL research reports:

- Arcing in damaged cables is an unlikely event and only occurs in less than 10% of high voltage surge events. When combined with cable damage; ignition is even a more unlikely event.

- In the most unlikely event that both had occurred, the resulting arcing “is much shorter than what is required for an AFCI to react” and (expectedly) the energy released is not expected to ignite the cables or surrounding materials.

- Furthermore, in the most remote chance that an arc with higher energy and duration does occur, there is 99% statistical assurance that it will be protected by the instantaneous trip function of the circuit breakers, which is better than the 90% protection level required of AFCI breakers.

We urge the panel to accept this proposal as an alternative means of protection for the branch circuit. Acceptance of this proposal will give consumers more economically viable options when choosing arc protection, which ultimately is one of the goals of Panel 2. In addition, it shows that the intent of the panel was never to require 100% equivalent performance, but rather, reasonable alternatives.

Submitter Information Verification

Submitter Full Name:	Joseph Debartolo Jr
Organization:	Hubbell Incorporated
Affilliation:	Arc Fault Circuit Interrupter Wiring Device Joint Research and Development Consortium
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Thu Sep 07 16:00:26 EDT 2017

Arc Fault

Cable Attenuation Testing

9/5/2017

Author: John Brower

DUT:
17ft 12/3 NM-B Cable
100ft 12/3 NM-B Cable
17ft 14/2 NM-B Cable
100ft 14/2 NM-B Cable

Test Setup:
Spectrum Analyzer
Mixed-Domain Oscilloscope
(2) Current Transformers: 1V/A

Contents

1. Test #1 Spectrum Analysis of 12/3 NM-B (100ft compared to 17ft) 2

1.1 Bandwidth: 9kHz to 500kHz (Green 100ft , Yellow 17ft) 2

1.2 Bandwidth: 9kHz to 1MHz (Green 100ft , Yellow 17ft) 3

2. Test #2 Spectrum Analysis of 14/2 NM-B (100ft compared to 17ft) 4

2.1 Bandwidth: 9kHz to 1MHz (Green 100ft , Yellow 17ft) 4

3. Test #3: Arc Generation with End to End Cable Measurement 5

3.1 Test setup 5

3.2 Test data 6

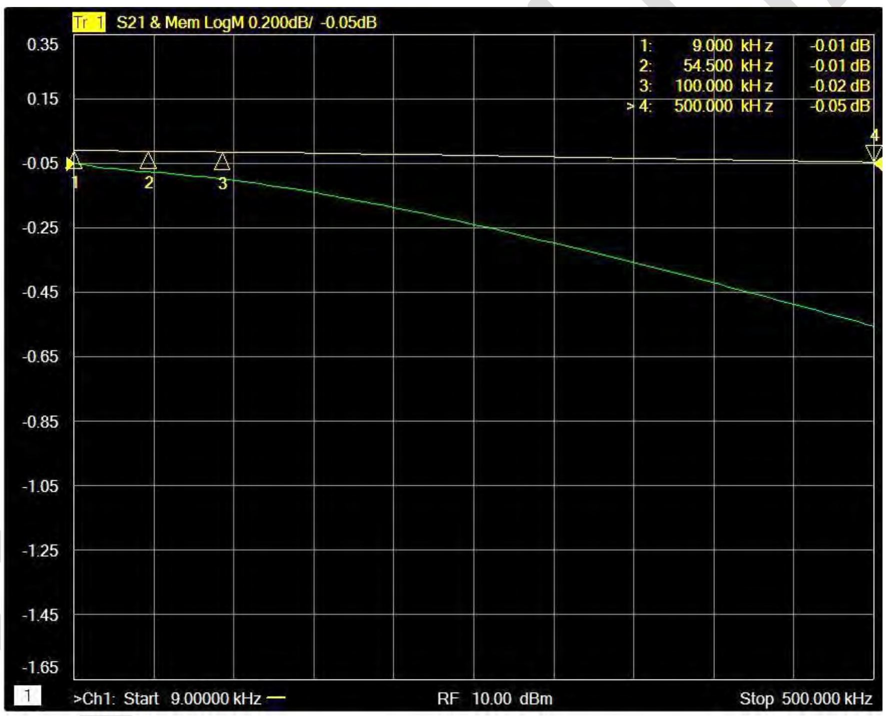
4. Summary 7

1. Test #1 Spectrum Analysis of 12/3 NM-B (100ft compared to 17ft)

The following test was performed to compare the end to end frequency response. In the diagrams below: Yellow line is 17ft cable, Green is 100ft cable. Measurements were taken by comparing input to output response of each cable. This response demonstrates the signal loss that occurs with respect to distance.

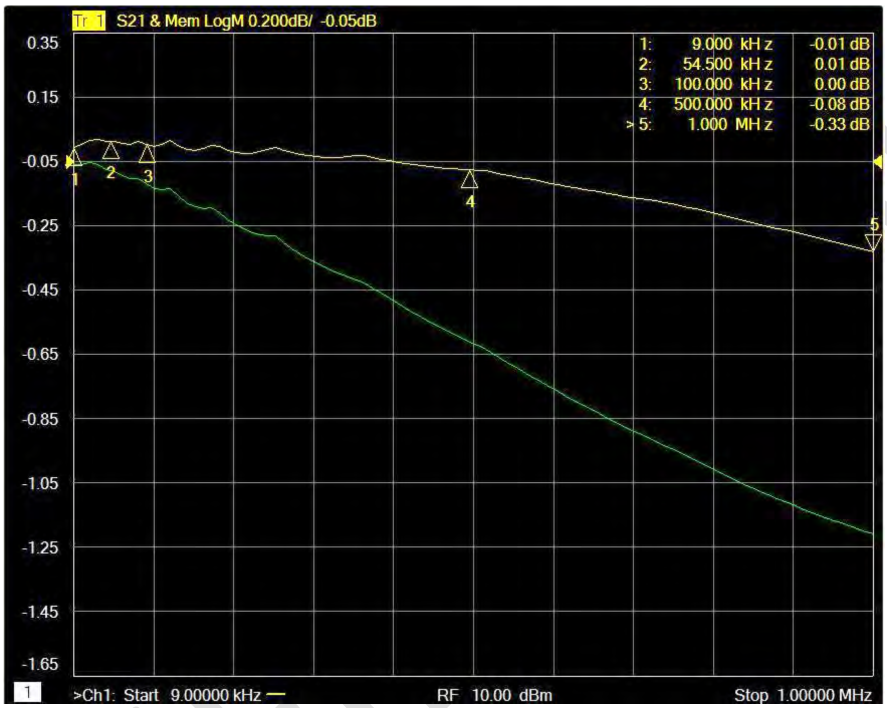
1.1 Bandwidth: 9kHz to 500kHz (Green 100ft , Yellow 17ft)

Distance (ft)	Min. Signal Loss (dB)(%)	Max. Signal Loss (dB)(%)
17	-0.01 (0.12%)	-0.05 (0.57%)
100	-0.05 (0.57%)	-0.6 (6.7%)



1.2 Bandwidth: 9kHz to 1MHz (Green 100ft , Yellow 17ft)

Distance (ft)	Min. Signal Loss (dB)(%)	Max. Signal Loss (dB)(%)
17	-0.01 (0.12%)	-0.33 (3.7%)
100	-0.05 (0.57%)	-1.22 (13.1%)



2. Test #2 Spectrum Analysis of 14/2 NM-B (100ft compared to 17ft)

The following test was performed to compare the end to end frequency response of 14/2 NM-B cables. In the diagrams below: Yellow line is 17ft cable, Green is 100ft cable. Measurements were taken by comparing input to output response of each cable. This response demonstrates the signal loss that occurs with respect to distance.

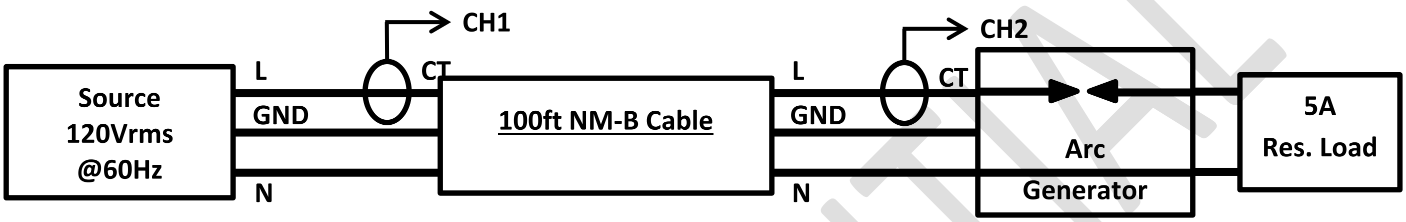
2.1 Bandwidth: 9kHz to 1MHz (Green 100ft , Yellow 17ft)

Distance (ft.)	Min. Signal Loss (dB)(%) (9.0 kHz)	Signal Loss (dB)(%) (0.5 MHz)	Max. Signal Loss (dB)(%) (1.0 MHz)
17	-0.06 (0.68%)	-0.30 (3.39%)	-0.49 (5.48%)
100	-0.06 (0.68%)	-0.68 (7.53%)	-1.60 (16.8%)

3. Test #3: Arc Generation with End to End Cable Measurement

The following tests were performed to observe signal differences between the input and output of a 100ft 12/3 NM-B cable.

3.1 Test setup



3.2 Test data

In the images below, CH1 (Yellow) is the source and CH2 (Blue) is the load side. From the figure below, a difference can be seen in the arcing signatures between CH1 and CH2. This shows a greater signal measured at CH2 closest to the arcing event (See 1:1 Overlay in Figure 3.2 below for detail)

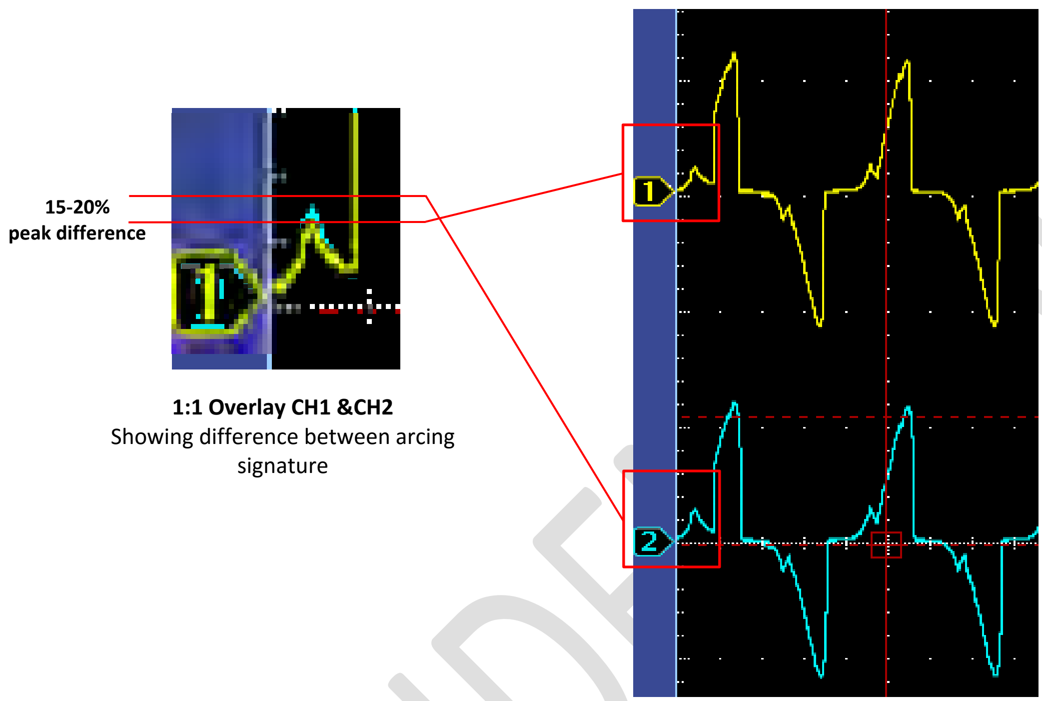


Figure 3.2: CH1 Source, CH2 Load, (Scope: 5.0 V/div, 20 ms/div)

4. Summary

From this testing, an observation can be made that attenuation can cause current signal loss the further a detection/measuring device is from an arcing event, by cable distance.

In Section 1.1 and 1.2, it can be seen with 100ft of 12/3 NM-B there is a maximum 6.7% to 13.1% (0.5MHz to 1.0MHz) signal loss, compared to 0.57% to 3.7% (0.5MHz to 1.0MHz) at 17ft.

In Section 2.1, it can be seen with 100ft of 14/2 NM-B there is a maximum 7.53% to 16.8% (0.5MHz to 1.0MHz) signal loss, compared to 3.17% to 5.48% (0.5MHz to 1.0MHz) at 17ft.

In Section 3.2, test data collected highlights the differences seen between arcing signatures from source to load(closest to an arcing event). These peak differences were found to be 15-20% between CH1 and CH2 arcing signatures of a 60Hz current waveform.

In summary, the above sections demonstrate with greater distance and signal loss accurate detection of an arc is reduced in comparison to a distance closer to the arc.

History:	This message has been forwarded.

To: STP 1699 Members and UL1699C Subscribers

The STP Chair has received a communication from the UL LLC representative on STP 1699 that they will not initiate any action within STP 1699 beyond voting and commenting on the current proposals. Should the need arise for a task force to address any issue regarding UL 1699C, participation on the task force will not include UL staff.

Best regards,

Bradley J. Schmidt, P.E.
Standards Program Manager

Underwriters Laboratories Inc
333 Pfingsten Road
Northbrook, IL 60062-2096

History:	This message has been forwarded.

Dear STP 1699 Members and UL 1699 Standard Subscribers:

A UL 1699C Work Area opened in CSDS February 6, 2014, consisting of a proposal document for preliminary review. The proposal document consisted of two topics as follows:

1. For Preliminary Review Only: Proposed First Edition of UL 1699C - Consortium Proposal

2. For Preliminary Review Only: Proposed First Edition - System Combination Arc-Fault Circuit Protection - ACBMA Proposal

The work area has now reached its deadline date of March 10, 2014, and comments have been posted on CSDS on both of the topics.

Since the proposals are considered competing proposals, they must be submitted for ballot consecutively, not concurrently. Our records indicate that the proposal of Topic 1 was submitted on CSDS by Frank Tse of Leviton on October 7, 2013 as PR20985, and the proposal of Topic 2 was submitted on CSDS by Kevin Lippert on October 9, 2013 as PR20999. (As a point of information, both proposal requests were subsequently moved as a clerical change to be under Standard Number 1699C on October 9, 2013.) Topic 1 was the first to be submitted on CSDS, and its continued processing is being initiated at this time. If Topic 1 fails to achieve consensus in accordance with STP regulation 2.3.4.7, then Topic 2 will proceed to ballot.

UL will notify the STP 1699 membership and UL 1699 Standard Subscribers of the next steps in the process.

We thank you for your contributions to the process and to the development of UL standards.

Regards,

Edward D. Minasian
Project Manager for STP 1699
Underwriters Laboratories Inc.

Influence of Damage and Degradation on Breakdown Voltage of NM Cables

Final Report

Fan He, PhD, and Paul W. Brazis Jr., PhD

1 November 2012

TABLE OF CONTENTS

Document Information 4

Disclaimer 5

Acknowledgement 6

Executive Summary 7

Introduction 9
Electrical Fire Incident Data 9

Objective 10

Scope 11

Project Plan 11

Research Report 12
Task 1 — Literature Search 12

Task 2 — NM Cable Sample Selection 18

Chemical Characterization – FTIR analysis 22

Insulation Breakdown Voltage Test 23

Assessment of the NM cable insulation breakdown voltage 25

Task 3 — Assessment of NM Cable Installation Damage 30

Overdriven Staple 32

Task 4 — Assessment of NM Cable Degradation 41

Insulation Weight Loss under Different Temperatures 44

Insulation Weight Loss and the Breakdown Voltage 45

Task 5 — Assessment of Combined NM Cable Installation Damage and Aging Degradation 49

Summary of Key Findings 57

References 60

Document Information

Release Type	☐ Internal ☐ External (Confidential) ☒ External (Public)	
UL Distribution	Corporate Research	
External Distribution		
Date: 12/16/2011	**Keywords:** NM cable, NM cable installation damage, NM cable degradation, breakdown voltage	
Title: **Influence Of Damage And Degradation On Breakdown Voltage Of NM Cables**		
Author(s)	**Department**	**Email**
Fan He, Paul Brazis	Corporate Research	Fan.He@ul.com Paul.Brazis@ul.com
Reviewer(s)	**Department**	**Email**
Pravinray Gandhi	Corporate Research	Pravinray.D.Gandhi@ul.com

Disclaimer

In no event shall UL be responsible to anyone for whatever use or nonuse is made of the information contained in this Report and in no event shall UL, its employees, or its agents incur any obligation or liability for damages including, but not limited to, consequential damage arising out of or in connection with the use or inability to use the information contained in this Report. Information conveyed by this Report applies only to the specimens actually involved in these tests. UL has not established a factory Follow-Up Service Program to determine the conformance of subsequently produced material, nor has any provision been made to apply any registered mark of UL to such material. The issuance of this Report in no way implies Listing, Classification or Recognition by UL and does not authorize the use of UL Listing, Classification or Recognition Marks or other reference to UL on or in connection with the product or system.

Acknowledgement

Underwriters Laboratories LLC (UL) is grateful to Fire Protection Research Foundation for its help in organizing a technical panel of experts to guide the UL research team in the investigation. The technical panel provided important review of project plan as well provided feedback on the results developed.

The technical panel consisted of the following members:

- John Allen, ATF Fire Research Laboratory
- Vyto Babrauskas, Fire Science and Technology Inc.
- Bill Burke, Electrical Division Director, NFPA
- Anthony Hamins, Building and Fire Research Laboratory, NIST
- Mark Hilbert, New Hampshire Department of Safety
- Doug Lee, Consumer Product Safety Commission
- Wei-Jen Lee, University of Texas at Arlington
- Dave Mercier, Southwire Company
- John Sleights, Travelers Insurance

Executive Summary

According to the fire incident data from 2003 to 2007[4], there is an average of 50,900 fires annually in homes related to electrical failure or malfunction. An NFPA analysis of home fire statistics shows that electrical fires result in an average of 490 civilian deaths, 1140 injuries, and $1.3B in direct property damage every year. Approximately 57% of these fires originate from wiring and related equipment[1]. Some key causes of fires due to electrical wiring result from arcing and loose connections. These conditions may develop from improper installation or maintenance and are exacerbated over time from exposure to high temperature and humidity.

Currently, the National Electrical Code (NEC®) requires the use of arc fault circuit interrupters (AFCIs) in the electrical panel of a dwelling unit to protect against arcing faults. The 2011 National Electric Code (Article 210.12) allows the use of an AFCI located in the first electrical receptacle of a residential circuit in lieu of an AFCI located inside the electrical panel as an exception. However, the wiring from the circuit panel to the first receptacle (home run) is required to be protected from damage during installation per code requirements.

In preparation for the 2014 Edition of the National Electrical Code® (NEC®), several proposals were made to revise Section 210.12 for arc-fault circuit-interrupter protection to permit a listed outlet branch circuit type arc-fault circuit interrupter (OBC AFCI) to be installed at the first outlet on the branch circuit under certain conditions of installation. Two questions have arisen regarding the use of an OBC AFCI: one, under what conditions, if any, would a conventional circuit breaker mitigate an arcing fault (with respect to the criteria in UL 1699); and two, if carbonized path arcing may occur within the home run given potential for installation damage and subsequent cable aging. The first question has been addressed in three UL research reports[2,3,27]; and the second question is addressed in this report.

This research investigation was undertaken to study the influence of damage (*i.e*., damage occurring during installation of the electrical wiring) and subsequent degradation of the dielectric breakdown voltage of the cable insulation. Dielectric breakdown is a primary cause of the formation of a carbonized path between conductors, which can result in a carbonized path arcing fault.

This project investigated commercially available 14-gauge, two-conductor (14-2) type NM (NEC 334.2) cables with bare ground conductor, from five different manufacturers. Two cables were selected after characterizing their insulating materials using a combination of analytical techniques and measurement of dielectric strength. The selected cable insulations had distinct plasticizer and additives, and measured dielectric strength values.

Two types of damage scenarios were investigated in this work, representative of the information found in the literature, associated with installation activities: (*i*) inadvertent hammer blow to the cable outer jacket; and (*ii*) compression of the insulation from over-driving staples through the outer jacket. In both cases, methods were developed to provide repeatable and controlled damage to the cable. Other types of damage scenarios like pest infestation are not discussed in this report due to lack of data and quantitative

test methods. The dielectric breakdown voltage of the cable insulation was tested after applying the damage conditions. The results showed that such damage to cables during installation may reduce the NM cable insulation breakdown voltage from over 20kV (in undamaged cables) to less than 1kV, and below the 5kV failure threshold set by UL719 and other related safety standards. Though carbonized arcing will not occur until the breakdown voltage falls below 170V, lowered breakdown voltage render the NM cable susceptible to further breakdown damage from voltage surges, which occur more frequently at or below 6kV. Thus, as the insulation breakdown voltage falls, the potential of a carbonized path and subsequent parallel arcing fault forming in the cable increases.

Another focus of this project was the influence of thermal aging of NM cable on its dielectric breakdown voltage. Selected cable samples were exposed to a range of elevated temperatures up to 150°C. This maximum temperature was selected to ensure that the cable insulation (plasticized PVC) does not undergo dehydrochlorination, but will still induce plasticizer loss, which is a major degradation pathway. The samples were weighed and dielectric breakdown voltage tests were performed at regular intervals. The project also investigated the combined effect on initial damage followed by thermal aging on the breakdown voltage. The influence of combined initial damage followed by thermal aging resulted in faster reduction of dielectric breakdown voltage of the cable insulation.

To evaluate the probability of arcing when NM cables have lowered breakdown voltages, hammer-damaged and aged NM cable samples were tested per UL1449 (Standard for Surge Protective Devices). This test showed despite a breakdown voltage lower than the surge voltage (using 6kV surges on samples with breakdown voltages below 5kV), 9% of the hammer-damaged and 2% of the hammer-damaged and then aged samples exhibited arcing after the surge occurred. All of these observed arcs were approximately 1.7ms in duration, meaning that the arcing was longer than the surge event (*i.e.*, supplied by 120VAC), but self-extinguished within a single AC half-cycle. These events did not have enough energy to ignite NM cable insulation and were not sustained for more than one half-cycle, a duration that is not expected to trip an AFCI and is shorter than the UL1699 eight half-cycle criterion. To evaluate whether subsequent damage would increase arcing duration or sustainability, samples were tested using 300 voltage surges to understand how likely the repeated voltage surge and arcing may result in sustainable arcing and ignite the NM cable insulation. But these tests did not show any sustained arcing.

The test results indicate that the probability of sustained arcing and ignition is low for hammer-damaged NM cable. The results also show that though a carbonized path may eventually be formed, this path formation did not lead to subsequent ignition of the cable jacket or surrounding materials, and self-extinguished after a short period of arcing.

THE INFLUENCE OF DAMAGE AND DEGRADATION ON THE BREAKDOWN VOLTAGE OF NM CABLES

Introduction

Electrical Fire Incident Data

According to published reports and research articles, the number of residential electrical fires ranges from 28,300 to 60,000 per year[4], depending on the source of the data. Since the terms 'electrical fire', 'electrical wiring', and 'electrical equipment' are not rigorously defined in literature, quantitative data varies among sources. Approximately half of all electrical fires can be attributed to installed wiring and related equipment[5]. Figure 1 shows the reported sources of electrical fires.

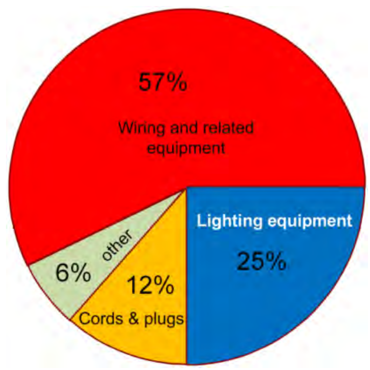


Figure 1 - Source of electrical fires

Table 1 provides a summary of the statistical data from a number of sources. Several investigations have identified that key contributors to electrical fires are wire degradation, damage[6], improper installation, and excessive electrical circuit load[7].

Table 1 - Electrical fire statistics

Source of data	Average number of electrical fires per year	% of fires caused by wiring and equipment	Reference
National Fire Protection Association	50,900	57	1
US Fire Administration	28,300	47	4
Other	32,000 to 60,000	N/A	6

Table 2 summarizes the causes of electrical fires and provides references for the data.

Table 2 – Possible faulty conditions c of electrical fires

Faulty condition	Description	Reference
Wire degradation	Aging over time under high temperature, high humidity and other environmental exposures	5, 7
Excessive load	Load greater than the rated current under specific temperature	7
Voltage surge	High Voltage may result in arcing and cause fire	14
Bad connection	High resistance connection in receptacles, junction boxes etc.	7
Mechanical damage in installation	Over compression by stapling the NM cable with high pressure, staple puncture, cracking by bending the NM cable with sharp angle, abrasion and hammer impact	21, 22
Damage due to pest infestation	Damages caused by rodent and other pests	7

The National Electrical Code (NEC®) requires the use of arc fault circuit interrupters (AFCIs) in the home electrical panel to protect against arcing faults. The 2011 NEC (Article 210.12) allows the use of an AFCI built into the first electrical receptacle after the circuit panel in lieu of an AFCI in the electrical panel provided the wiring from the circuit panel to the first receptacle (home run) is installed in a metal conduit (or similar type of raceway) to protect it from damage during installation.

NM cable is used extensively in the USA, with approximately 8 billion feet of NM cable sold in 2007, and is used in nearly 75% of new single family homes[8]. Thus, the NEC requirement would exclude the use of the receptacle-based AFCI in many communities where NM cabling is permitted without the use of protective metal conduit.

The research investigation described in this report was undertaken to study the influence of damage (*i.e.*, from installation) and subsequent degradation on the dielectric breakdown voltage of NM cable insulation, since this is an important electrical property relative to carbonization of electrical insulation and potential for ignition.

Objective

The objective of this project was to develop data on the influence of damage during installation and degradation of NM cable's insulation relative to its dielectric breakdown voltage.

Scope

- This investigation was focused on commercially available NM cables in USA.
- This investigation did not develop data to predict service life of the NM cables under installed field conditions.

Project Plan

A technical plan to meet the research objectives was developed as follows:

- Task 1. Literature search.
- Task 2. Sample selection.
- Task 3. Installation damage assessment.
- Task 4. Aging and service life assessment.
- Task 5. Combined installation and aging degradation.
- Task 6. Technical report.

The research report is presented herein.

Research Report

Task 1 — Literature Search

The literature search for this project focused on (i) types of electrical wiring used in homes; extensive use of NM cable in the US; the typical construction of NM cable; and (ii) data for damage and degradation of electrical wiring.

Electrical Wiring in US Homes[9]

There are several types of electrical wiring permitted in homes by the NEC. These include (i) separated conductors; (ii) armored cable; and (iii) non-metallic (NM) cable. A brief background on these wiring systems is presented herein.

Separated Conductors

Beginning in Thomas Edison's timeframe, the original residential wiring systems used conductor insulation made of gum-rubber. This "rubber" insulation was a mixture of ingredients including vulcanizing agents containing sulfur for curing. These various additives, especially sulfur, had a very corrosive effect on the copper conductor, so the copper had to be tin-coated.

During the 1950's, the wire industry began transitioning residential wire insulation from rubber to the newly developed polyvinyl chloride (PVC) thermoplastics with the extensive use of low molecular weight ester plasticizers (typically based on phthalic or trimellitic anhydride and various short chain alcohols (from C8 to C15). Plasticized PVC compounds have advantages over vulcanized rubbers in that they did not suffer from the brittleness and cracking with age that was typical of the older rubber insulation. It also did not contain sulfur additives that could damage the conductor, so the copper did not have to be tin-coated. Another advantage of plasticized PVC compounds is that there were more options with color pigmentations, and the color tended to hold its pigmentation better than rubber, which often had a painted wrap that discolored with time. In the mid-1980's, 90°C rated wire began replacing the 60°C and 75°C wire typical of the earlier installations.

Today the separated conductor type of electrical wire is mostly used in the building electrical systems that require metal tube or metal conduit for wire protection. The installation procedure is to first install the metal tubes or conduits as the wire protection in the electrical distribution system, and then feed the insulated electrical wires through the metal tubes or conduits for electrical connections.

Armored Cable

Armored cable (AC) was first Listed in 1899 for the Sprague Electric Co. of New York, and was originally called "Greenfield Flexible Steel-Armored Conductors," after one of its inventors, Harry Greenfield. There were originally two experimental versions of this product, one called "AX" and the other "BX," with the "X" standing for "experimental." The "BX" version became the one that eventually got produced, and hence the name "BX" stuck, which also became the registered trade name of armored cable for General Electric, which later divested this business to Sprague Electric.

Armored cable, or BX, first appeared in the 1903 NEC, but did not start becoming popular until around 1930, and is still a popular wiring method today. AC cable is described in Article 320 of the NEC. The armor of AC cable systems is tested for grounding and can provide a suitable equipment grounding path. AC cable made after 1959 requires an aluminum bonding strip under the armor to help improve the conductivity of this path. Although originally produced with steel armor, in the late 1980's lightweight aluminum armored AC cable first became Listed in accordance to NEC requirements.

Nonmetallic Cable

Nonmetallic-sheathed cable, or NM for short, was first Listed and described in the NEC in 1926, but it was invented a few years earlier by Rome Wire Company in 1922 in Rome, NY, and marketed under the trade name "Romex®." Romex® is now a registered trademark of Southwire Company of Carrollton, GA[10]. Early NM cable had their individual conductor insulation wrapped in a cotton braid that was impregnated with either a varnish or tar-like substance for moisture protection.

Around 1950, synthetic spun rayon was being permitted to replace the cotton thread in the jacket braid. Then in the early 1960's, thermoplastic began replacing the braided jacket altogether, and by about 1970, most all NM cable had a compounded PVC outer jacket, even though a braid was still permitted until 1984. Also in 1984, NM-B cable was developed and required to have 90°C rated individual conductors, and a 75°C outer jacket.

Until the early 1960's, most NM cable for residential use did not have a grounding conductor. However, changes in the 1962 Code that mandated equipment grounding for all branch circuits popularized the use of NM cable with ground. Earlier versions of NM cable with ground permitted the grounding conductor to be one or even two sizes smaller than the current carrying conductors. For example, a 16 AWG ground wire was permitted for 14 and 12 gauge copper NM, and 14 AWG ground for 10 gauge copper NM. In 1969, new requirements no longer permitted an undersized grounding conductor for 14, 12 and 10 AWG NM cable.

A survey of residential cable usage shows that NM cable is used extensively in the USA, with approximately 8 billion feet of NM cable sold in 2007, and is used in nearly 75% of new single family homes[8].

Residential Electrical Cable Installation

In the United States, the indoor residential electric power wiring system is typically considered to start at the electric power meter installed by the utility company, and includes all wiring within the home. Heavy gauge cables (*i.e.*, 2/0 AWG cable) connect the electric power meter to the service panel box. The electric power is then distributed to each room through circuit breakers with NM cable or other types of cables depending on the local Code.

NM Cable Installation

1. A typical single-family house in US has about 2,500 feet of NM cable in the electrical power system. Because the distance between the service panel box and any room in a house is much longer than 5 feet, it is necessary[11] to secure the NM cable when distributing the electric power to different areas in the house. For the purpose to quantitatively assess the NM cable damage in the installation process, this project follows the NEC and NEMA[12,13] guidelines when installing the NM cable test samples.NEMA RV2 2008. Protection for cable in concealed locations: where NM cable is run through studs, joists or similar wooden members, the outer surface of the cable must be kept at least 32 mm (1.25 inches) (from the edges of the wooden members, or the cable should be protected from mechanical injury. This latter protection can take the form of metal plates (such as spare outlet box ends) or conduit
2. NEC 2011 300.4. In both exposed and concealed locations, where cables are installed through bored holes in joists, rafters, or wood framing members, the holes shall be bored so that the edge of the hole is not less than 1¼ inch from the nearest edge of the wood member. Where this distance cannot be maintained, or where screws or nails are likely to penetrate the cable, it shall be protected by a steel plate at least 1/16" thick and of appropriate length and width.
3. NEC 2011 334.30. NM cable shall be supported within 300 mm (1 foot) of every box or fitting, and at intervals of no more than 1.4 m (4.5 feet).
4. 2- NEMA RV2 2008. Conductor NM cable should never be stapled on edge.
5. NEC 2011 334.12. NM cable should not be embedded in masonry, concrete, adobe, fill or plaster. NEC 300.7. Portions of raceways and sleeves subject to different temperatures (where passing from the interior to the exterior of a building) shall be sealed with an approved material to prevent condensation from entering the service equipment.
6. NEC 300.22. Type NM cable shall not be installed in spaces used for environmental air, however NM is permitted to pass through perpendicular to the long dimension of such spaces.
7. NEMA RV2 2008. Wire should be selected, but de-rated in current carrying capacity to 60°C.
8. NEC 2011 334.15. Cable shall be protected from physical damages when necessary by rigid metal conduit, intermediate metal conduit, electrical metal tubing, Schedule 80 PVC conduit, Type RTRC marked with suffix –XW, or other approved means.
9. NEC 2011 334.12. NM, NMC and NMS should not be used in wet and dump locations.

These guidelines were used to develop data on damage and degradation of the electrical performance of NM cables in this project.

Potential of Damage to Cable Insulation from Common Installation Practices

The most common method of installing NM cable is to secure the NM cable with staples onto wooden framing members. The tools used to install NM cable include hammer, manual staple gun, and electric staple gun. Figure 2 shows a picture of some NM cable installation tools. Because of the accuracy and applied force of the NM cable installation tools, there is a potential of damage to the NM cable during a home installation. According to the inspection reports[21,22], the most common types of cable damage include cable puncture, cable over-compression and hammer impact. Electrical Code inspection organizations record many NM cable installation code violations every year, but there are few quantitative reports which provide details of how likely the NM cable can be damaged during installation, and what level of damage the NM cable may suffer.

Figure 2 - NM cable installation tools

There are several kinds of staples used in the installation of NM cables as shown in Table 3. These include bare metal staples, metal staples with plastic insulation, and plastic staples with metal pins. Potential damage to the NM cable may occur during installation depending the staples and tools used (Table 3).

Table 3 - NM cable installation tool and damage mechanisms

Stapler / Tool	Metal staple 	Metal staple with plastic insulation 	Plastic staple with metal nails 
Hand hammer	Damage due to (I) direct hammer impact on cable; and (ii) over driving the staple	Damage due to direct hammer impact on cable	Damage due to direct hammer impact on cable
Stapler	Damage due to (i) puncturing of insulation; and (ii) over driving the staple	Damage due to puncture	N/A

Damage to Cable Insulation from Voltage Surges

Francois Martzloff investigated residential voltage surges in the 1960s and his research work is still used as an important reference for expected surge voltages for residential electricity distribution system design and test. Figure 3 shows frequency data on voltage surges from Francois Martzloff and other sources[14].

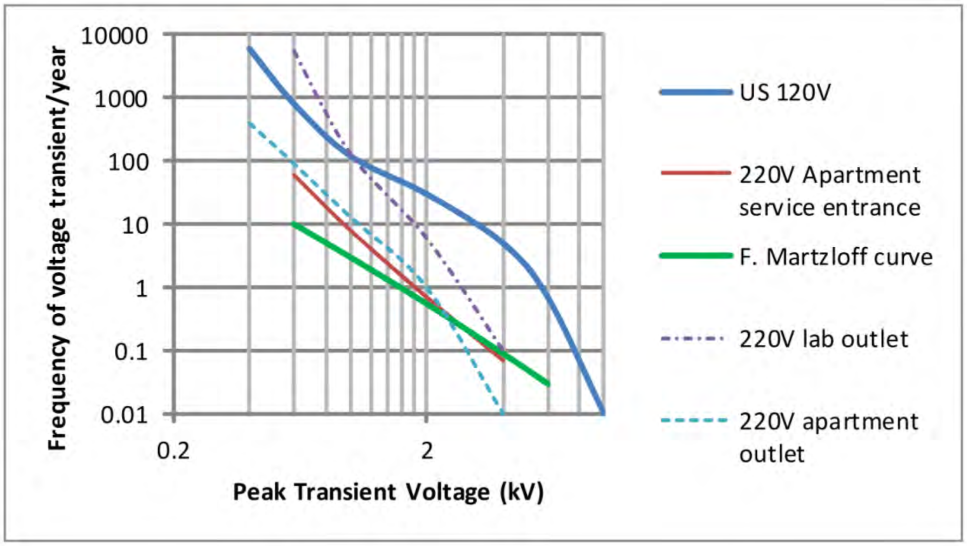


Figure 3 - Residential voltage surge statistics.[14]

According to the data, the probability of 6 kV and higher voltage surge is relatively low in the residential electricity distribution system, with less than one surge event greater than 6kV expected per year. This coincides with requirements in electrical wiring test standards for the dielectric breakdown voltage for home electrical wiring insulation materials. It may be observed from the figure that the frequency of voltage surge in the USA (blue line in Figure 3) of 2 kV is 15 per year and surges of 1 kV are more than 100 per year.

Cable Insulation Degradation

In addition to either mechanical damage or from voltage surges, the NM cable insulation may experience subsequent degradation of electrical safety performance during its service life from a number of factors that include the following:

- **High-temperature exposure due to overload and/or increased ambient temperature.** Exposing to elevated temperatures can cause accelerate loss of additives, including stabilizer(s) and plasticizer(s). This is likely to reduce the dielectric strength of the insulation.
- **High humidity exposure.** Exposure to humidity may result in moisture penetration into NM cable insulation, which could increase the insulation leakage current and reduce the insulation breakdown voltage.

- **Exposure to salt and other contaminants.** Salt and other contaminants or pollutants may penetrate into the NM cable insulation and accelerate NM cable insulation decomposition and thus will increase the insulation leakage current and reduce the insulation breakdown voltage.
- **UV exposure.** Ultraviolet radiation has higher energy than visible spectrum photons. If the UV photon energy is higher than the insulation additive activation energy, UV exposure will accelerate the loss of insulation additives including stabilizer and plasticizer, and depending on the temperature material decomposition may also occur.

It is assumed that thermal aging caused either by high ambient temperature or overload is a dominant factor that accelerates cable insulation degradation over time. This degradation may be further exacerbated by high humidity and exposure to salts, contaminants or pollutants. Based on the lack of availability of field samples for calibration and the fact that little residential electrical wiring is exposed to UV in the real world applications, the scope of this project was limited to investigating only the effect of thermal degradation of cable insulation materials. UV/visible radiation exposure to conductor insulation is more likely at splice points or junction boxes (where the outer jacket is removed), but this is also considered outside the scope of this project.

There are many technical papers in the area of electrical insulation aging and degradation,[15,25,16] but there was lack of data on correlation between cable insulation degradation and electrical performance such as reduction of the dielectric strength.

Literature Search Summary

Based upon the literature search, a focus for this research project was defined as follows:

- Select NM cables in the investigation since NM cables are used commonly in residential buildings in the USA, and that the insulation used in NM cable are the same or similar to the insulation used in other types of electrical wiring (*i.e*., plasticized PVC).
- Consider mechanical damage conditions encountered in installing NM cables, such as inadvertent hammer blows and improper stapling.
- Consider only temperature-related degradation conditions of the NM cable insulation materials that may occur due to overload or high ambient temperature.

Task 2 — NM Cable Sample Selection

Five major manufacturers of NM cables, commercially available in the USA, were selected initially for the research project. The test cables were designated as A, B, C, D, and E, representing the five manufacturers. The cables were screened using analytical techniques and dielectric breakdown testing to select two NM cables with distinct cable characteristics.

NM Cable Insulation Characterization

NM cable insulation materials from five manufacturers were characterized with respect to their thermal, chemical, and electrical properties. Based upon results, two cables with distinct properties were identified for further evaluation in this research investigation.

Thermal Characterization – Thermogravimetric Analysis

Thermogravimetric analysis (TGA) was performed on the NM cable insulation materials to develop information on the thermal degradation of cable insulation under controlled temperature conditions.

In the temperature scan mode, the TGA furnace temperature is increased at a constant rate in air or nitrogen environment, and the insulation sample weight is monitored. Figure 4 through Figure 8 show the TGA weight loss rate results in air environment and at 20 ^{0}C/min scan rate for ten different NM cable insulation materials from the five NM cable samples. The results for white insulation material are on the left hand side, and results for the black insulation are on the right hand side.

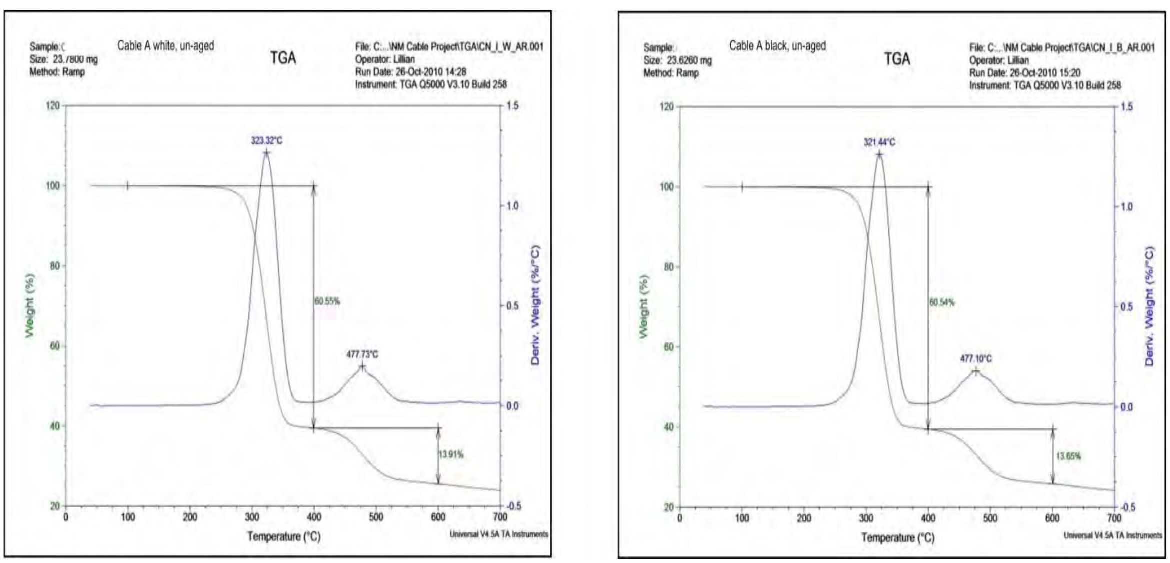


Figure 4 - TGA from Cable A Insulation

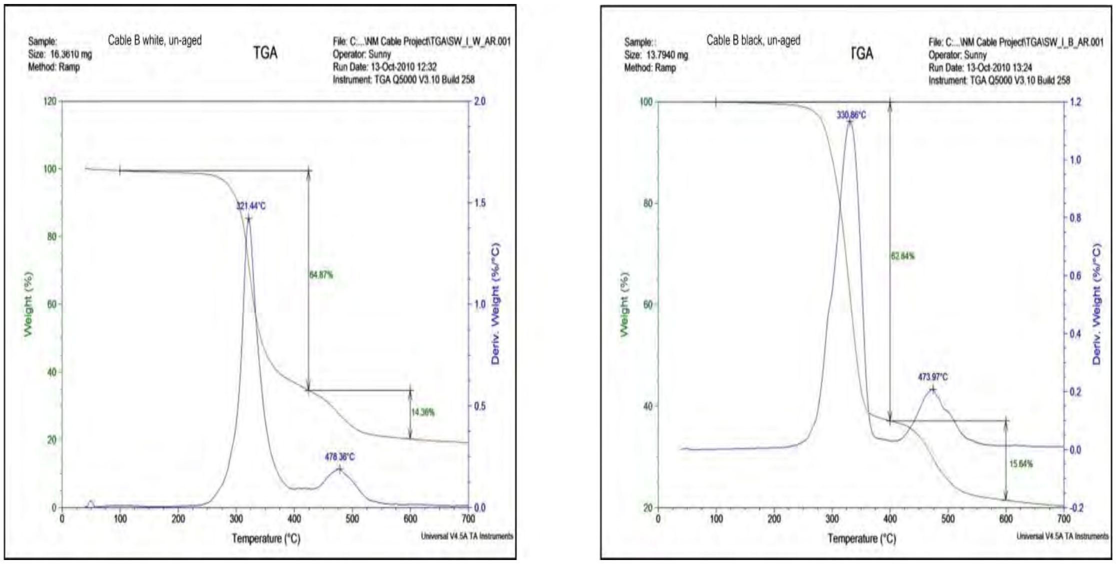


Figure 5 - TGA from Cable B Insulation

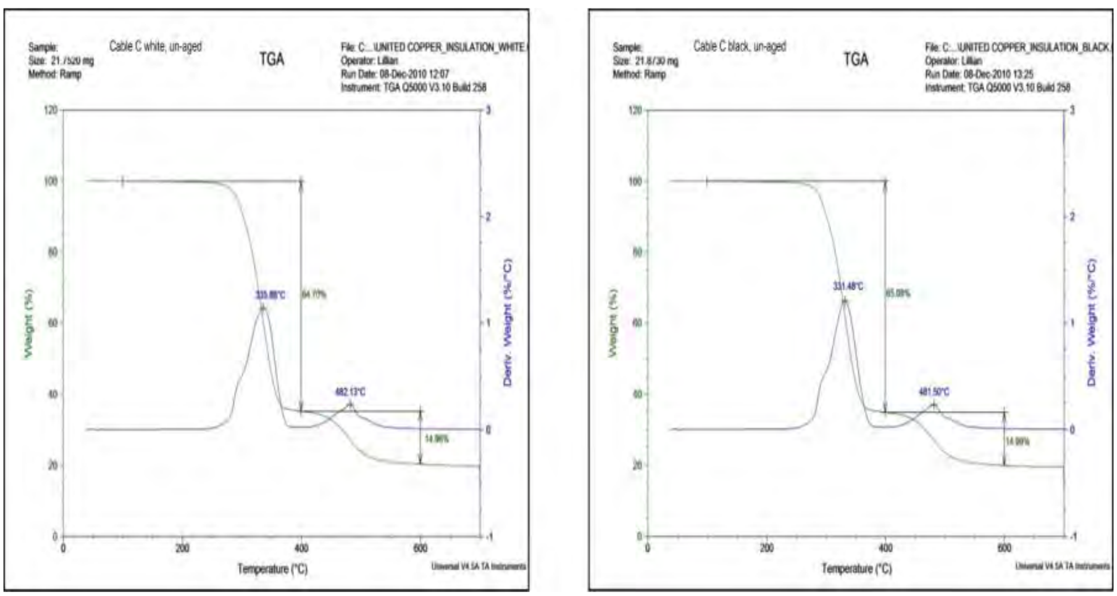


Figure 6 - TGA from Cable C Insulation

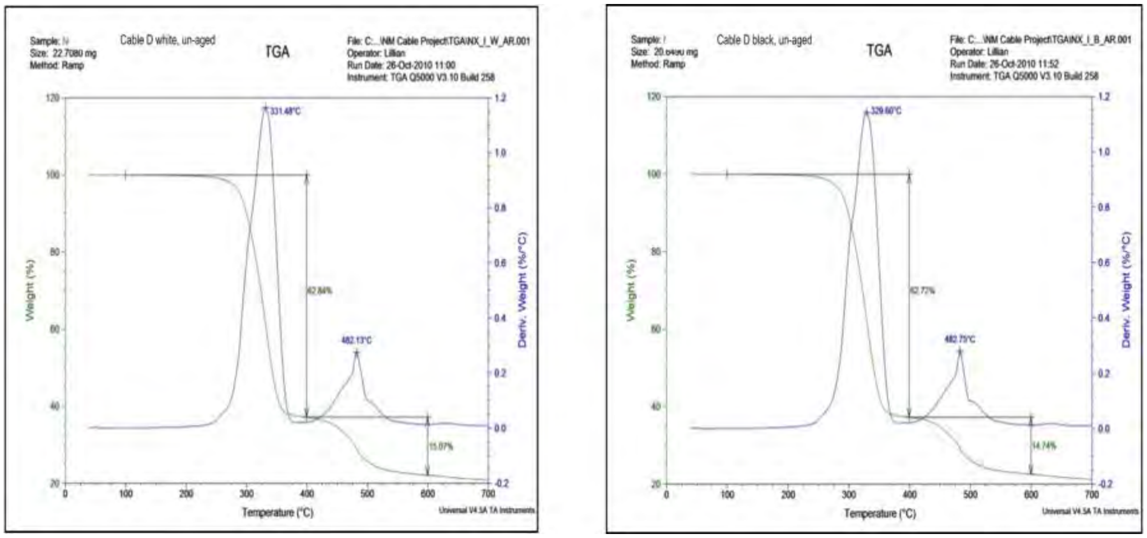


Figure 7 - TGA from Cable D Insulation

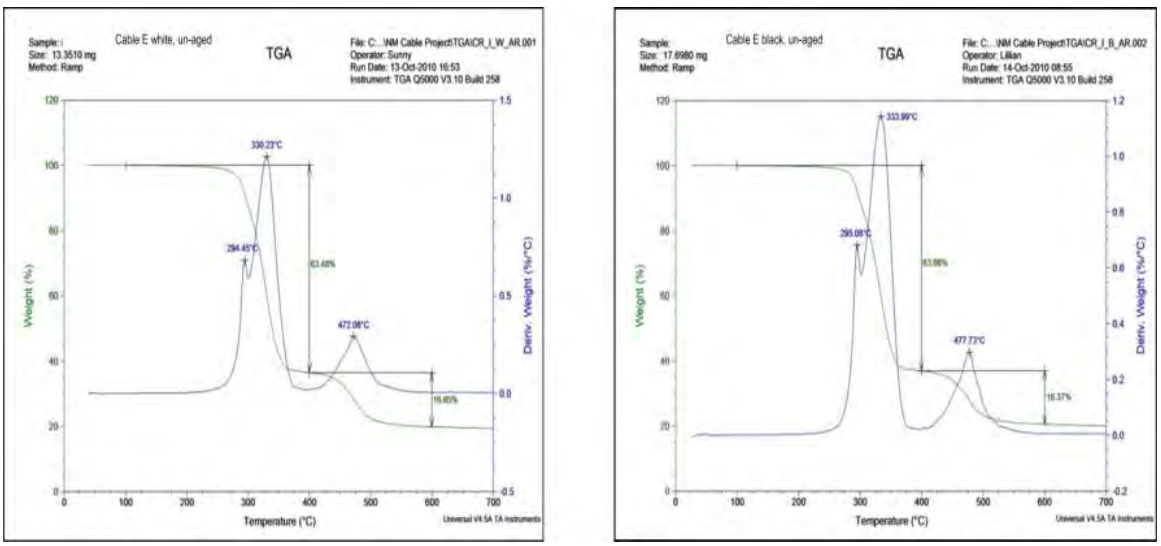


Figure 8 - TGA from Cable E Insulation

The TGA data from the insulation materials (white and black samples) of the NM cables depict some distinct behavior. For example, Cables B, C, and D show a slight curvature in the first peak indicating that the weight loss rate is a combination of thermal degradation from multiple insulation components. The weight loss rate of Cable E is different from others as it displays three main peaks, and an earlier first peak indicating a more volatile insulation component. Because the TGA profile can be a convolution of thermal decomposition of many chemical compounds, these differences point to the presence of different plasticizer compounds used in the different insulations. The thermogravimetric data from the selected NM cables are summarized in Table 4, which indicates that Cable E is quite different from the others.

Table 4 - Weight loss rate peak temperature

	1st peak (°C)	2nd peak (°C)	3rd peak (°C)
Cable A white	N/A	323.32	477.73
Cable A black	N/A	321.44	477.10
Cable B white	N/A	321.44	478.36
Cable B black	N/A	330.86	473.97
Cable C white	N/A	335.88	482.13
Cable C black	N/A	331.48	481.50
Cable D white	N/A	331.48	482.13
Cable D black	N/A	329.60	482.75
Cable E white	294.45	330.23	472.08
Cable E black	295.08	333.99	477.73

The TGA equipment may also be programmed to obtain insulation weight loss data exposed to a constant temperature (isothermal mode). The weight loss data acquired in this manner can be used in estimating the activation energy of different chemical components in the insulation. It also aids in the understanding of the temperature-dependent accelerated aging effects when using a thermal chamber to evaluate the insulation material thermal degradation.

Figure 9 depicts weight loss of four different insulation materials. The chart shows that the insulation material weight loss is a nonlinear function of time, and insulation materials from different brands of NM cable have different weight loss rates at a particular TGA temperature. The nonlinear characteristic observed in the weight loss data is indicative of multiple thermal decomposition processes in the insulation material

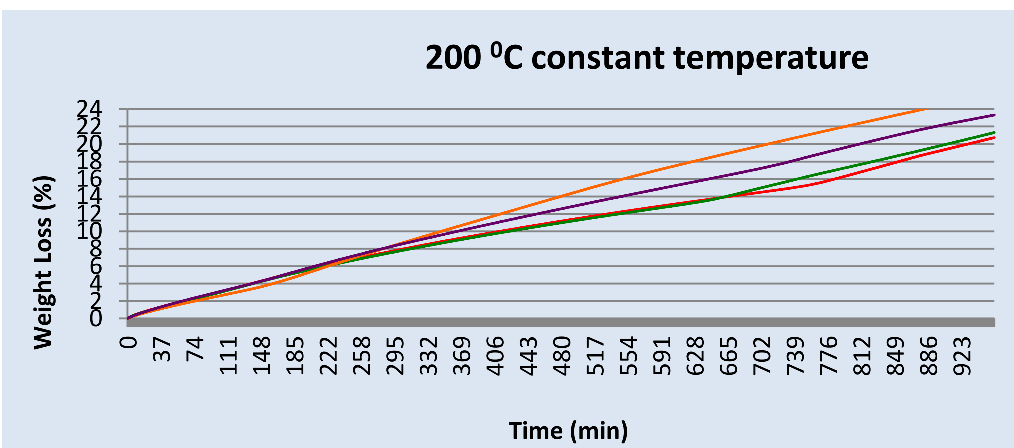


Figure 9 - Constant temperature TGA data. The red trace is cable B white insulation weight loss, the green trace is cable B black insulation weight loss, the purple trace is cable E black insulation weight loss, and the orange trace is cable E white insulation weight loss.

Chemical Characterization – FTIR analysis

The insulation materials from the NM cables were chemically analyzed with an FTIR (Fourier Transform Infrared) analyzer using the attenuated total reflectance method.

Figure 10 shows the test results for Cable B and Cable E insulation (in blue) for the white insulation. The black insulation also has similar IR characteristics. The plasticizers used in the cables were identified through comparison to a chemical library (in red).[17] The FTIR results indicate that Cable B has a phthalate plasticizer, while Cable E has trimellitate plasticizer. These plasticizers exhibit significantly different properties as will be discussed in the following sections. The plasticizer data for each NM cable are summarized in Table 5.

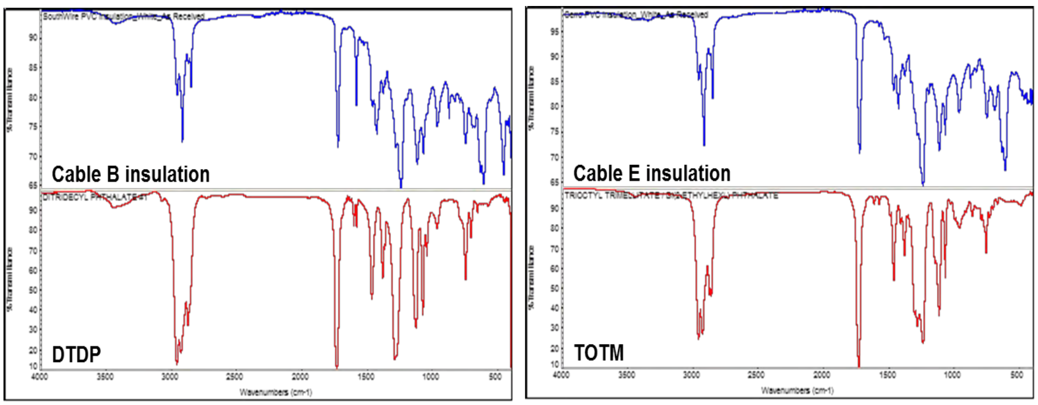


Figure 10 - FTIR spectrum for Cable B and Cable E insulation

Table 5 – Cable Insulation Plasticizers

Cable	Plasticizer
Cable A white	Phthalate
Cable A black	Phthalate
Cable B white	Phthalate
Cable B black	Phthalate
Cable C white	Trimelliate
Cable C black	Trimelliate
Cable D white	Trimelliate
Cable D black	Trimelliate
Cable E white	Trimelliate
Cable E black	Trimelliate

Table 6 – Property Comparison of Selected Phthalate and Trimellitate Plasticizers Di-iso-nonyl phthalate (DINP), Di-tri-decyl phthalate (DTDP), Tri-2-ethylhexyl Trimellitate (TOTM)

Plasticizer	**DINP**	**DTDP**	**TOTM**
Molecular Formula	$C_{26}H_{42}O_4$	$C_{34}H_{58}O_4$	$C_{33}H_{54}O_6$
Appearance@25°C	Clean liquid	Clean liquid	Clean liquid
Molar Mass (Molecular weight)	418.61 g/mol	530.82 g/mol	546.79 g/mol
Melting Point	-43°C	-37°C	-38°C
Boiling Point at 760mm Hg	405.7°C	508.2°C	414°C
Vapor Pressure at 25°C	8.61×10^{-7} mmHg	3.63×10^{-8} mmHg	4.10×10^{-14} mmHg

From Plastics Additives[18] "trimellitate esters are distinguished by high thermal stability and low volatility". This is evidenced by the low vapor pressure in comparison to the two common phthalates listed in the table. The trifunctional ester in trimellitates provides superior permanence and dispersion in polar PVC formulations. Note that other properties of the phthalates and trimellitates are quite similar (molecular weight, boiling point and water solubility) so the key property is vapor pressure.

Insulation Breakdown Voltage Test

As was shown in the literature discussion conducted in Task 1 and illustrated in Figure 3, significant surge voltages are encountered in home wiring below 6 kV. There are several breakdown voltage test standards for dielectric strength evaluations. Since the equipment used in the breakdown voltage test is calibrated for RMS values at 60Hz, all breakdown voltage measurements cited in this report are RMS values[19].

When performing breakdown voltage tests in air, it was observed that the air is ionized and generates a corona when the electric field strength is greater than the air breakdown threshold of 3 kV/mm. Since high speed particles in the corona can preheat the sample and weaken the wire insulation, it impacts the measurement of the breakdown voltage. Thus, the test fixture was redesigned to reduce the impact of the corona on the measurement, as it was anticipated that the breakdown voltage of the insulation materials to be greater than 3 kV. The test fixture is depicted in Figure 11. The test fixture was designed to test a single-insulation conductor (without the NM cable outer jacket).

Figure 11 - Fixture for the NM cable breakdown voltage test

The sample preparation procedure was as follows:

1. Pull out the conductors from the NM cable outer jacket
2. Strip insulation by a half inch at one end of the conductor
3. Bend the conductor around a quarter inch diameter rod
4. Vary the voltage across the conductor until insulation breakdown occurs. Breakdown of the insulator is detected when the leakage current reaches 10 mA.

A schematic of the cable sample under test and the test probe during the breakdown voltage test is depicted in Figure 12.

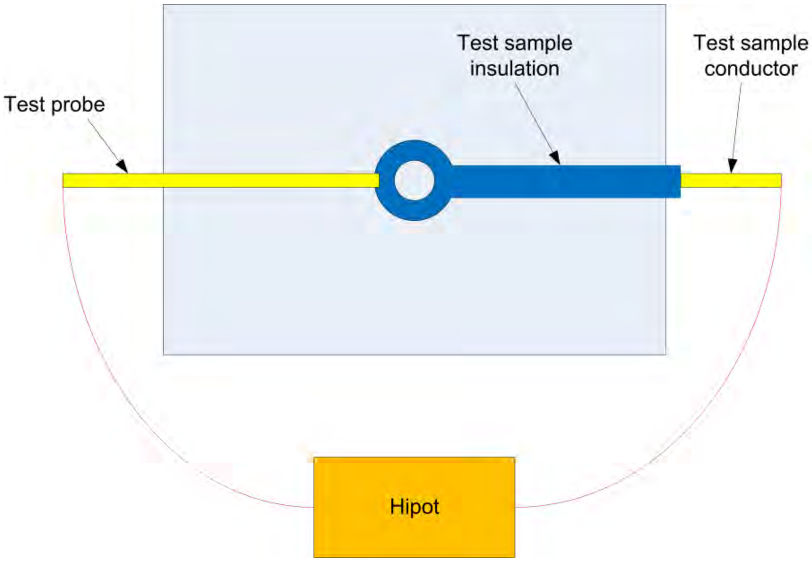


Figure 12 – Cross-section of the Teflon fixture for the NM cable breakdown voltage test

Assessment of the NM cable insulation breakdown voltage

To develop statistically significant data, 30 specimens were tested on both the black and white insulation for each type of the NM cables, except for Cable C (29 white specimens and 29 black specimens). The average, minimum, and maximum values of the breakdown voltage are depicted in Figure 13.

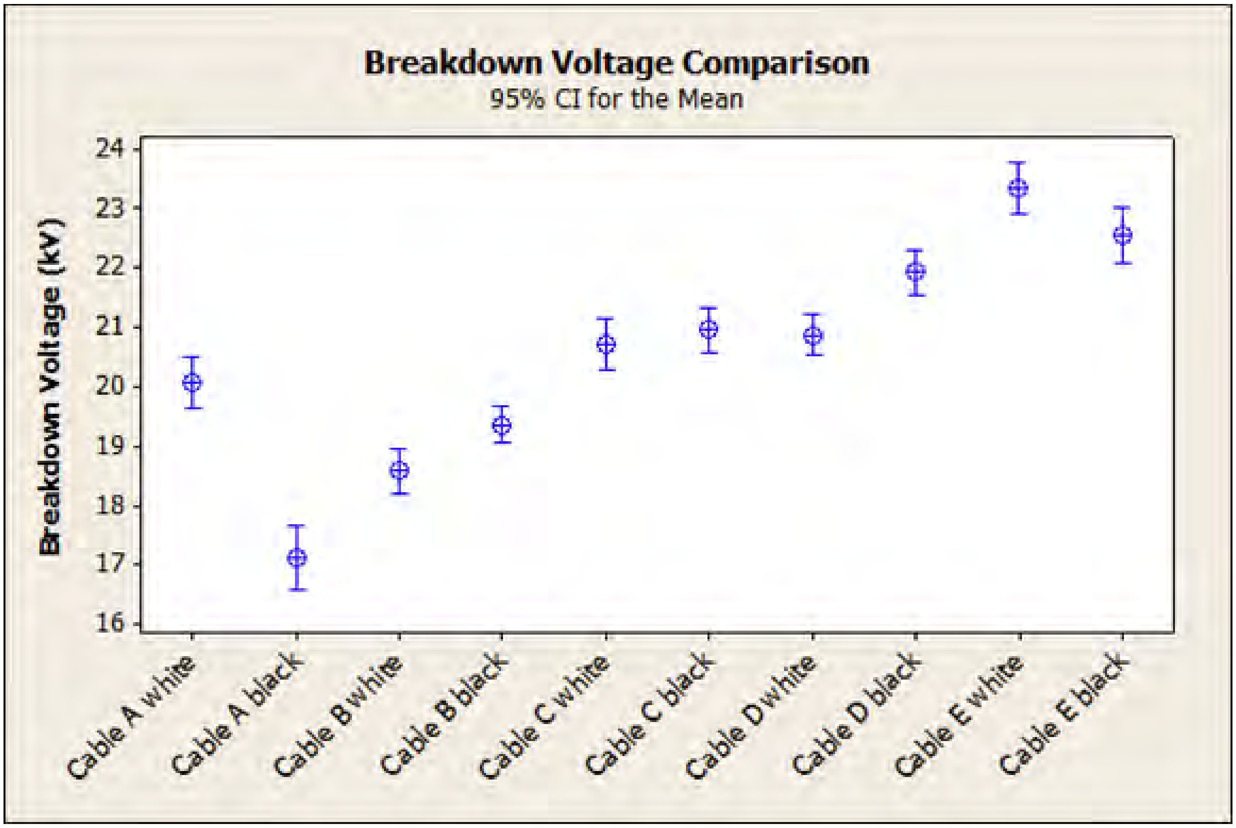


Figure 13 - Average breakdown voltage comparison

The average breakdown voltages along with the standard deviation are summarized in Table 7. Pearson analysis[20] was applied to determine if insulation thickness had an influence of breakdown voltage, and the result showed that insulation thickness of the selected NM cables was not correlated to the measured dielectric breakdown voltage.

The results of dielectric breakdown voltage were further analyzed to assess if the difference in measurements were statistically significant. Figure 14 through Figure 18 show the breakdown voltage distribution for the black and white insulation of Cables A, B, C, D and E, respectively. The breakdown voltage results indicate that the distributions are normally distributed (*i.e.*, Gaussian).

Table 7 - Average breakdown voltage and standard deviation

Sample Type	Average breakdown voltage (kV)	Insulation Thickness	Number of samples	Standard Deviation (kV)
Cable A white	20.1	0.35	30	1.15
Cable A black	17.1	0.37	30	1.42
Cable B white	18.57	0.40	30	1.04
Cable B black	19.36	0.41	30	0.81
Cable C white	20.7	0.40	29	1.13
Cable C black	20.95	0.39	29	1.02
Cable D white	20.87	0.38	30	0.93
Cable D black	21.93	0.38	30	1.02
Cable E white	23.34	0.39	30	1.15
Cable E black	22.54	0.39	30	1.23
			Pearson coefficient	0.096
			P value	0.791

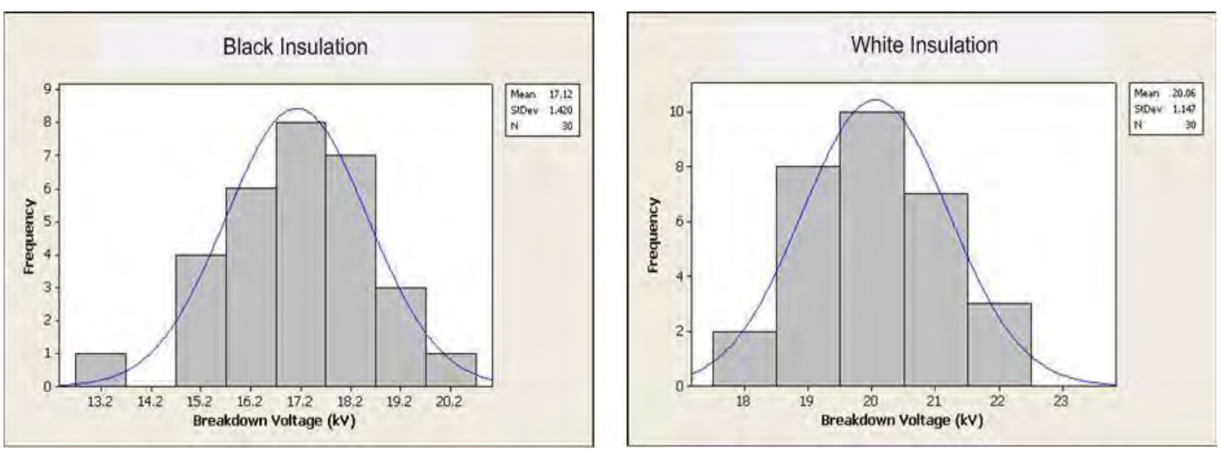


Figure 14 - Cable A breakdown voltage distribution

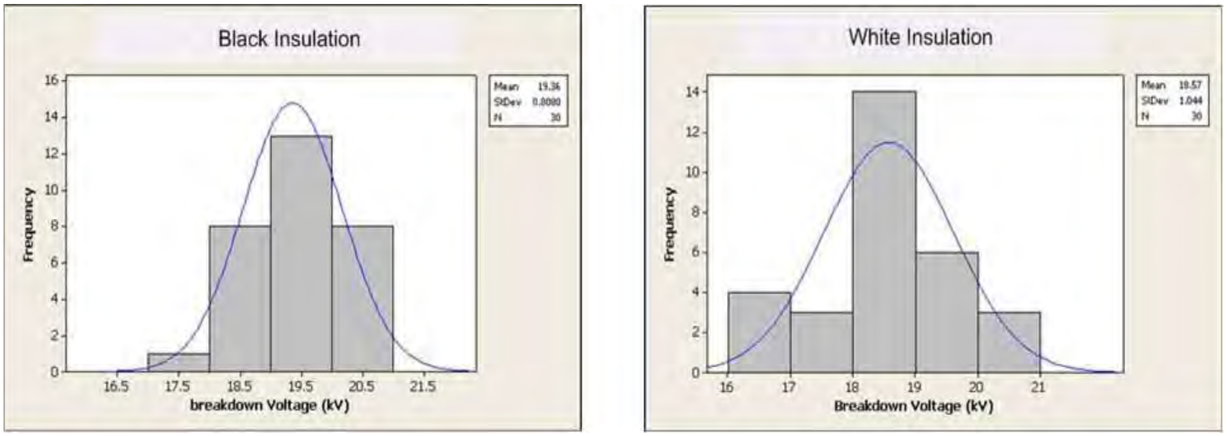


Figure 15 - Cable B breakdown voltage distribution

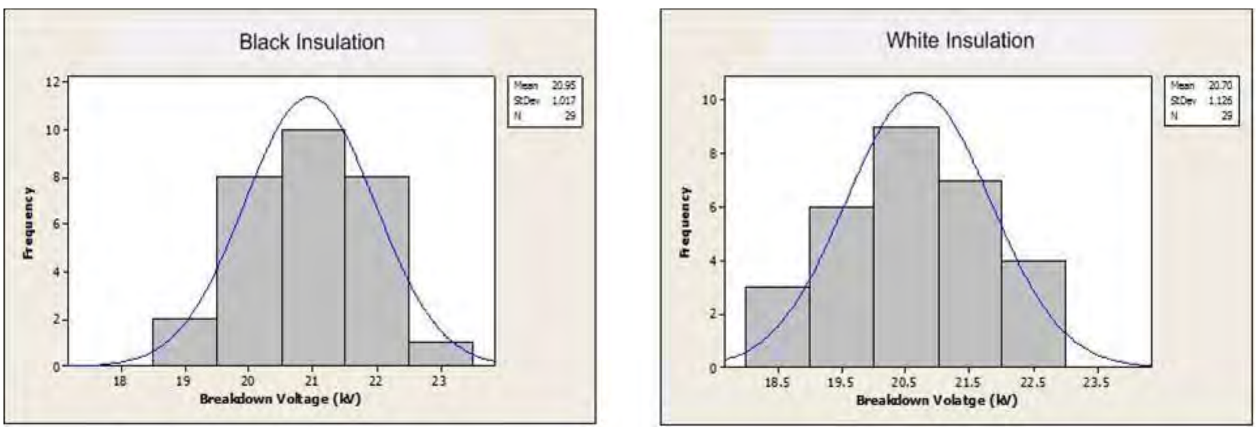


Figure 16 - Cable C breakdown voltage distribution

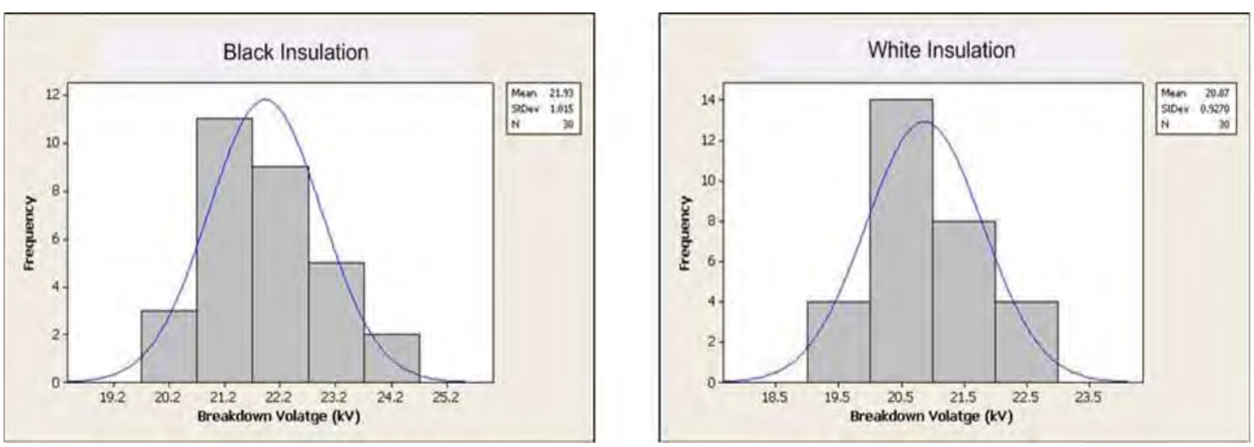


Figure 17 - Cable D breakdown voltage distribution

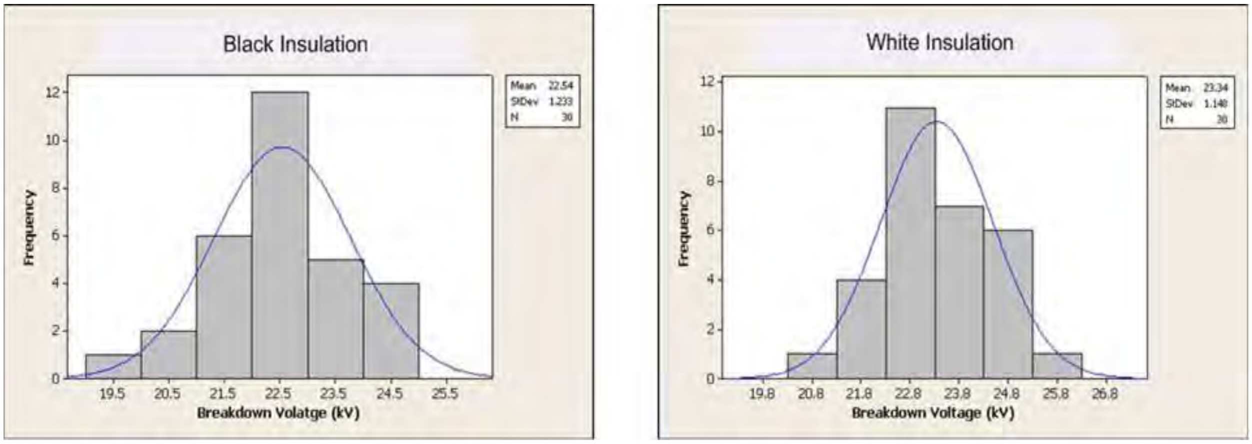


Figure 18 - Cable E breakdown voltage distribution

To verify if two different insulation materials may have different breakdown voltages[20], the following equation was used to calculate the breakdown voltage difference between two different types of NM cable insulation compositions:

$$\Delta V_{ij} = abs(V_i - V_j) - C_i - C_j$$

Where ΔV_{ij} is the difference between the two measured average breakdown voltages, V_i is the average breakdown voltage for cable *i*, V_j is the average breakdown voltage for cable *j*, C_i is the 95.4% confidence interval for cable *i*, and C_j is the 95.4% confidence interval for cable *j*. If ΔV_{ij} is larger than zero, there is no overlap between the two measured average breakdown voltages, in other words, the two insulations have different breakdown voltages. Table 8 shows the calculated results for the white insulation of five different NM cables.

Table 8 - Differences in white insulation breakdown voltage

white	A	B	C	D	E
A		0.73 kV	-0.24 kV	0.01 kV	2.40 kV
B	0.73 kV		1.33 kV	1.58 kV	3.97 kV
C	-0.24 kV	1.33 kV		-0.59 kV	1.80 kV
D	0.01 kV	1.58 kV	-0.59 kV		1.71 kV
E	2.40 kV	3.97 kV	1.80 kV	1.71 kV	

The numbers in Table 8 are the differences between the measured average breakdown voltages with 95% confidence level for white insulation. For instance, the value in the cell at column A and row B shows that the breakdown voltage difference between Cable A and Cable B white insulation is 0.73 kV with a confidence level of 95%. Since the average breakdown voltage difference is greater than zero, Cable A and Cable B white insulation may be considered to be statistically different. On the other hand, the difference of the breakdown voltage between white insulation from Cable A and Cable C is minus 0.24

kV. Since this is less than zero, there is no statistical difference between the breakdown voltages of Cable A and C insulation materials.

The influence of the PVC plasticizer on breakdown voltages can be seen in Table 9, showing that the insulation breakdown voltage using trimellitate as plasticizer had a statistically higher breakdown voltage versus phthalate plasticizer.

Table 9 – Influence of PVC Plasticizer on Breakdown Voltage

NM Cable Insulation	Breakdown Voltage	Plasticizer
Cable A white	20.10 kV	Phthalate
Cable A black	17.10 kV	Phthalate
Cable B white	18.57 kV	Phthalate
Cable B black	19.36 kV	Phthalate
Cable C white	20.70 kV	Trimellitate
Cable C black	20.95 kV	Trimellitate
Cable D white	20.87 kV	Trimellitate
Cable D black	21.93 kV	Trimellitate
Cable E white	23.34 kV	Trimellitate
Cable E black	22.54 kV	Trimellitate

NM Cable Selection for Investigation of Damage and Degradation

According to the chemical composition analysis and electrical test data, the five types of NM cables can be categorized into two groups. Based on TGA data, the plasticizer used in the insulation, and the breakdown voltage, two cables, B and E, with distinct properties were selected for further investigation of the influence of installation damage and thermal degradation on dielectric strength. The characteristics of the selected cables are summarized in Table 10.

Table 10 - Cable B and Cable E characteristics

TGA results	Cable B	Cable E
Thermal decomposition rate peaks		
White Insulation (TGA test result)	321 °C; 478 °C	294 °C; 330 °C; 472 °C
Black insulation (TGA test result)	330 °C; 474 °C	295 °C; 333 °C; 477 °C
Insulation Plasticizer (FT-IR test result)	Phthalate	Trimellitate
Lead additive (EDS test result)	No	Yes
Dielectric breakdown voltage (kV)	18.97	22.94

Task 3 — Assessment of NM Cable Installation Damage

Electrical code inspection organizations record a significant number of NM cable installation Code violations every year[21], for the purpose of addressing improper installation issues and to improve installation practices. To better understand potential damage to the NM cable qualitatively as well as quantitatively, cables were installed using NEMA guidelines.

A series of scoping tests were conducting using common installation methods to assess the nature and degree of possible damage to NM cable insulation. Cable segments were installed on wood studs using NEMA the guidelines for installing the cables.

Figure 19 - NM cables installed on wood studs

Based upon field inspection reports[22], three types of damage scenarios were considered: (*a*) misaligned staple; (*b*) over-driven staple; and (*c*) inadvertent hammer impact to the NM cable jacket. The staples were driven into the wood studs using either a manual stapler; an electric stapler; or a hammer. At least 100 staples were used with each installation method. A typical installation of the NM cables is illustrated in Figure 19. The test results from staple puncture, over-driven staple, and hammer impact are described in the following sections.

Staple Puncture

When installing NM cable with a hammer, it was observed that the user has to tap the staple into the wood frame before hitting it hard and securing it. Therefore, it is unlikely to have staple puncture damage when using a hammer to install the NM cable. However, when installing NM cable with a staple gun, the view of the NM cable can be blocked to the installer by the staple gun. In this case, the staple gun may be misaligned with the NM cable and the staple may damage the conductor insulation. Figure 20 shows a picture of a misaligned staple and the conductor insulation damaged by the staple.

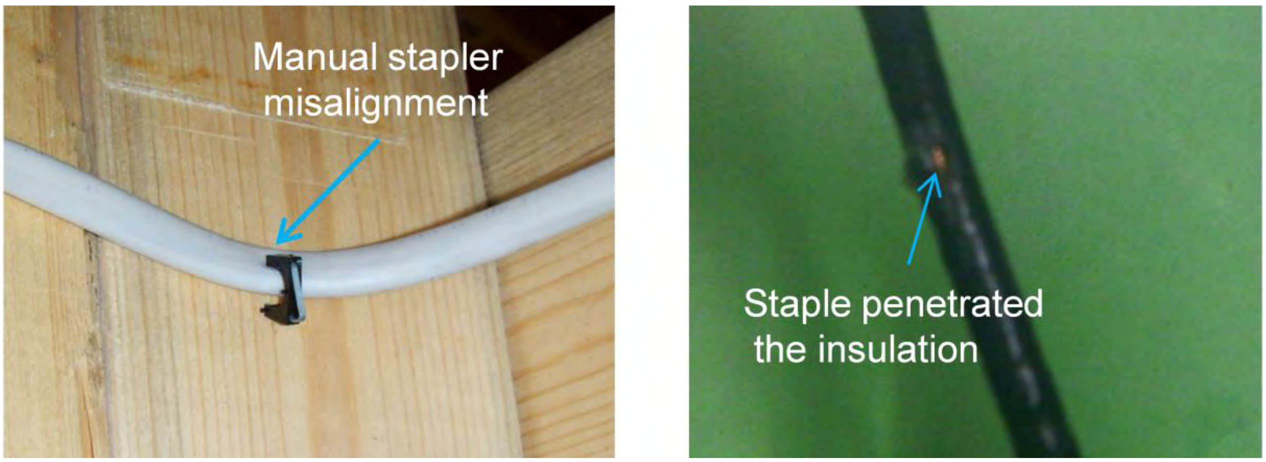


Figure 20 - NM cable damaged by misaligned staple

To estimate the potential for staple misalignment, using a stapler, and damage to the NM cable, 350 feet of NM cable was installed in a simulated attic space with 452 staples. The distance between the adjacent two staples is less than the maximum distance recommended by the NEMA NM cable installation guideline. After installation, the cable segments around the stapes with visible damage to the jacket were further examined for damage to the insulation. These segments were then tested for the breakdown voltage. The results are summarized in Table 11.

Table 11- NM cable staple misalignment damage

Installation method	Number of samples	Samples with visible jacket puncture	Samples with visible insulation puncture	Percentage of samples with insulation puncture
Electric stapler	136	22	5	3.7%
Manual stapler	207	5	1	0.5%

The result in Table 11 indicates that the manual stapler is less likely to misalign with the NM cable. One reason for this may that the manual stapler used in this investigation had a notch to align with the staple, thus facilitating installation without having the staple in sight (Figure 21).

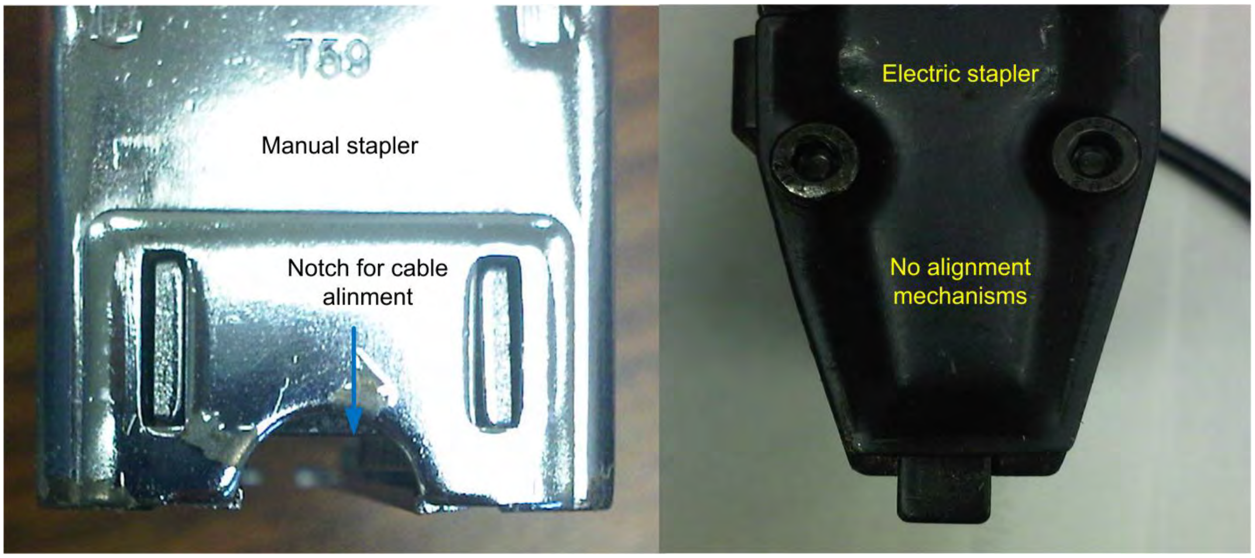


Figure 21 – Photograph of staplers with and without alignment notch

Overdriven Staple

During installation, a staple may be forced, over the NM cable jacket, into the wood stud to compress the jacket and insulation. It was observed that the degree of compression of the cable jacket by a staple is influenced by the type of staple used. Figure 22 compares the cross section of uncompressed NM cable with that of NM cable compressed by a staple with plastic insulation; and while Figure 23 compares the cross section of uncompressed NM cable with that compressed by a metal staple. Figure 22 shows that the staple with plastic insulation may act to protect the NM cable from being over-compressed.

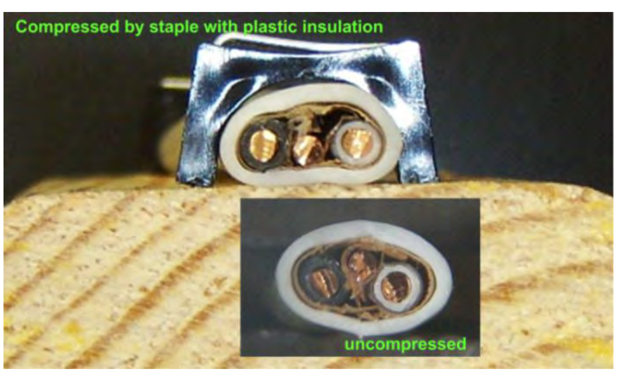


Figure 22 - NM cable compressed by a staple with plastic insulation

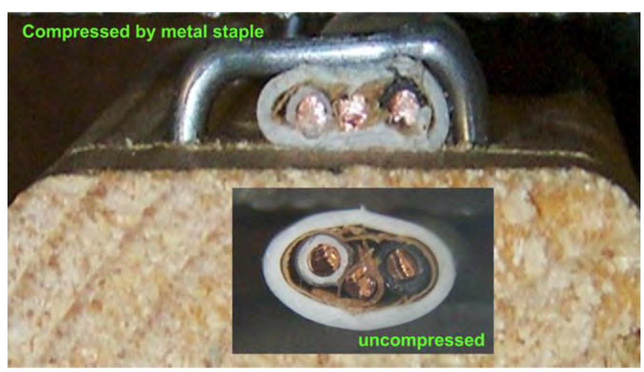


Figure 23 - NM cable compressed by a metal staple

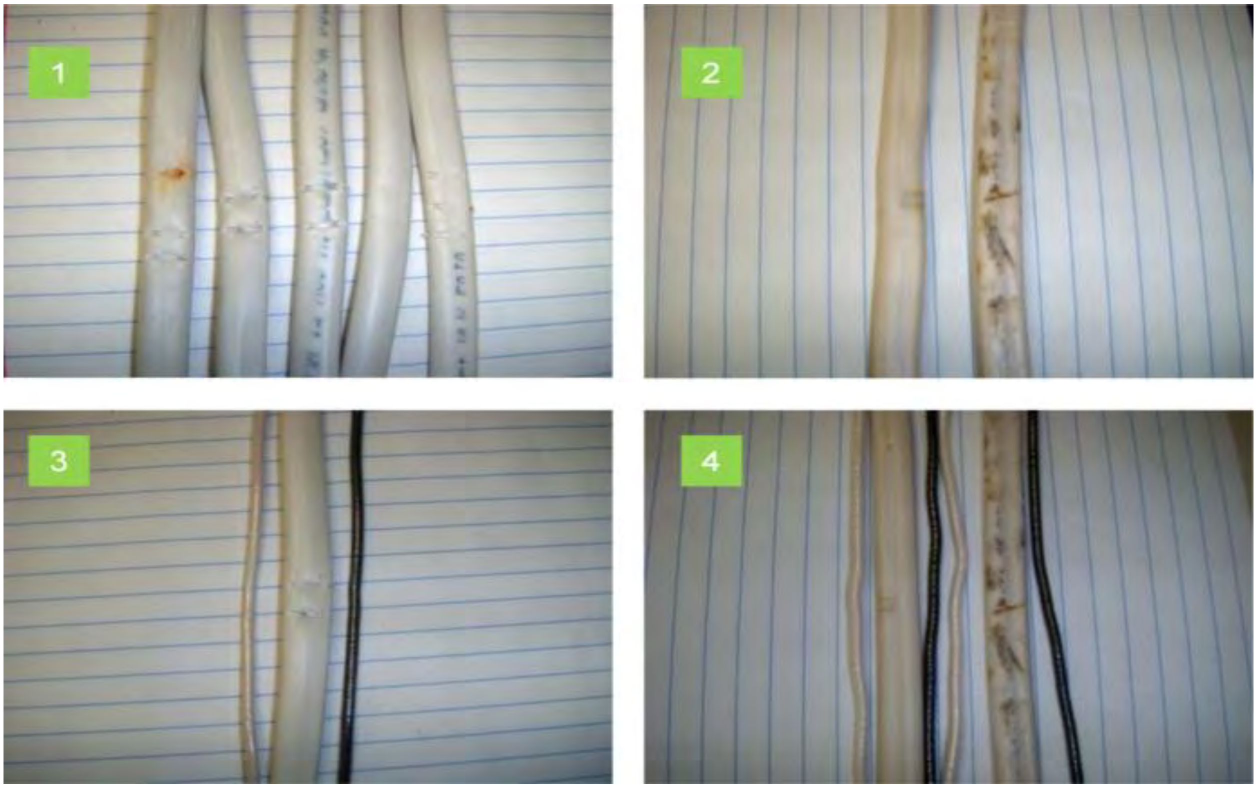


Figure 24 - Overdriven NM cable samples

Figure 24 depicts damage to NM insulation jackets by overdriven staples using various methods. Picture 1 shows NM cable damaged by staples overdriven by an electric stapler. Picture 2 shows NM cable samples damaged by staples overdriven with a hammer. Picture 3 shows exposure of conductor from a staple overdriven by an electric stapler. Picture 4 shows exposure of conductor from staples overdriven by a hammer. The visual inspection of the conductor insulation reveals that installation damage sometimes may generate visible damage to the jacket, but the same impact may not always generate visible damage on the conductor insulation.

To quantify the damage due to overdriven staples, the insulation breakdown voltage of the overdriven NM cable samples were measured as summarized in table 12.

Table 12 - Breakdown voltage of overdriven NM cable samples for cable E

Installation method	Compression mark	Number of damaged samples	Breakdown voltage (kV)	Number of samples with breakdown voltage less than 6 kV after damage
New	No	60	19.05 to 22.91	0
Manual stapler	No	10	19.3 to 21.8	0
Hammer	Yes	2	16.3 to 20.1	0
Electric stapler	Yes	11	10.51 to 20.1	0

The data in table 12 indicate that the staples overdriven by the hammer and electric stapler can significantly reduce the breakdown voltage of the NM cable conductor insulation, but overdriven staples with plastic insulation may not degrade the breakdown voltage of NM cable insulation. Table 12 also shows that all the overdriven samples passed the 6 kV breakdown voltage threshold, but had shown reduction in breakdown voltage from the undamaged values. Though initial damage from overdriven stapes was not expected to pose a serious issue with respect to breakdown voltage, this project also investigated whether breakdown voltage degraded further when overdriven NM cables were aged. This is discussed in Task 5.

Hammer Impact Damage

Since hammer is a common tool used to install NM cables, the potential for damage from this common practice was assessed. The depth to which the staple may be driven with a hammer into a wood stud was first characterized using a 16 oz. hammer with a head of 1 inch in diameter. The staple was 0.5 inches in height. Tests were conducted with one type of NM cable (Cable E) to measure the depth to which a metal staple is driven into the wood stud. In each case, two hammer blows were used to drive the staple into the wood stud. An illustration of the measurement is shown in Figure 25.

The measurements of the staple height, *d*, are presented in Table 13. The results were used to design a mechanical hammer simulator that provided a repeatable staple driving capability. The data indicate that the average distance between the top of the installed staple to the wood frame is 0.30 in. and the distribution is normal as shown in Figure 26.

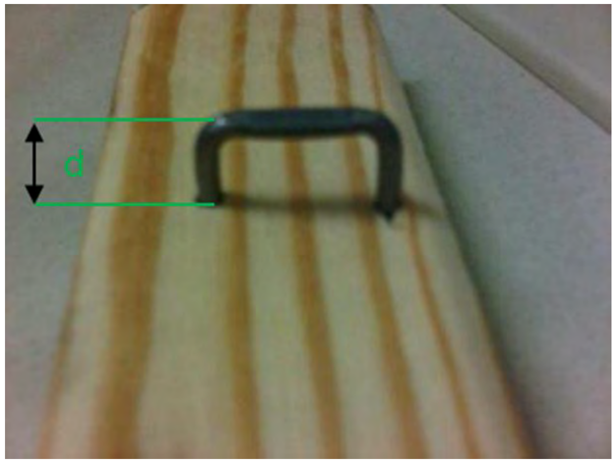


Figure 25 – Illustration of staple depth by hammer blows

Table 13 - NM cable installation by hammer and metal staples

Number of samples	Average distance from the top of the staple to the wood frame surface when NM cable is not compressed Ct (mm/in)	Average distance from the top of the staple to the wood frame surface d (mm/in)	Standard deviation (mm/in)
119	6.95/0.27	7.62/0.3	1.78/0.07

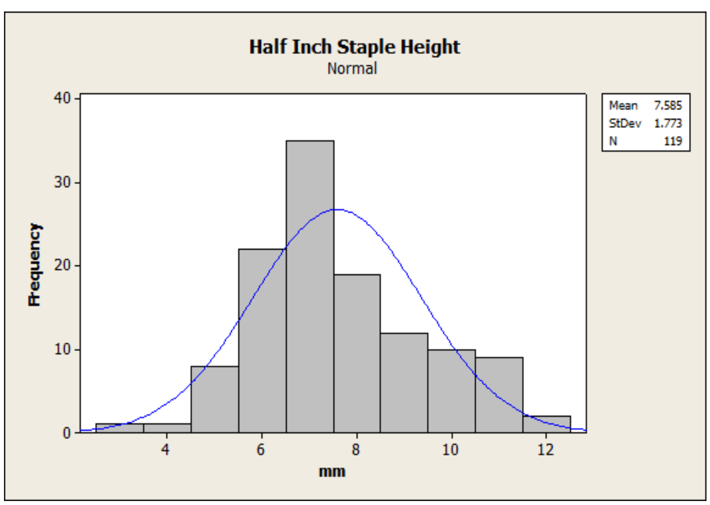


Figure 26 - Distribution of the distance between the top of the installed staple to the wood frame.

Hammer Impact Simulator Parameters

A hammer simulator shown in Figure 27 is designed for this project to test NM cable damage due to hammer hit. The hammer simulator consists of a metal base, adjustable arm, an electromagnet, and a power supply. Adjusting the height of the adjustable arm, or changing the weight of the hammer head allows for the application of different amounts of force to the NM cable samples under the test.

The following procedure was used to develop the drop height for the hammer head to simulate a repeatable staple driving depth of 0.30 inches with two or three drops.

1. Tap a metal staple on construction grade wood frame lumber and place it under the hammer of the hammer simulator as shown in Figure 27.
2. Set the hammer head at an initial height (*e.g*., 3 ft.).
3. Release the hammer head.
4. Energize the electromagnet and set the hammer head.
5. Reposition the staple under the hammer head.
6. Release the hammer head.
7. Measure the distance between the top of the staple to the wood frame.
8. If the distance is less than 0.3 inches, reduce height of the hammer drop. If the distance is greater than 0.3 inches, increase the height of the hammer drop.
9. Repeat step 1 to step 8 until a staple depth of 0.3 inches is obtained with two hammer blows.

With this procedure, it was found that a 7ft-lb force would provide the required staple depth with two hammer drops; and a 5 ft-lb force would result in the required depth in three hammer blows.

Figure 27 - Hammer impact simulator

Breakdown Voltage Distribution of Hammer Impact Damaged NM Cable

The selected cables (Cable B and Cable E) were subjected to direct hammer blows using the hammer impact apparatus, which allows the ability to apply repeatable force to the cable jacket. The test cable was placed below the apparatus head as shown in Figure 27. The height of the head was adjusted to provide either 5 ft-lb or 7 ft-lb impact onto the test cable.

The hammer impact apparatus was released to provide a direct hit on the cable outer jacket. The black and white insulations within the cable were labeled and electrical breakdown tests were conducted on both the insulations. Figure 28 shows the procedure used. A total of 30 tests were conducted for each of the selected cables.

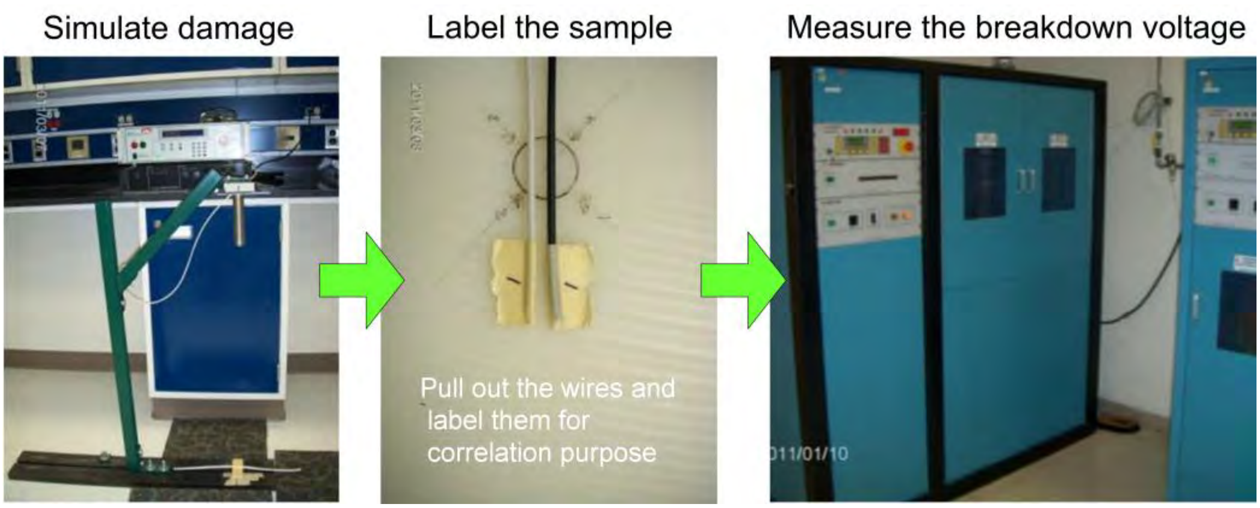


Figure 28 - Step-by-step procedure for damage to NM cable through direct hammer hit

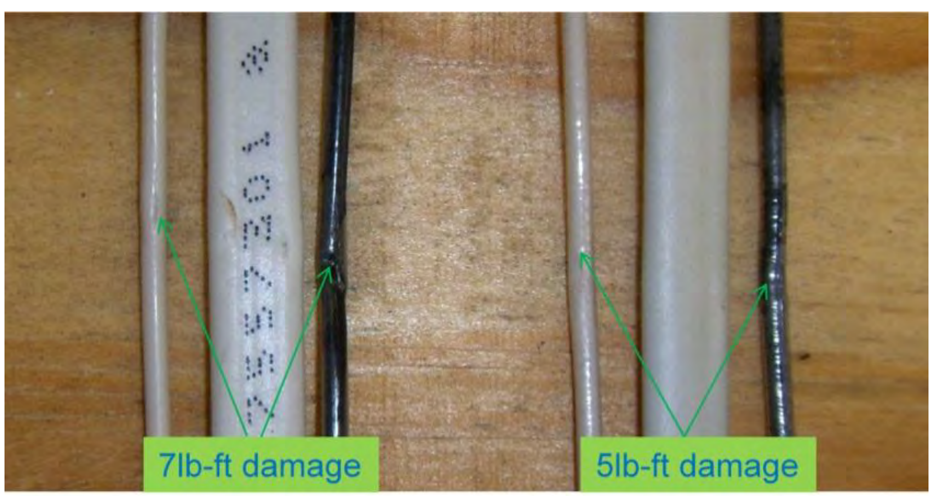


Figure 29 - Comparison of 7ft-lb and 5ft-lb damaged NM cable samples

Figure 29 compares the NM cable samples damaged by 7 ft-lb and 5 ft-lb hammer drops. Figure 29 shows that the 7 ft-lb hammer impact is visible, while the 5 ft-lb hammer impact creates damage that is difficult to detect visually. The hammer impact damage to both the black and the white conductor in the same piece of the NM cable sample was characterized though breakdown voltage tests of both the black and white conductors. The electrical breakdown voltages for Cable E are shown in Figure 30.

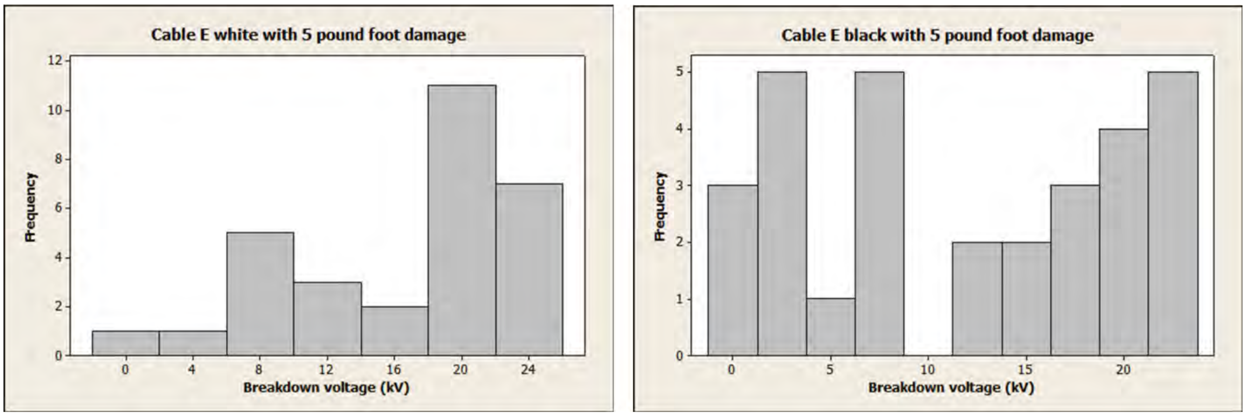


Figure 30 - Breakdown voltage distribution of hammer-damaged NM cable insulation

The breakdown voltages for the white and black insulation were combined to provide an assessment for the whole cable. This is presented, as an example, for Cable E for data with 5 ft-lb hammer drop in Figure 31.

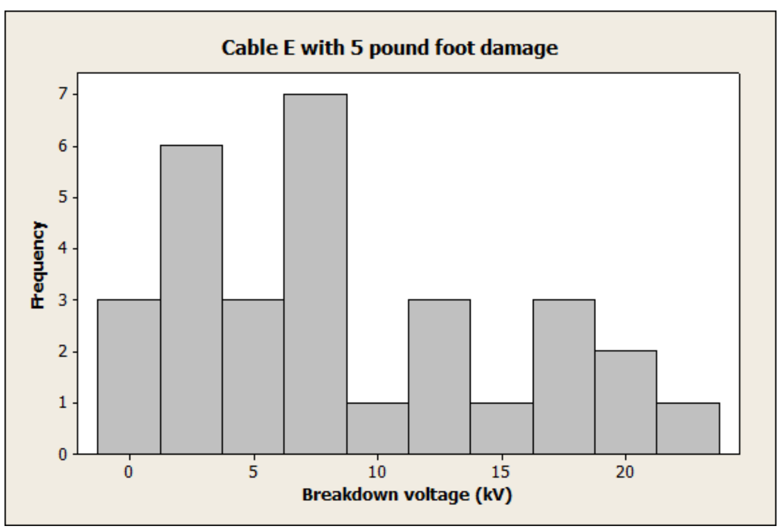


Figure 31 - Breakdown voltage distribution for combined black and white insulation (Example using Cable E data from a 5 ft-lb hammer blow)

The combined (black and white insulation) breakdown insulation data for all 30 replicates of each sample, and for 5 and 7 ft-lb hammer drops are shown in Figure 32 and Figure 33. The data in Table 14 show that a hammer impact can result in the NM cable insulation dielectric strength to fall well below the 6 kV threshold value. In some cases, the 7 ft-lb hammer impact cracked the NM cable insulation, an example of this is shown in figure 34.

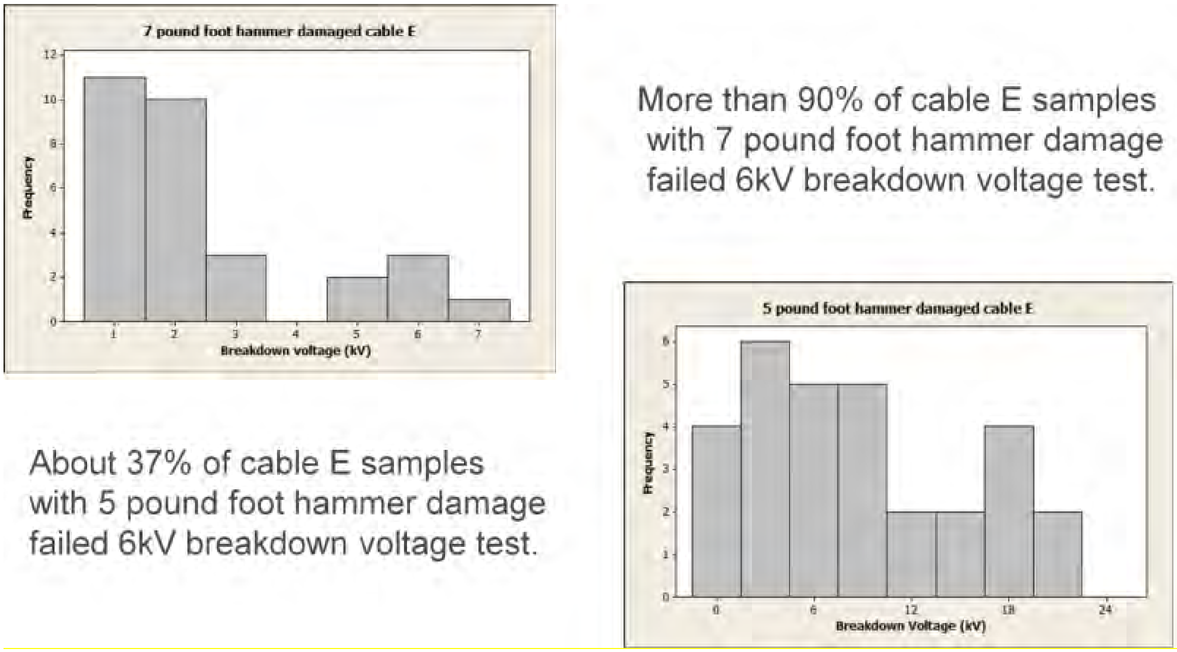


Figure 32 - Breakdown voltage distribution of cable E damaged by hammer impact

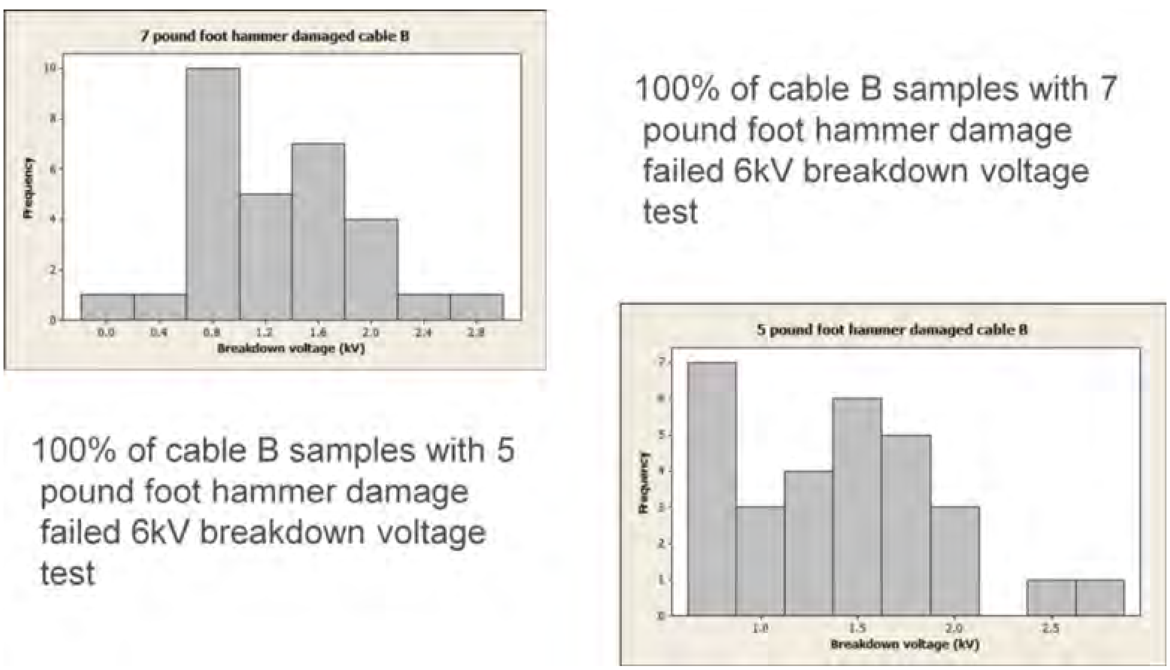


Figure 33 - Breakdown voltage distribution of cable B damaged by hammer impact

Table 14 provides a summary the average breakdown voltages, from 30 replicates for each cable and hammer ft-lb values.

Table 14 - Breakdown voltage of hammer-damaged NM cable (measurement of the damaged portion)

Sample	Minimum breakdown voltage (kV)	Average breakdown voltage (kV)	Maximum breakdown voltage (kV)	% of samples below 6kV
Cable B 5ft-lb	0.71	1.40	2.70	100
Cable B 7ft-lb	0.13	1.25	2.68	100
Cable E 5ft-lb	0.08	8.79	21.38	37
Cable E 7ft-lb	0.64	2.42	6.89	93

Figure 34 - NM Cable insulation cracked by 7ft-lb hammer impact

Summary of Damage to NM Cable from Common Installation Practices

The findings of damage from common installation practices of the NM cable may be summarized as follows:

- Misalignment is an issue when installing NM cable with a stapler. The misaligned staple may puncture the conductor insulation. Once punctured, the insulation breakdown voltage reduces to the level of an air gap comparable with the insulation thickness, which can be much lower than 1 kV (0.3 mm gap with a dielectric strength of air of 3 MV/m, which is approximately 900V).[23,24,37]

- Overdriving a staple reduces the NM cable insulation breakdown voltage, but the dielectric breakdown voltage was still above 6 kV for both types of NM cables under the test.
- Typical hammer impact force during typical installation is estimated to vary from 5 ft-lb to 7 ft-lb.
- Damage from a direct hammer impact to the cable jacket during installation may significantly reduce the breakdown voltage of the insulation materials.

Task 4 — Assessment of NM Cable Degradation

Introduction

Over the service life, the NM cable may be exposed to a range of temperature and humidity conditions, with the insulation materials degrading with time (*i.e*., age). This variation in insulation composition is expected to change the dielectric breakdown voltage of the cable. If the insulation breakdown voltage falls below 6 kV, the increased frequency of voltage surges occurring at these lower magnitudes (see Figure 3) may lead to an accelerated rate of carbonization of the insulation material, and therefore increased potential for ignition from arcing. The insulation aging involves both chemical and physical processes whose rates are correlated to the surrounding temperature. The insulation materials from all the selected NM cables were found to be plasticized PVC-based compounds with a co-extruded nylon protective layer. The PVC-based insulation has several components (*e.g*., plasticizer, thermal stabilizer) to provide the appropriate mechanical and processing properties. The main aging mechanism that may lead to insulation embrittlement and reduction of breakdown voltage is anticipated to be the loss of plasticizer as this is typically present in PVC compounds in the range of 15 to 40%.

To study the effect of aging on materials, it is desirable to accelerate the aging process. A common approach to achieve this is to assume that thermal aging follows Arrhenius type rate processes,[25] where a faster degradation rate may be achieved by increasing the exposure temperature. However, based upon the polymer chemistry there is a practical upper limit of the temperature that may be utilized without altering the degradation mechanism. Literature on compounded PVC degradation[26] suggests that dehydrochlorination may start at temperatures exceeding 150°C, a temperature which is not expected to be reached in real-world applications and therefore would result in aging data that is not representative of natural aging. Thus, to investigate the rate of loss of the plasticizer and the consequent reduction in electrical breakdown voltage, an upper limit of 150°C was selected.

Test Procedures

Controlled Temperature Exposure Tests

The test specimens were prepared for the controlled temperature exposure tests as follows: (i) samples of NM Cables B and E were cut into 18-inch long test specimens and the insulated conductors were separated from the outer cable jacket; (ii) a half-inch of the insulation was removed from each end, thus exposing the copper conductor, and the copper conductor was bent into a hook to facilitate post-exposure breakdown voltage testing. A total of 30 specimens of a particular cable type (either B or E) were loaded into the exposure chamber. Each test specimen was weighed prior to elevated temperature exposure, and the specimens were then looped and hung in a temperature-controlled chamber as shown in Figure 35. To understand the contamination from off-gassing from the insulation, the initial weight loss test had only one black conductor sample and one white conductor sample placed in the temperature controlled chamber at any time. Test specimens were removed at regular intervals, and reweighed to document weight loss with time. The comparison of weight loss data indicates that there is no measurable weight loss difference when aging small number of samples in the chamber and aging large number of samples in the chamber.

Figure 35 - Black and white NM cable conductors in the test chamber for thermal aging

Accelerated Aging Insulation Weight Loss

The results from the accelerated aging and the subsequent breakdown voltage tests for the cable insulation materials are presented herein. Table 15 the weight loss data for Cable B wire insulation. The normalized weight was calculated as the weight ratio of the aged wire insulation to the original wire insulation. The data in the table shows that the normalized weight decreases over the time.

Table 15 – Example of 150 °C weight loss data for Cable B insulation with nylon layer, showing exposure time and the normalized weight for white and black insulation materials.

Time (days)	sample	original insulation (g)		aged insulation (g)		normalized weight	
		white	Black	white	black	white	black
0.02	1	1.787	2.127	1.777	2.110	0.9944	0.9920
	2	1.827	1.963	1.815	1.948	0.9934	0.9924
	3	1.769	2.069	1.76	2.053	0.9949	0.9923
0.04	1	1.869	1.901	1.857	1.885	0.9936	0.9916
	2	1.742	1.926	1.730	1.908	0.9931	0.9907
	3	1.958	1.939	1.946	1.922	0.9939	0.9912
0.29	1	1.702	2.015	1.691	1.998	0.9935	0.9916
	2	2.043	2.136	2.026	2.112	0.9917	0.9888
	3	1.870	1.853	1.852	1.831	0.9904	0.9881
1	1	1.750	1.898	1.726	1.872	0.9863	0.9863
	2	1.934	1.848	1.913	1.822	0.9891	0.9859
	3	1.974	1.92	1.952	1.898	0.9889	0.9885
2	1	1.901	2.12	1.875	2.085	0.9863	0.9835
	2	1.781	1.906	1.756	1.876	0.9859	0.9842
	3	1.749	2.036	1.732	2.002	0.9903	0.9833
3.25	1	1.996	2.085	1.967	2.038	0.9855	0.9775
	2	1.612	1.858	1.588	1.824	0.9851	0.9817
	3	1.710	1.899	1.684	1.863	0.9848	0.9810
5	1	1.836	1.926	1.804	1.883	0.9826	0.9777
	2	1.799	1.938	1.769	1.892	0.9833	0.9763
	3	1.787	2.226	1.754	2.176	0.9815	0.9775
7	1	1.794	2.003	1.755	1.937	0.9783	0.9670
	2	1.826	1.891	1.785	1.831	0.9775	0.9683
	3	1.979	1.997	1.934	1.933	0.9773	0.9679

For the measurement of insulation weight loss with the nylon layer, the sample preparation and measurement procedure are the same as that for the insulation without the nylon, except aging the NM cable insulation samples with the nylon intact. Figure 36 compares the measured weight loss of Cable B insulation with and without the nylon layer. The result shows that the nylon significantly retards weight loss.

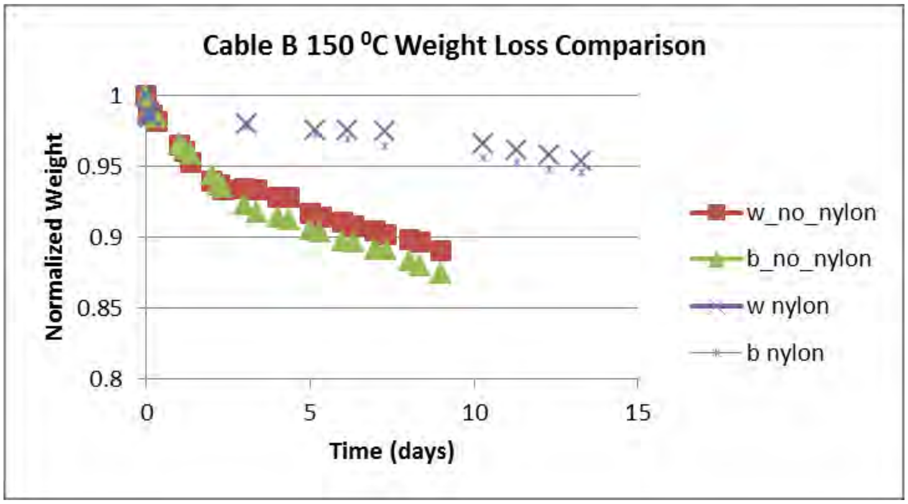


Figure 36 Comparison of Cable B insulation aging with and without nylon layer

Figure 37 shows a similar result for Cable E. The data indicate that the insulation weight loss occurs approximately twice as fast when the nylon coat is removed compared to when it is present.

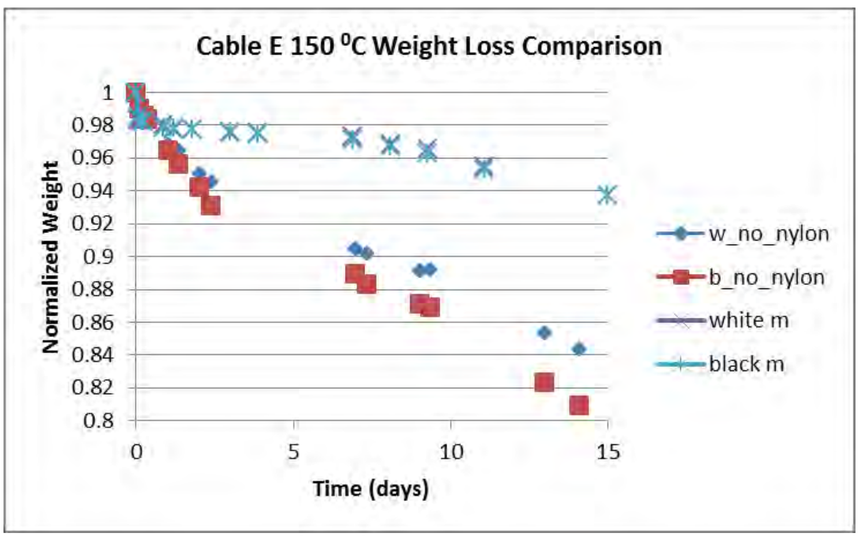


Figure 37– Comparison of Cable E insulation aging with and without nylon layer

Insulation Weight Loss under Different Temperatures

Because the insulation weight loss rates are different at different temperatures, weight loss data were obtained at different temperatures. Figure 38 shows the Cable B normalized weight loss at 120°C, 135°C and 150°C. Figure 39 shows the Cable E normalized weight loss at 120°C, 135°C and 150°C. The data indicate that the Cable B weight loss rates at 150°C starts accelerating after about three days of aging, while Cable E weight loss at 150°C starts accelerating after about seven days of aging. Cable B also has higher weight loss rate than Cable E at 120°C and 135°C.

Based on the NM cable insulation chemical composition analysis in Section 4, the lower weight loss rate of Cable E may correlate to the trimellitate plasticizer, while the higher weight loss rate of Cable B may correlate to the phthalate plasticizer.

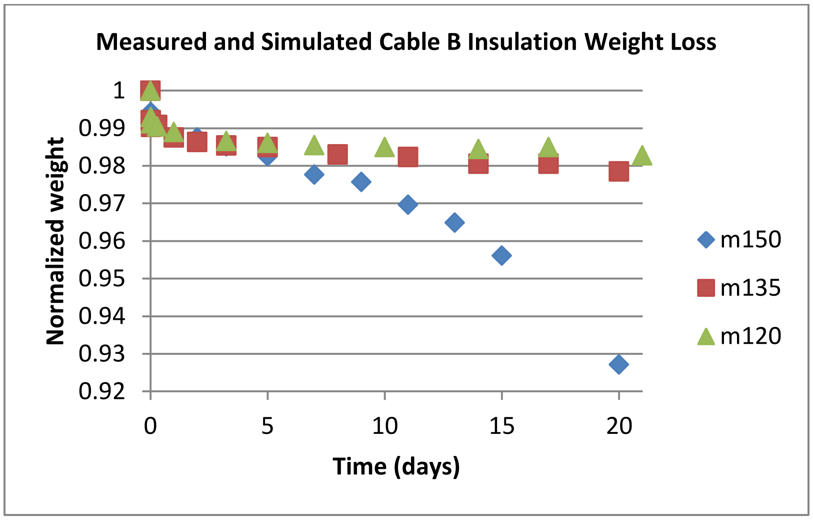


Figure 38 – Cable B insulation weight loss under different temperatures. m150 is the data at 150°C, m135 is the data at 135°C, and m120 is the data at 120°C.

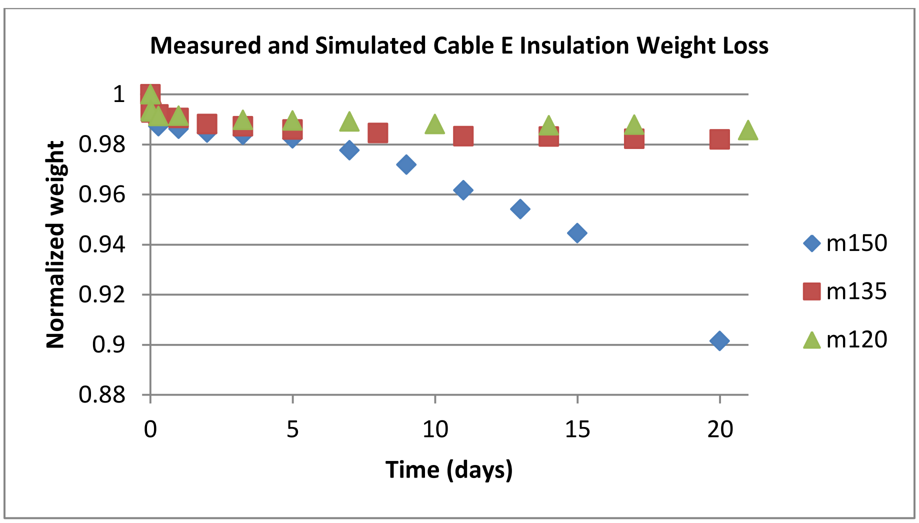


Figure 39 – Cable E insulation weight loss under different temperatures. m150 is the data at 150°C, m135 is the data at 135°C, and m120 is the data at 120°C.

Insulation Weight Loss and the Breakdown Voltage

The aged cable samples were tested for dielectric breakdown voltage to establish a correlation of dielectric breakdown and insulation weight loss. Table 17 and Table 16 show the weight loss data for Cable B and Cable E (with nylon layer), respectively.

Table 17 – Weight loss data for Cable B insulation with nylon layer, showing exposure time, the normalized weight and the corresponding breakdown voltage.

Cable B 150 ^{0}C	Breakdown Voltage (kV)		Normalized Weight		Average Normalized Weight		Average Breakdown Voltage (kV)	
time	white	black	white	black	white	black	white	black
0					1	1	18.6	19.4
0.02 days	23.34	23.52	0.9944	0.9920	0.9942	0.9922	24.3	24.4
	25.08	24.65	0.9934	0.9924				
	24.61	24.93	0.9949	0.9923				
0.04 days	23.18	24.21	0.9936	0.9916	0.9935	0.9912	24.0	25.5
	23.84	25.06	0.9931	0.9907				
	25.06	27.1	0.9939	0.9912				
0.29 days	24.55	26.51	0.9935	0.9916	0.9919	0.9895	25.6	23.5
	26.14	22.81	0.9917	0.9888				
	26.2	21.08	0.9904	0.9881				
1.00 days	21.48	25.85	0.9863	0.9863	0.9881	0.9869	22.7	24.1
	23.55	23.31	0.9891	0.9859				
	23.04	23.07	0.9889	0.9885				
2.00 days	24.61	20.5	0.9863	0.9835	0.9875	0.9837	22.4	19.9
	20.48	19.34	0.9860	0.9843				
	22.04	19.81	0.9903	0.9833				
3.25 days	24.34	23.04	0.9855	0.9775	0.9851	0.9801	23.1	21.3
	22.25	19.89	0.9851	0.9817				
	22.78	21.06	0.9848	0.9810				
5.00 days	21.91	22.14	0.9826	0.9777	0.9825	0.9772	22.1	21.4
	21.56	19.97	0.9833	0.9763				
	22.73	22.14	0.9815	0.9775				
7.00 days	23.76	22.54	0.9783	0.9670	0.9777	0.9678	21.9	17.2
	21.96	17.72	0.9775	0.9683				
	20.1	11.42	0.9773	0.9680				
9.00 days	22.04	18.67	0.9738	0.9601	0.9757	0.9615	22.5	19.3
	22.28	18.14	0.9745	0.9622				
	23.1	21.01	0.9789	0.9621				
11.00 days	21.46	17.93	0.9706	0.9528	0.9697	0.9533	20.6	18.6
	18.91	19.02	0.9688	0.9524				
	21.51	18.99	0.9696	0.9547				
13.00 days	18.52	19.68	0.9644	0.9511	0.9649	0.9491	18.9	18.7
	17.96	18.22	0.9652	0.9478				
	20.1	18.25	0.9650	0.9483				
15.00 days	19.89	16.58	0.9564	0.9439	0.9561	0.9439	18.1	17.0

Table 18 – Weight loss data for Cable E insulation with nylon layer, showing exposure time, the normalized weight and the corresponding breakdown voltage.

Cable E 150 ^{0}C	Breakdown Voltage (kV)		Normalized Weight		Average Normalized Weight		Average Breakdown Voltage (kV)	
time	white	black	white	black	white	black	white	black
0					1	1	23.3	22.5
0.02 days	28.82	26.06	0.9934	0.9938	0.9935	0.9935	25.5	26.7
	19.73	25.27	0.9943	0.9931				
	27.97	28.69	0.9927	0.9935				
0.04 days	26.38	24.48	0.9924	0.9920	0.9923	0.9923	26.4	26.3
	26.38	28.77	0.9917	0.9927				
	26.46	25.64	0.9927	0.9923				
0.21 days	27.2	27.2	0.9869	0.9904	0.9872	0.9872	26.9	26.4
	27.36	27.92	0.9870	0.9877				
	26.22	23.97	0.9878	0.9833				
1.00 days	25.98	27.81	0.9884	0.9852	0.9862	0.9870	26.5	26.4
	26.28	27.52	0.9864	0.9890				
	27.31	23.95	0.9837	0.9870				
2.00 days	21.14	24.66	0.9846	0.9834	0.9847	0.9843	23.7	24.3
	23.71	24.45	0.9848	0.9839				
	26.20	23.92	0.9846	0.9858				
3.25 days	24.29	23.89	0.9825	0.9820	0.9837	0.9828	23.8	23.8
	21.40	21.75	0.9855	0.9827				
	25.59	25.69	0.9831	0.9837				
5.00 days	23.65	23.97	0.9823	0.9821	0.9823	0.9819	22.6	21.8
	23.71	22.57	0.9818	0.9822				
	20.45	18.89	0.9828	0.9814				
7.00 days	22.94	21.88	0.9775	0.9762	0.9777	0.9767	22.8	21.1
	21.53	20.13	0.9774	0.9776				
	23.95	21.30	0.9782	0.9762				
9.00 days	22.28	23.07	0.9725	0.9705	0.9718	0.9703	21.9	22.2
	21.61	23.20	0.9724	0.9704				
	21.91	20.29	0.9706	0.9700				
11.00 days	21.01	21.40	0.9625	0.9597	0.9616	0.9603	20.5	21.8
	18.70	22.12	0.9615	0.9603				
	21.67	21.77	0.9609	0.9609				
13.00 days	23.20	21.06	0.9542	0.9610	0.9540	0.9514	21.1	20.9
	19.92	21.75	0.9537	0.9524				
	20.24	19.97	0.9542	0.9407				
15.00 days	20.34	20.42	0.9442	0.9469	0.9445	0.9460	20.9	20.0
	21.91	19.5	0.9453	0.9453				
	20.53	20	0.9441	0.9460				

The influence of weight loss for NM cable B insulation from thermal aging on breakdown voltage is presented in Figure 40. The degradation data for cable E is under development and will be added to the final report shortly.

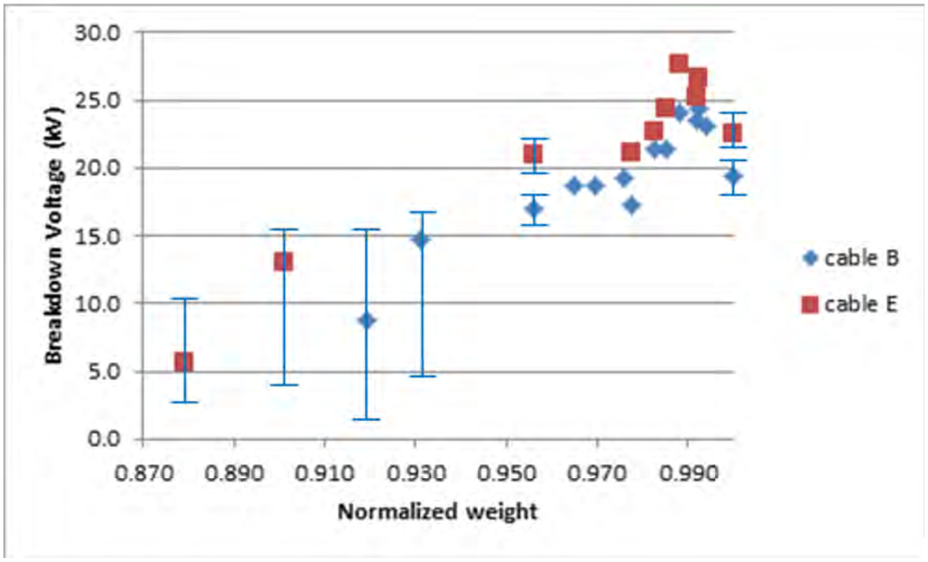


Figure 40 - Breakdown voltage and normalized insulation weight from samples aged at 120 °C, 135°C and 150°C. The error bars indicate the range of the test data.

The aged insulation breakdown voltage was initially seen to increase when the weight loss was less than 2%. But when the weight loss exceeded 4%, the aged insulation breakdown voltage trended lower. When the weight loss exceeds 8%, the aged insulation average breakdown voltage was less than 10kV. A breakdown voltage distribution for Cable B is depicted in Figure 41; and shows that 30% of the samples aged at 150 °C for 29 days have breakdown voltage less than 6kV.

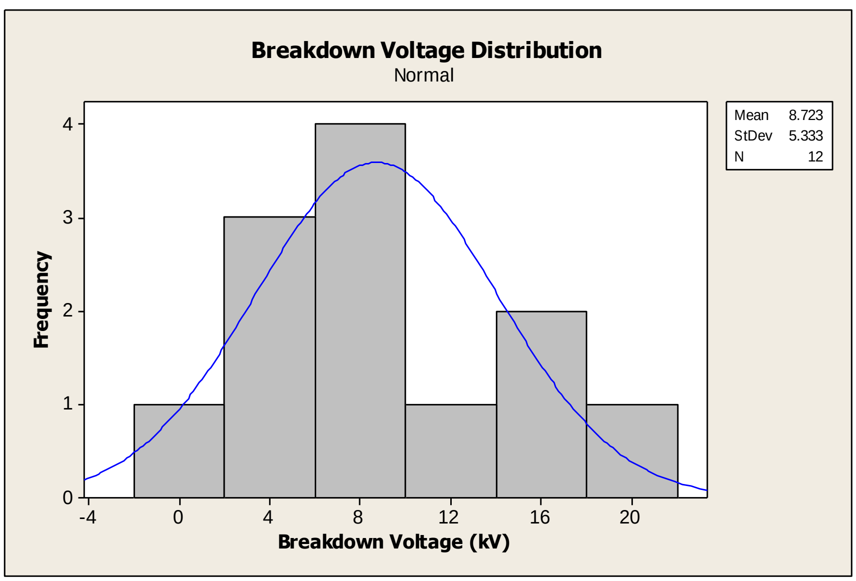


Figure 41 – Cable B insulation breakdown voltage distribution after aged at 150 °C for 29 days

Summary of Thermal Degradation of NM Cables

- Weight loss is found to be a good aging indicator, since weight loss occurs due to loss of PVC plasticizer.
- Weight loss rate increases with the temperature.
- Breakdown voltage of the NM cable conductor insulation initially increases with the loss of weight but then trends lower. The reason for this behavior is under the investigation for the final report.
- The nylon layer was found to retard the rate of weight loss for both cable B and cable E.

Task 5 — Assessment of Combined NM Cable Installation Damage and Aging Degradation

Task 3 discussed potential causes and consequences of NM cable damage during installation. The test results showed that hammer impact can result in immediate NM cable breakdown voltage failure, while over-compression may only reduce the NM cable breakdown voltage, instead of causing immediate failure of the NM cable. Because hammer impact results in NM cable failure without the need for an aging effect, this section focuses only on the thermal aging impact to the over-compressed NM cable.

Breakdown Voltage Measurement of the NM Cable with Jacket

Measuring the thermal aging impact to NM cable damaged through over-compression required the measurement of the breakdown voltage of the NM cable with its jacket intact. The challenge of testing the complete NM cable is that the corona formed at the test voltages above 3 kV may short the electrodes before insulation breakdown is achieved. To reduce the impact of the corona, a longer NM cable sample was used and the cable jacket opening was sealed with silicone based sealant. Figure 42 shows the prepared sample inside the chamber of the high-voltage tester.

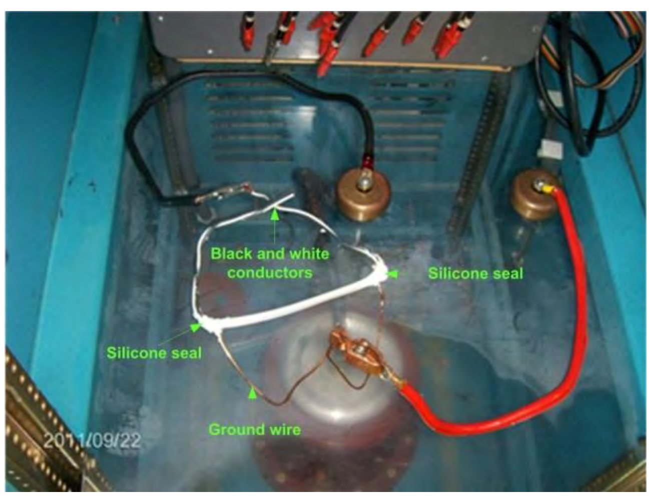


Figure 42 – Setup for the breakdown voltage test for intact NM Cable

Since most of the experiments conducted in this work use short segments of NM cable as test samples, and samples with relatively high breakdown voltage (*e.g.*, in excess of 15 kV), the effect of corona discharge required that breakdown voltage testing be conducted by testing the black and white conductors separately. As it was necessary to use intact cable to evaluate the effect of over-compression on breakdown voltage, and since corona discharge was found to still be an issue over 20 kV with the intact NM cable even after test modifications were made, it was possible to use only samples from Cable B for the test. This was because Cable B exhibited breakdown voltage values for undamaged, intact cable less than 20 kV. Samples from Cable E therefore were not evaluated for the influence of combined damage and degradation on dielectric breakdown voltage.

To check if the two different breakdown voltage test methods are consistent, or at least correlate, with one another, the breakdown voltage of 30 undamaged, intact NM Cable B samples were characterized and the results were compared with those from the breakdown voltage of the separated NM Cable B conductors. Table 19 is a comparison of Cable B breakdown voltages from the two different test methods. The result shows that the intact NM cable breakdown voltage is statistically identical to the single conductor.

Table 19 - Breakdown voltage comparison

Cable B with jacket	White conductor	Black conductor
19.1 ± 0.9kV	18.6 ± 1kV	19.4 ± 0.8kV

Test Sample Preparation and Test Results

Two sets of test specimens were prepared for this study. One set of samples were damaged through over-compression, the other set were subjected to both over-compression damage and subsequent thermal degradation.

The preparation of the over-compressed samples is as follows:

1. Cut the NM cable into two-foot long samples
2. Remove three quarters of the NM cable jacket from the sample
3. Tie the two ends of the ground wire together
4. Remove about one half-inch of insulation from the end of the black and the white conductors
5. Twist the black and white conductors together
6. Use the hammer simulator to staple the sample onto the wood stud
7. Measure the distance from the top of the staple to the top surface of the wood stud
8. Label the sample and record the measured distance between the top of the staple to the top surface of the stud
9. Seal the cable jacket openings with silicone

The procedure to prepare the over-compressed and thermally aged sample is the same as above, but the samples were then aged in the thermal chamber at a constant temperature using the same method as described in Task 4. Figure 43 shows a prepared over-compressed sample. Figure 44 shows a prepared over-compressed sample that was subsequently aged at 150°C for three days.

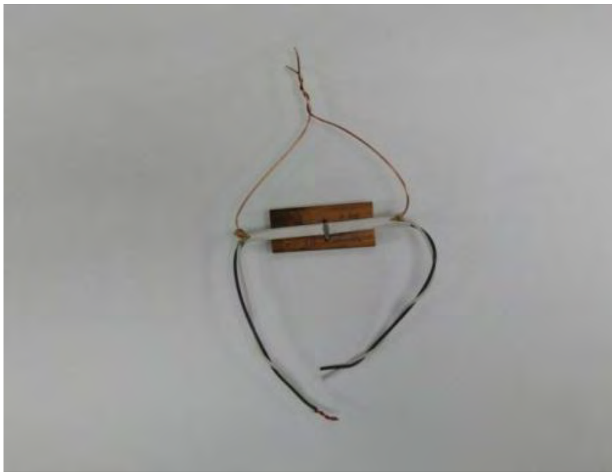


Figure 43 - Over-compressed NM cable B sample for breakdown test

Figure 44 - Over-compressed and thermally aged NM cable B sample for breakdown test

Table 20 - Comparison of new, aged, and over-compressed Cable B samples

	Cable with jacket	Over-compressed cable with jacket	Over-compressed and aged at 150°C for 3 days	Un-compressed and aged at 150°C for 3 days
Average breakdown voltage	19.1±0.9kV	18.6±0.5kV	12.7±7kV	20.7±1.2kV
Distance from the stud to the staple top	> 5.4 mm	4.44±0.44mm	4.80±0.27mm	N/A

To obtain statistically significant data, 30 samples were prepared for each of the four different sample conditions. Table 20 is a comparison of the measured results. The first row in Table 20 shows the breakdown voltages of different samples. The second row of Table 20 shows the distance from the top the staple to the top surface of the wood stud, which indicates how hard the NM cable is compressed. The staple distance measurements show that the over-compressed and aged cable samples were compressed by 0.6 mm, comparable with the intact cable samples, but not as severe as the over-compressed cable samples.

The data in Table 20 also show that the over-compressed and aged NM cable samples have significantly lower breakdown voltage compared with other samples, which indicates that the service life of the over-compressed NM cable can potentially be much shorter than the intact NM cable in a hot environment.

NM Cable Voltage Surge Test

The damage and degradation work conducted in this report demonstrates that the insulation breakdown voltage of NM cable can be significantly reduced, which increases the potential of formation of a carbonized path and arcing. However, this does not yet show the propensity of insulation breakdown to cause sufficient arcing to ignite the cable insulation. Therefore, to understand whether reduced breakdown voltages may lead to ignition of the damaged and aged NM cables, 100 hammer-damaged NM cable samples and 100 aged NM cable samples were tested per the UL1449 voltage surge standard. Figure 45 shows the samples prepared for voltage surge test. The hammer-damaged samples were prepared as follows:

- Samples were cut to a length of about 18 inches.
- The sample is secured to a piece of pinewood with two metal staples.
- A test fixture is used to damage the NM cable by dropping a two-pound steel hammer head on the test sample from a height of 3.5 ft. This is the same method described in the prior hammer impact studies.

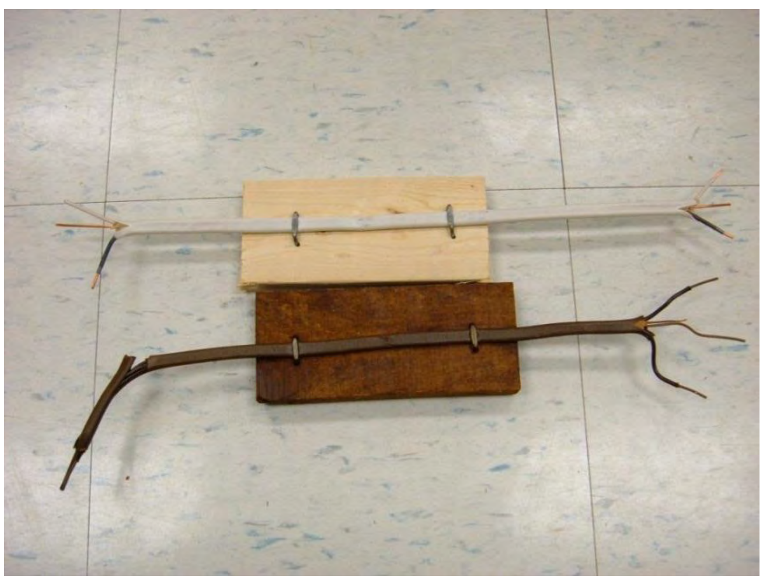


Figure 45 – Hammer-damaged and aged NM cable samples for the UL1449 test.

The test setup was as follows:

- Line and neutral of the tested samples were energized with 120VAC during the voltage surge.

- 6kV positive surge was applied from both line and neutral to ground, 1.2μs rise time, 50μs fall time, 500A, triggered at 120VAC phase angle of 90° (wave form in Figure 46).
- 6kV negative surge was applied from both line and neutral to ground, 1.2μs rise time, 50μs fall time, 500A, triggered at 120VAC phase angle of 270°.
- Each sample was tested with one positive 6kV surge and one negative 6kV surge.

The hammer-damaged NM cable samples exhibited arcing for nine of the 100 damaged samples during the tests. Because the electrical arcing was of a very short duration and generated little damage to the samples, the same 100 hammer damaged samples were placed into a temperature chamber and aged at 145°C (145 °C was used for the purpose to collect thermal aging data at an additional temperature point, in addition to the purpose of aging for the surge testing) for eight days. Figure 46 shows the schematic for the test and Table 21 summarizes the test results.

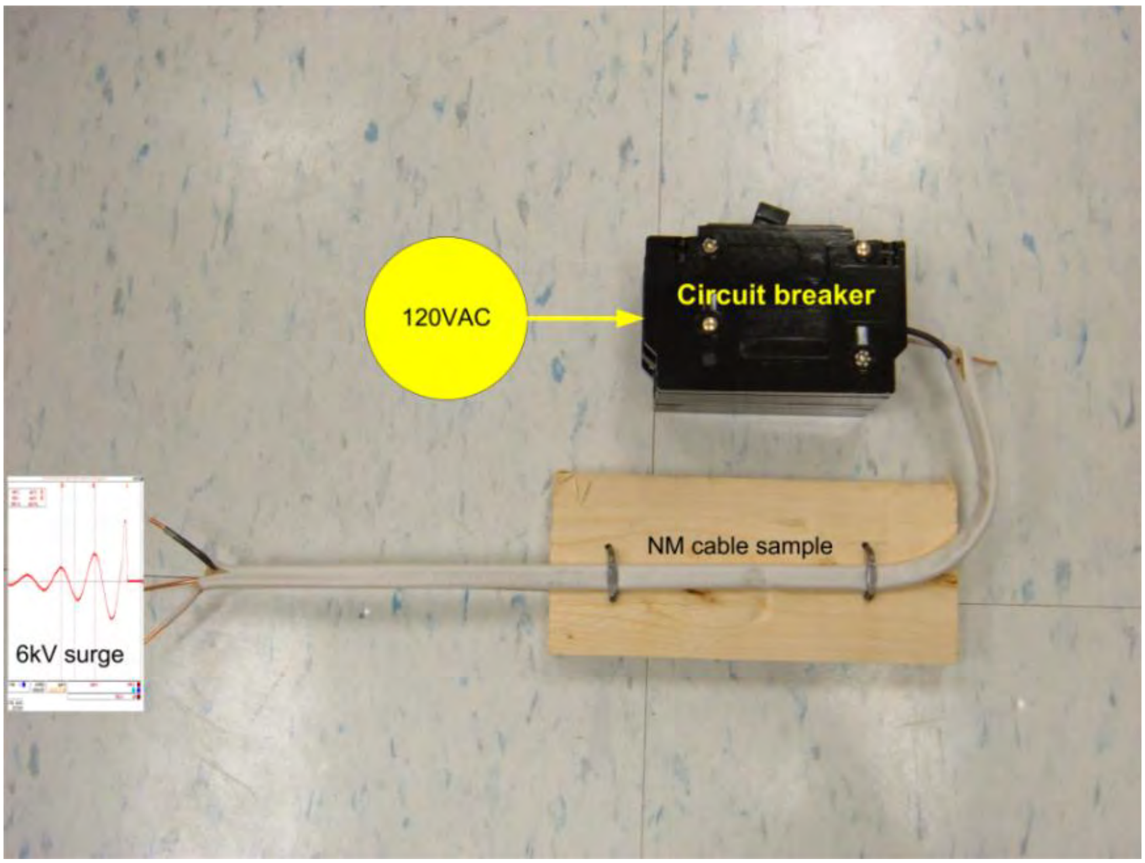


Figure 46 – NM cable voltage surge test schematic.

Table 21 – Summary of the UL1449 test results.

	Hammer damaged	Hammer damaged and aged
Total number of samples	100	100
Number of samples arced due to hammer damage	9	2
Number of samples arced due to over compression	0	0
Number of samples triggered 120VAC breaker	0	0
Number of samples with smoke and fire	0	0

During the voltage surge test, a high-speed camcorder was used to record the arcing events. Since the frame rate was 600 fps and only two frames captured arcing in an arcing event, the duration of the arc was estimated to be approximately 1.7ms, or one-tenth of the 60Hz 120VAC voltage cycle. Figure 47 shows the two frames arc captured in an arc event.

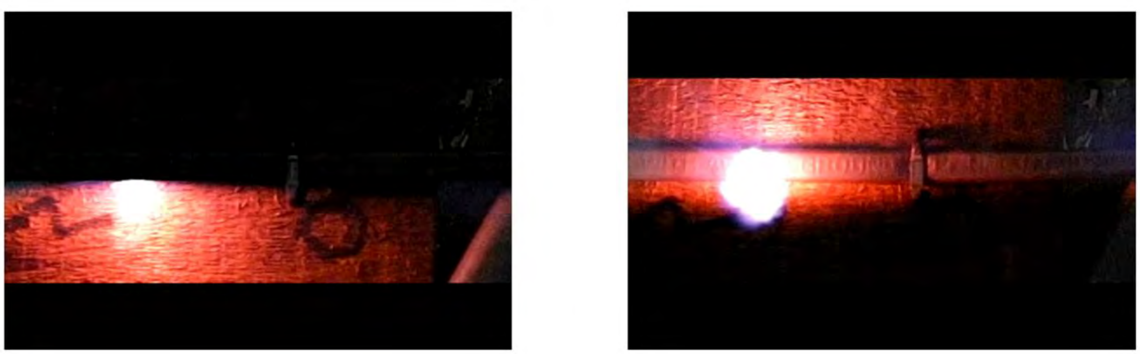


Figure 47 – Voltage surge generated electrical arc. On the left is the 1st image with arc, on the right is the 2nd image with arc.

In the tests, the maximum voltage and current applied to the NM cable sample through the circuit breaker are 120VAC and 100A to provide a maximum arcing power of 12kW. With an arc duration of 1.7ms, the maximum energy released in this arcing event was less than 200 Joules. Previous research has estimated that the minimum energy to ignite the NM cable insulation is 2000 Joules[27]. Since a single arcing event is unlikely to ignite the NM cable, data were developed on arcing and subsequent ignition of the NM cable insulation from one hundred 6kV surges using the UL 1499 transient waveform.

For these tests, the NM cable was damaged with five hammer blows using the hammer impact simulator, using a 7ft-lb force. Table 22 shows the test results.

Table 22 Repeated Voltage Surge Test

Sample	Peak breakdown voltage			Arcing	Ignition
	Before surge test	After 100 surges	After 300 surges		
1	4.2kV	3.6kV	1.6kV	Yes	No
2	1.6kV	3.8kV	0.9kV	Yes	No
3	4.8kV	1.8kV	shorted after 208 surges	Yes	No
4	3.3kV	1.8kV	0.7kV	Yes	No
5	5.6kV	4.5kV	1.7kV	Yes	No

The test results in Table 22 indicate that one hundred 6kV voltage surges to the same damaged area may not be able to ignite the NM cable.

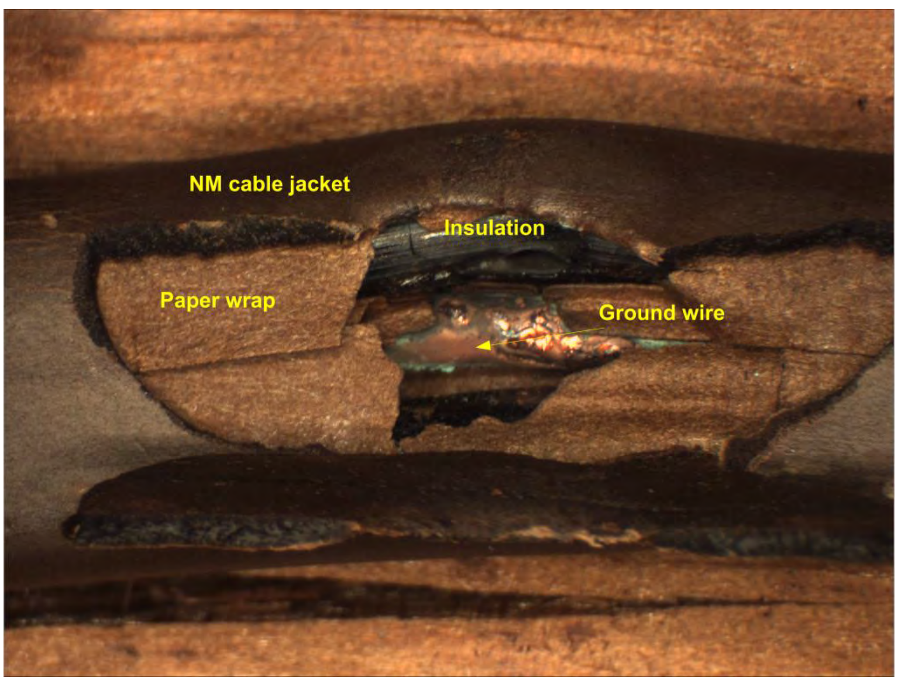


Figure 48 - Arcing area of damaged NM cable

Figure 48 is an image of arcing area of a damaged, then aged NM cable sample, simulating the effects of cable aging after it was damaged during installation. The image shows that there is an area of electric arc erosion on the ground wire and there is a crack on the conductor insulation. However, ignition was not observed for these tests.

Summary of Combination Effect of Damage and Thermal Degradation

- Over-driven staples may not initially reduce the conductor insulation breakdown voltage significantly, but the test result in Table 20 indicates that it leads to faster aging degradation for Cable B.
- No electrical arcing was observed from the over-compressed areas on the NM cable samples during the voltage surge testing.
- Electrical arcing was observed on 9 out of100 hammer-damaged NM cable samples.
- Electrical arcing was observed on 2 out of100 hammer-damaged and thermally aged NM cable samples.
- The test data indicate that the duration of the electrical arcing in the hammer-damaged area was about 1.7ms and the single electric arc event observed did not ignite the NM cable insulation materials.
- No sustained arcing and insulation ignition were observed during the repeated voltage surge test of 300 6kV voltage surges in parallel with 120VAC applied to the NM cable sample under the test.
- The test data indicate that the arcing event may further reduce the breakdown voltage (Table 22). One of the five samples in the test was shorted after 208 arcing events induced by the voltage surges. This short circuit blew a 20A fuse in the 120VAC test system, but it did not trigger the 20A circuit breaker in the system.

Summary of Key Findings

1. Commercially available NM cables in the USA have plasticized PVC-based cable insulation materials and may differ in the type of plasticizer used. The dielectric breakdown of new NM cables sampled had electrical breakdown voltage in excess of 15kV.
2. Common NM cable installation tools such as hammers or staple drivers can result in damage to the cable insulation.
    a. A misaligned staple may puncture the conductor insulation. Once punctured, the insulation breakdown voltage is down to the level of an air gap comparable with the insulation thickness, which is around 1.5kV.
    b. Overdriving a staple does not significantly reduce the NM cable breakdown voltage initially.
    c. A hammer blow of 7 ft-lb is 90% to 100% likely to reduce the insulation breakdown voltage below 6 kV, depending on the type of the cable. A hammer blow of 5 ft-lb is 37% to 100% likely to reduce the insulation breakdown voltage below 6 kV, depending on the type of the cable.
3. It was found that NM cables may age during their service life resulting in reduced electrical breakdown voltage due to the loss of plasticizer. This aging process was accelerated using elevated temperatures and a relationship was found between breakdown voltage and weight loss (primarily from loss of plasticizer). The results showed that thermal aging of an over-compressed NM cable from installation can lead to faster reduction of the electric breakdown voltage. However, these results were only based on Cable B data.
4. Electrical arcing was observed in the hammer-damaged area of NM cable samples under the voltage surge test (UL1449). The duration of these electrical arcs were about 1.7ms, and test result showed that the single arc event did not ignite the NM cable insulation materials. The number of arcing events compared to surge events was small (9 out of 100 for hammer-damaged cables).
5. Since the energy associated with the 1.7ms arc in the voltage surge test is only about 200 Joules, a single voltage surge event is unlikely to ignite the NM cable insulation material at room temperature. However, this damage will remain and therefore could increase the likeliness of forming a new and stronger carbonized path according to the test results shown in Table 22 (*i.e.*, more conducive to sustain arcing).
6. The repeated voltage surge tests however showed that a hammer-damaged NM cable could not be ignited with three hundred 6kV voltage surges using UL1499.

Discussion and Conclusions

This work shows that NM cable damage and/or aging can reduce the breakdown voltage of the cable insulation. Of the damage mechanisms tested, it is observed that hammer impact can inflict the most significant immediate damage to NM cable insulation. The thermal aging data indicate that as cable is aged its breakdown voltage will tend to fall, eventually falling below 6 kV. The concern is that lowered breakdown voltages increase the probability of formation of carbonized paths and arcing, since lower-voltage surges occur more frequently. This suggests that a combination of impact damage to NM cable during installation, followed by aging of the cable, may lead to a fire hazard over long periods of time. However, the results from this investigation did not demonstrate the formation of sustained electrical arcing.

In addition of a need to break down the cable insulation and formation of a carbonized path to initiate arcing, ignition of the cable insulation and/or surrounding material typically requires sustained arcing with sufficient energy release. To understand whether voltage surges can induce sustained electrical arcing, 100 damaged and aged NM cable samples were tested per the UL1449 (Standard for Surge Protective Devices). The test result showed that despite breakdown of the dielectric, there was no sustained arcing or ignition of the insulation. This is because the voltage surge is of a very short duration (50 μs) followed by 120VAC arcing that stopped before the zero crossing (1.7 ms). The zero crossing in an AC supply tends to extinguish the arcing event, with a re-strike requiring the continued presence of a well-defined carbonized path. The short arcing events found in the UL1449 tests show that the carbonized paths formed tend to be small and are destroyed during the arcing event (since no re-strike of the arc was observed).

In order to evaluate whether subsequent voltage breakdown occurrences further lower dielectric performance, 300 voltage surges (in parallel with 120VAC supply. Figure 46) were applied to each of five selected hammer-damaged NM cable samples and the breakdown voltages were measured before and after the voltage surges. The test result shows that the hammer-damaged NM cable samples did not ignite after 300 arcing events.

Since the plasticized PVC compounds exhibit time-dependent, viscoelastic behavior, the response of the NM cable structure (external jacket and insulation) to external damage may not manifest itself for months or years after the time of initial damage. This effect was reflected in the aging experiments with NM cables secured with over-driven staples, where the breakdown voltages continued to degrade with time. Though characterized through these aging studies, the time-dependent effects of plasticized PVC compounds could be evaluated by Dynamic Mechanical Analysis (DMA) under various conditions of temperature and frequency (isochron or Master Curve analysis). The effects of different plasticizer loadings, type and even filler level may affect the relaxation process and ultimately breakdown behavior. This would add a more fundamental understanding to the physical mechanisms involved when NM cable is subjected to sustained compressive stresses, such as through stapling or being compressed within a wall.

The data included in this work demonstrates a relationship between breakdown voltage and insulation weight loss. Leveraging these data from the accelerated aging tests, may allow for the development of a mathematical model that characterizes insulation aging with electrical performance in the field. This model would support an ability to predict aged cable performance under a variety of conditions, including damaged cable and undamaged cable in elevated-temperature environments.

In summary, the work described here shows that damage and degradation of a residential NM cable can lead to an arcing event, through voltage surges that break down the cable insulation and ignite arcing.

However, the test results also indicate that the breakdown event is unlikely to initiate arcing that is sustained long enough to ignite the cable insulation or surrounding materials. In this study, arcing for hammer-damaged cable exhibited arcing during less than 10% of the surge events, and exhibited arcing that lasted over a single half-cycle. The arcing observed in this study is much shorter than what is required for an AFCI to react to the event (eight arcing half-cycles within 0.5 seconds, per UL1699); however, the energy released in that short event is not expected to ignite the cable insulation.

References

[1] "Home Electrical Fires". National Fire Protection Association, May 2010.

[2] Evaluation of Run Length and Available Current on Breaker Ability to Mitigate Parallel Arcing Faults,
[2] Evaluation of Run Length and Available Current on Breaker Ability to Mitigate Parallel Arcing Faults, Part I: Effect of Panelboard Current for 50 Foot Run Lengths," P. Brazis and D. Dini, UL Research Report, July 2012.

[3] "Evaluation of Run Length and Available Current on Breaker Ability to Mitigate Parallel Arcing Faults, Part II: Effect of Run Length with 500A Available at the Panelboard," P. Brazis, D. Dini, and F. He, UL Research Report, October 2012.

[4] "Residential Building Electrical Fires". US fire administration. March, 2008.

[5] "Aged Electrical Systems Research Application Symposium Keynote Address". John Wafer. October, 2006.

[6] "Aging Residential Wiring Issues: Concerns for Fatalities, Personal Injuries, and Loss of Property". Joyce Rasdall. Annual Household Equipment Technical Conference. October, 2005.

[7] "Identifying Causes for Certain Types of Electrically Initiated Fires in Residential Circuits". John Shea. Fire and Materials, 2010.

[8] "Wire and Cable Insulation and Jacketing: Life Cycle Assessments for Selected Applications". Office of Pollution Prevention and Toxics, US EPA. June, 2008.

[9] "Some History of Residential Wiring in the US". David Dini, Underwriters Laboratories Inc. 2006.

[10] "Wire Company Wages Long War to Win Approval for Romex". Daily Sentinel, Rome, N.Y. Wednesday Evening, March 24, 1928.

[11] "Installation of Wiring Methods in Modular Homes". Richard M. Flynn, et al. State of New Hampshire Department of Safety. September, 2006.

[12] "Application and Installation Guidelines for Nonmetallic-Sheathed Cable and Underground Feeder and Branch Circuit Cable". NEMA RV2, 2008.

[13] NEC 2011. ISBN: 978-087765914-3.

[14] "Transient Over voltages in Secondary Systems". Francois Martzloff. GE technical report 81CRD121

[15] "Aging of NMD-7 Wire Insulation." D. J. Stonkus. Ontario Hydro Report. December, 1989.

[16] “Prediction of Insulation Degradation of Distribution Power Cables Based on Chemical Analysis and Electrical Measurements”. Doctoral Dissertation, Petri Hyvonen. Helsinki University of Technology. Espoo, Finland. 2008.

[17] “Pyrolysis GC/MS spectra from NIST 08 Mass Spectral Library”. IR spectra are in-house spectra developed by Thermo Scientific Company; the source of DTDP and TOTM were provided by VELSICOL Chemical and EASTMAN companies, respectively.

[18] “Plastics Additives Handbok”. R. Gachter and H. Muller. Hanser Publishers, 1983.

[19] ASTM D149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies.

[20] “Introduction to Mathematical Statistics”. R. Hogg et al. Prentice Hall, 2005.

[21] “Oregon Electrical and Elevator Board License Enhancement Report”. March, 2007.

[22] “Violations of Stapling NM-B on Edge Persist”. NEMA document. 2005.

[23] Tipler, Paul A., *College Physics*. Worth, 1987: 467.

[24] Rigden, John S., *Macmillan Encyclopedia of Physics*. Simon & Schuster, 1996: 353.

[25] “Electrical Aging of Extruded Dielectric Cables”. C. Dang, et al. IEEE Transaction on Dielectrics and Electrical Insulation. April, 1996.

[26] “Mechanisms and modes for ignition of low-voltage, PVC-insulated electrical products”. Vytenis Babrauskas. Fire and Materials 30, 2006.

[27] “Effectiveness of Circuit Breakers in Mitigating Parallel Arcing Faults in the Home Run, 2nd Edition”. Paul Brazis and Fan He. UL Research Report, January 2012.

Public Input No. 4189-NFPA 70-2017 [Section No. 210.12(A)]

(A) Dwelling Units.

All 120-volt, single-phase, 15- and 20-ampere branch circuits supplying outlets or devices installed in dwelling ~~unit kitchens, family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, laundry areas, or similar rooms or areas~~ units shall be protected by any of the means described in 210.12(A)(1) through (6):

(1) A listed combination-type arc-fault circuit interrupter, installed to provide protection of the entire branch circuit

(2) A listed branch/feeder-type AFCI installed at the origin of the branch-circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit. The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(3) A listed supplemental arc protection circuit breaker installed at the origin of the branch circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit where all of the following conditions are met:

   (4) The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.

   (5) The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.

   (6) The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(7) A listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet on the branch circuit in combination with a listed branch-circuit overcurrent protective device where all of the following conditions are met:

   (8) The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.

   (9) The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.

   (10) The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

   (11) The combination of the branch-circuit overcurrent device and outlet branch-circuit AFCI shall be identified as meeting the requirements for a system combination–type AFCI and shall be listed as such.

(12) If RMC, IMC, EMT, Type MC, or steel-armored Type AC cables meeting the requirements of 250.118, metal wireways, metal auxiliary gutters, and metal outlet and junction boxes are installed for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

(13) Where a listed metal or nonmetallic conduit or tubing or Type MC cable is encased in not less than 50 mm (2 in.) of concrete for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

Exception: Where an individual branch circuit to a fire alarm system installed in accordance with 760.41(B) or 760.121(B) is installed in RMC, IMC, EMT, or steel-sheathed cable, Type AC or Type MC, meeting the requirements of 250.118, with metal outlet and junction boxes, AFCI protection shall be permitted to be omitted.

Informational Note No. 1: For information on combination-type and branch/feeder-type arc-fault circuit interrupters, see UL 1699-2011, *Standard for Arc-Fault Circuit Interrupters*. For information on outlet branch-circuit type arc-fault circuit interupters, see UL Subject 1699A, *Outline of Investigation for Outlet Branch Circuit Arc-Fault Circuit-Interrupters*. For information on system combination AFCIs, see UL Subject 1699C, *Outline of Investigation for System Combination Arc-Fault Circuit Interrupters*.

Informational Note No. 2: See 29.6.3(5) of *NFPA 72*-2013, *National Fire Alarm and Signaling Code*, for information related to secondary power-supply requirements for smoke alarms installed in dwelling units.

Informational Note No. 3: See 760.41(B) and 760.121(B) for power-supply requirements for fire alarm systems.

Statement of Problem and Substantiation for Public Input

The time has come to provide the safety requirements afforded by AFCI protection to the entire dwelling unit. This was well on its way for the 2017 NEC when SR 319 failed written ballot and reverted 210.12(A) back to the 2014 NEC Code language. The failed written ballot had nothing to do with "whole house" AFCI protection which received minimal objection from CMP-2.

The following is part of the panel statement from CMP-2 on FR 329 which supported "whole house" AFCI protection:

AFCIs have been required in the Code since 1999. The initial requirement covered only bedroom receptacle outlets, giving installers an opportunity to gain experience with what was at that time a new product, and for manufacturers to address any unforeseen problems with their designs. In the 2002 edition the requirement was expanded to include all bedroom outlets.
In the 2008 edition the requirement was expanded once again to include bedrooms, family rooms, living rooms, parlors, libraries, dens, sun rooms, recreation rooms or similar rooms. Kitchens, laundry areas and devices located in the specified areas were added to the requirement in the 2014 edition. By the time the 2017 edition is published, the industry will have over 15 years of experience with the manufacture and installation of AFCIs and over 9 years of experience with combination type AFCIs. With the expanded requirement in the 2014 edition, there are very few 120-volt single-phase 15- and 20-ampere branch circuits in a dwelling unit that do not require AFCI protection. This will accomplish the original objective sought by the CPSC to reduce residential electrical wiring fires.

Submitter Information Verification

Submitter Full Name:	L Keith Lofland
Organization:	IAEI
Affilliation:	Self
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Thu Sep 07 16:05:28 EDT 2017

Copyright Assignment

I, L Keith Lofland, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am L Keith Lofland, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 4328-NFPA 70-2017 [Section No. 210.12(A)]

(A) Dwelling Units.

All 120-volt, single-phase, 15- and 20-ampere branch circuits supplying outlets or devices installed in the envelope of a dwelling unit including rooms such as kitchens, family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, laundry areas, or similar rooms or areas shall be protected by any of the means described in 210.12(A)(1) through (6):

(1) A listed combination-type arc-fault circuit interrupter, installed to provide protection of the entire branch circuit

(2) A listed branch/feeder-type AFCI installed at the origin of the branch-circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit. The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(3) A listed supplemental arc protection circuit breaker installed at the origin of the branch circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit where all of the following conditions are met:

(4) The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.

(5) The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.

(6) The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(7) A listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet on the branch circuit in combination with a listed branch-circuit overcurrent protective device where all of the following conditions are met:

(8) The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.

(9) The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.

(10) The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

(11) The combination of the branch-circuit overcurrent device and outlet branch-circuit AFCI shall be identified as meeting the requirements for a system combination–type AFCI and shall be listed as such.

(12) If RMC, IMC, EMT, Type MC, or steel-armored Type AC cables meeting the requirements of 250.118, metal wireways, metal auxiliary gutters, and metal outlet and junction boxes are installed for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

(13) Where a listed metal or nonmetallic conduit or tubing or Type MC cable is encased in not less than 50 mm (2 in.) of concrete for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a listed outlet branch-circuit type AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

Exception: Where an individual branch circuit to a fire alarm system installed in accordance with 760.41(B) or 760.121(B) is installed in RMC, IMC, EMT, or steel-sheathed cable, Type AC or Type MC, meeting the requirements of 250.118, with metal outlet and junction boxes, AFCI protection *shall be permitted to be omitted.*

Informational Note No. 1: For information on combination-type and branch/feeder-type arc-fault circuit interrupters, see UL 1699-2011, *Standard for Arc-Fault Circuit Interrupters*. For information on outlet branch-circuit type arc-fault circuit interupters, see UL Subject 1699A, *Outline of Investigation for Outlet Branch Circuit Arc-Fault Circuit-Interrupters*. For information on system combination AFCIs, see UL Subject 1699C, *Outline of Investigation for System Combination Arc-Fault Circuit Interrupters*.

Informational Note No. 2: See 29.6.3(5) of *NFPA 72*-2013, *National Fire Alarm and Signaling Code*, for information related to secondary power-supply requirements for smoke alarms installed in dwelling units.

Informational Note No. 3: See 760.41(B) and 760.121(B) for power-supply requirements for fire alarm systems.

Statement of Problem and Substantiation for Public Input

The language as written may unintentionally leave out a room type and be thought to be all inclusive allowing some areas to remain unprotected. I believe the intention of 210.12 is to protect the dwelling unit as a whole, so a garage which is built into a dwelling unit "envelope" would also need protection. The recommended change provides clarity without adding to the list.

Submitter Information Verification

Submitter Full Name: T David Mills

Organization: T David Mills Associates LLC

Street Address:

City:

State:

Zip:

Submittal Date: Thu Sep 07 21:12:44 EDT 2017

Public Input No. 3183-NFPA 70-2017 [New Section after 210.12(A)]

Addition to 210.12 (A) Dwelling Units

(7) A listed branch-circuit overcurrent protective device installed at the origin of the branch circuit in combination with a listed outlet branch-circuit type arc-fault circuit interrupter installed at the first outlet box on the branch circuit where all of the following conditions are met:

a. The branch-circuit wiring shall be continuous from the branch-circuit overcurrent device to the outlet branch-circuit arc-fault circuit interrupter.

b. The maximum length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall not exceed 15.2 m (50 ft) for a 14 AWG conductor or 21.3 m (70 ft) for a 12 AWG conductor.

c. The first outlet box in the branch circuit shall be marked to indicate that it is the first outlet of the circuit.

d. The length of the branch-circuit wiring from the branch-circuit overcurrent device to the first outlet shall be supported and secured by listed insulated staples, cable supports, standoff connectors or similar fittings.

Statement of Problem and Substantiation for Public Input

Damage to branch-circuit cables during installation has been perceived to be a cause of arcing that may result in electrical fires. This proposal provides installation solutions to address these supposed sources of arc faults; implementation of the securing and supporting requirements summarized in (7)d will protect the lengths (i.e. – 50 feet or less for a 14 AWG conductor, 70 feet or less for a 12 AWG conductor) of branch-circuit cabling as described in (7)b against this type of damage that could result in an arcing condition.

210.12(7) will provide comprehensive arc protection by using devices that provide a high level of arc mitigation, and by protecting the branch-circuit cable to the first outlet against physical damage that could result in an arcing condition. The means described here within this proposed installation method delivers AFCI protection due to these factors:

A. Listed circuit breakers provide a significant level of parallel arc mitigation in the specified lengths of the branch-circuit conductors.

B. The listed outlet branch-circuit type AFCI provides parallel-type downstream and series-type upstream and downstream AFCI protection, and…

C. The listed insulated staples, cable supports and standoff connectors used to support and secure the limited length of cable to the first outlet provides protection against damage due to inadvertently placed drywall screws or nails, direct hammer blows, overdriven staples and similar circumstances involving installation fastening means.

The use and installation methods as described in (7)d for nonmetallic-sheathed cable commonly used in these applications are in alignment with and complementary to the securing and supporting requirements in 334.30.

Although both Sections 300.4 and 334.30 specify requirements to ensure that properly installed cables are protected against physical damage, the proposed 210.12(7)d provides for an additional level of installation safety to further protect cables against damage that could result in arcing conditions.

Submitter Information Verification

Submitter Full Name: Stephen Rood
Organization: Legrand North America
Street Address:
City:
State:
Zip:
Submittal Date: Sun Sep 03 10:45:56 EDT 2017

Copyright Assignment

I, Stephen Rood, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Stephen Rood, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 2995-NFPA 70-2017 [New Section after 210.12(D)]

TITLE OF NEW CONTENT

Exception No. 2: AFCI protection shall not be required where the panelboard has been replaced and relocated to increase the service size.

Statement of Problem and Substantiation for Public Input

Most service panel relocation are limited to 6 ft., because of this exception. There is the argument among inspectors and contractors alike that once you move that panel more that 6 ft. all branch circuits must be AFCI protected, because of the extension of the conductors. Perhaps another exception would clarify this topic.

Submitter Information Verification

Submitter Full Name: Lorenzo Adam

Organization: City Of Mason

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 30 14:07:15 EDT 2017

Public Input No. 1498-NFPA 70-2017 [Section No. 210.12(D)]

(D) Branch Circuit Extensions or Modifications — Dwelling Units and Dormitory Units.

In any of the areas specified in 210.12(A)~~or~~ , (B) or (C) , where branch-circuit wiring is modified, replaced, or extended, the branch circuit shall be protected by one of the following:

(1) A listed combination-type AFCI located at the origin of the branch circuit

(2) A listed outlet branch-circuit-type AFCI located at the first receptacle outlet of the existing branch circuit

Exception: AFCI protection shall not be required where the extension of the existing conductors is not more than 1.8 m (6 ft) and does not include any additional outlets or devices.

Statement of Problem and Substantiation for Public Input

I think you guys already know this.

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 01 11:15:33 EDT 2017

Public Input No. 169-NFPA 70-2017 [Section No. 210.12(D)]

(D) Branch Circuit Extensions or Modifications~~ — Dwelling Units and Dormitory Units~~

.

In any of the areas specified in 210.12(A) ~~or~~ through (~~B~~ C)

, where branch-circuit wiring is modified, replaced, or extended, the branch circuit shall be protected by one of the following:

(1) A listed combination-type AFCI located at the origin of the branch circuit

(2) A listed outlet branch-circuit-type AFCI located at the first receptacle outlet of the existing branch circuit

Exception: AFCI protection shall not be required where the modification, replacement or extension of the existing branch circuit conductors ~~is~~ are not more than 1.8 m (6 ft) and does not include any additional outlets or devices, other than splicing devices .

Additional Proposed Changes

File Name	Description	Approved
splicinginwall.jpg	splicing device allowed for NM cable 334.40 (B)	✓
h30VH.jpg	device	✓

Statement of Problem and Substantiation for Public Input

This allowance should be across the board. The very nature of an extension requires a device or splice to make that extension for the device or outlet you may be moving. The device for making splices concealed for NM cable is in 334.40 (B) ......Even a wire nut is a device see 110.14 (B)

Submitter Information Verification

Submitter Full Name: Alfio Torrisi
Organization: Master Electrician
Street Address:
City:
State:
Zip:
Submittal Date: Sat Feb 04 11:46:00 EST 2017

Copyright Assignment

I, Alfio Torrisi, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Alfio Torrisi, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 2251-NFPA 70-2017 [Section No. 210.12(D)]

(D) Branch Circuit Extensions or Modifications ~~— Dwelling Units and Dormitory Units~~ .

In any of the areas specified in 210.12(A)~~or~~ , (B), or (C) where branch-circuit wiring is modified, replaced, or extended, the branch circuit shall be protected by one of the following:

(1) A listed combination-type AFCI located at the origin of the branch circuit

(2) A listed outlet branch-circuit-type AFCI located at the first receptacle outlet of the existing branch circuit

Exception: AFCI protection shall not be required where the extension of the existing conductors is not more than 1.8 m (6 ft) and does not include any additional outlets or devices.

Statement of Problem and Substantiation for Public Input

This public input addresses an issue created during the 2017 NEC code cycle when Guest Rooms and Guest Suites was added to those areas requiring AFCI protection. The list of locations for AFCI protection has grown beyond just dwelling units and dormitory units.

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich

Organization: Eaton Corporation

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 15 14:53:47 EDT 2017

Public Input No. 236-NFPA 70-2017 [Section No. 210.12(D)]

(D) Branch Circuit Extensions or Modifications~~ — Dwelling Units and Dormitory Units~~

.

~~In~~ Branch cuircuits suppling outlets or devices in any of the areas specified in 210.12(A)~~ or~~ , (B) or (C)

, where branch-circuit wiring is modified, replaced, or extended, the branch circuit shall be protected by one of the following:

(1) ~~A listed combination-type AFCI located at the origin of the branch circuit~~ By any of the means discribed in 210.12 (A) (1) through (6)

(2) A listed outlet branch-circuit-type AFCI located at the first receptacle outlet of the existing branch circuit

Exception: AFCI protection shall not be required where the extension of the existing conductors is not more than 1.8 m (6 ft) and does not include any additional outlets or devices.

Statement of Problem and Substantiation for Public Input

this requirement should not be subjected to areas not requiring AFCI protection,

Submitter Information Verification

Submitter Full Name: Alfio Torrisi
Organization: Master Electrician
Street Address:
City:
State:
Zip:
Submittal Date: Fri Feb 10 14:52:59 EST 2017

Public Input No. 2643-NFPA 70-2017 [Section No. 210.12(D)]

(D) Branch Circuit Extensions or Modifications — Dwelling Units ~~and~~ , Dormitory Units ~~.~~

~~In~~

and Guest Rooms or Guest Suites

Where branch circuit wiring for any of the areas specified in 210.12(A)~~or~~ , (B), ~~where branch-circuit wiring~~ or (C) is modified, replaced, or extended, the branch circuit shall be protected by one of the following:

(1) A listed combination-type AFCI located at the origin of the branch circuit

(2) A listed outlet branch-circuit-type AFCI located at the first receptacle outlet of the existing branch circuit

Exception: AFCI protection shall not be required where the relacement or extension of the existing conductors is not more than 1.8 m (6 ft) and does not include any additional outlets or devices.

Statement of Problem and Substantiation for Public Input

I may catch some flak for this one, but I am going to stick my neck out and boldly state that AFCI protection is presently not required when replacements or extensions are made to existing 120-volt, single phase 15-amp or 20-amp branch circuits for dwelling unit bedrooms. This may seem to contradict the requirements of section 210.12(D) of course, but in my interpretation it would depend upon exactly WHERE those extensions or modifications are made. The literally wording in section 210.12(D) requires AFCI protection for branch circuit modifications, replacements, or extensions “IN” any of the areas in section 210.12(A). Bedrooms are one of the areas specified in section 210.12(A). But what if the modifications or extensions to the bedroom circuit are not made “IN” the bedroom? What if the modifications to the bedroom circuit are made “IN” the unfinished basement? For example what if I rerouted and extended some wiring supplying the bedroom 20 feet because a wooden beam in the basement was being replaced due to termite damage? What if I even added a basement receptacle to that same circuit wiring while I was at it? The exception to 210.12(B) says that AFCI protection is not required when the extension is not more than 6 feet and does not contain any additional outlets or devices. I contend however, that since all of this work was done “IN” the basement, and not “IN” the bedroom, the literal wording in section 210.12(D) does not require AFCI protection to be provided for that branch circuit. We could argue the same point for extensions or modifications made in garages or attics too since those areas are not specified in section 210.12(A) either. Is this the intent of the wording? I think not. This revision will also clarify that extending or replacing wiring that happens to pass through the bedroom walls does NOT need AFCI protection if that circuit is supplying only an outside lighting fixture or perhaps an outside receptacle outlet, but does not also supply any areas specified in 210.12(A)(B) or (C). The additional inclusion of a reference to 210.12(C) in this rule is now appropriate since that section was added for the 2017 NEC. The addition of the wording "replacement" is needed to clarify that this type of work requires the AFCI protection as well.

Submitter Information Verification

Submitter Full Name: Russ Leblanc

Organization: Leblanc Consulting Services

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 23 12:03:02 EDT 2017

Copyright Assignment

I, Russ Leblanc, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Russ Leblanc, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 2982-NFPA 70-2017 [Section No. 210.12(D)]

(D) Branch Circuit Extensions or Modifications — Dwelling Units and Dormitory Units.

In any of the areas specified in 210.12(A)or (B), where branch-circuit wiring is modified, replaced, or extended, the branch circuit shall be protected by one of the following:

(1) A listed combination-type AFCI located at the origin of the branch circuit

(2) A listed outlet branch-circuit-type AFCI located at the first receptacle outlet of the existing branch circuit

Exception: AFCI protection shall not be required where the extension of the existing conductors is not more than ~~1~~ 3 .~~8 m~~ 05 m (~~6 ft~~ 10 ft) and does not include any additional outlets or devices. This measurement shall not include the conductors inside an enclosure or junction box.

Statement of Problem and Substantiation for Public Input

I wrote this section but the code panel members added the 6' limitation. IMO, this is not long enough. I wrote the section to cover panel change outs where wires would not reach and had to be extended. If the wire has to be spliced in an attic or a crawl space and we add the amount of wire inside the panel and splice box then it defeats the purpose of this section. I don't believe the wiring inside the panel or a junction box should count in the measurement and from experience a few extra feet is very helpful when high ceilings are encountered.

Submitter Information Verification

Submitter Full Name: Dennis Alwon

Organization: Alwon Electric

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 30 08:03:10 EDT 2017

Public Input No. 2996-NFPA 70-2017 [Section No. 210.12(D)]

(D) Branch Circuit Extensions or Modifications — Dwelling Units and Dormitory Units.

In any of the areas specified in 210.12(A)or (B), where branch-circuit wiring is modified, replaced, or extended, the branch circuit shall be protected by one of the following:

(1) A listed combination-type AFCI located at the origin of the branch circuit

(2) A listed outlet branch-circuit-type AFCI located at the first receptacle outlet of the existing branch circuit

Exception No.1 : AFCI protection shall not be required where the extension of the existing conductors is not more than 1.8 m (6 ft) and does not include any additional outlets or devices.

Statement of Problem and Substantiation for Public Input

See public input No. 2995

Submitter Information Verification

Submitter Full Name: Lorenzo Adam
Organization: City Of Mason
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 30 14:15:53 EDT 2017

Public Input No. 3998-NFPA 70-2017 [Section No. 210.12(D)]

(D) Branch Circuit Extensions or Modifications — Dwelling Units ~~and~~ , Guest Rooms/Guest Suites and Dormitory Units.

In any of the areas specified in 210.12(A)~~or~~ , (B) or (C) , where branch-circuit wiring is modified, replaced, or extended, the branch circuit shall be protected by ~~one~~ any of the ~~following:~~

(1) ~~A listed combination-type AFCI located at the origin of the branch circuit~~

(2) ~~A listed outlet branch-circuit-type AFCI located at the first receptacle outlet of the existing branch circuit~~

~~Exception~~

means described in 210.12(A)(1) through (6).

Exception No. 1 : AFCI protection shall not be required where the extension of the existing conductors is not more than 1.8 m (6 ft) and does not include any additional outlets or devices.

Exception No. 2: Where a means, as required by 210.12(A)(1) through (6), is not listed for the installed electrical equipment, a listed outlet branch-circuit-type AFCI located at the first receptacle outlet of the existing branch circuit shall be installed.

Statement of Problem and Substantiation for Public Input

Section 210.12(A) clearly lists the acceptable installations of Arc-Fault Circuit-Interrupter Protection. An exception is added in the event a commercial solution does not exist for one of these acceptable installation methods.

Guest Rooms and Guest Suites requirement was added in the 2017 code cycle so should also be included in this section.

It was shown during the last code cycle that OBC AFCIs do not provide complete protection to the home run of the circuit upstream of the OBC AFCI. This change in the language will ensure that if a circuit is modified that it will have complete protection of the entire branch circuit if the installed equipment will allow it.

Submitter Information Verification

Submitter Full Name: Kenneth Rempe

Organization: Siemens Industry Inc

Affilliation: American Circuit Breaker Manufacturers Association

Street Address:

City:

State:

Zip:

Submittal Date: Thu Sep 07 11:53:50 EDT 2017

Copyright Assignment

I, Kenneth Rempe, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Kenneth Rempe, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 507-NFPA 70-2017 [Section No. 210.12(D)]

(D) Branch Circuit Extensions or Modifications — Dwelling Units and Dormitory Units.

In any of the areas specified in 210.12(A) or (B), where branch-circuit wiring is modified, replaced, or extended, the branch circuit shall be protected by one of the following:

(1) A listed combination-type AFCI located at the origin of the branch circuit

(2) A listed outlet branch-circuit-type AFCI located at the first receptacle outlet of the existing branch circuit

Exception: AFCI protection shall not be required where the extension of the existing conductors ~~is not more than 1.8 m (6 ft)~~ and does not include any additional ~~outlets~~ loads or devices.

Statement of Problem and Substantiation for Public Input

A common practice is the replacement of distribution panelboards in existing dwelling units. Relocation of the equipment beyond 6 feet may be necessary to meet the requirements of 110.26 and to make the equipment readily accessible. A junction box will be necessary to extended the branch circuit conductors to the new point of origination. A junction box can be considered an outlet, by definition. The existing wiring in many dwelling units may not be compatible with the AFCI technology, like existing knob and tube circuits. The proposed change provides relief and allows the branch circuit conductors to be extended to a new point of distribution without the requirement of AFCI protection, as long as no new loads or devices are added to the branch circuit.

Submitter Information Verification

Submitter Full Name: Brian Baughman

Organization: Generac Power Systems Inc

Street Address:

City:

State:

Zip:

Submittal Date: Tue Apr 11 10:57:33 EDT 2017

Public Input No. 2140-NFPA 70-2017 [Section No. 210.19(A) [Excluding any Sub-Sections]]

Informational Note No. 1: See 310.15 for ampacity ~~ratings~~ of conductors.

Informational Note No. 2: See Part II of Article 430 for minimum rating of motor branch-circuit conductors.

Informational Note No. 3: See 310.15(A)(3) for temperature limitation of conductors.

Informational Note No. 4: Conductors for branch circuits as defined in Article 100, sized to prevent a voltage drop exceeding 3 percent at the farthest outlet of power, heating, and lighting loads, or combinations of such loads, and where the maximum total voltage drop on both feeders and branch circuits to the farthest outlet does not exceed 5 percent, provide reasonable efficiency of operation. See Informational Note No. 2 of 215.2(A)(1)for voltage drop on feeder conductors.

Statement of Problem and Substantiation for Public Input

This public input is the work of an Ampacity Task Group. The task group consisted of the following members: Thomas Domitrovich, Dave Mercier, Christine Porter, Derrick Atkins, and Christel Hunter.

The Task Group identified the use of the word rated to describe ampacity is not appropriate when addressing the ampacity of a conductor. The use of the term "rating" generally applies to equipment where as ampacity applies to conductors.

Ampacity of a conductor is defined as part of Article 100 as "The maximum current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating." Tables 310.15(B)(16) through (21) establish the ampacity of conductors under specified conditions of use.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 919-NFPA 70-2017 [Definition: Overload.]	Removal of the term "rated" as it pertains to ampacity
Public Input No. 920-NFPA 70-2017 [Section No. 450.6(A)(1)]	Removal of the term "rated" as it pertains to ampacity
Public Input No. 921-NFPA 70-2017 [Section No. 450.6(A)(2)]	Removal of the term "rated" as it pertains to ampacity
Public Input No. 922-NFPA 70-2017 [Section No. 530.18(E)]	Removal of the term "rated" as it pertains to ampacity
Public Input No. 923-NFPA 70-2017 [Section No. 630.31(A)]	Removal of the term "rated" as it pertains to ampacity
Public Input No. 924-NFPA 70-2017 [Section No. 660.6(B)]	Removal of the term "rated" as it pertains to ampacity
Public Input No. 949-NFPA 70-2017 [Section No. 230.23]	Removal of the term "rated" as it pertains to ampacity
Public Input No. 950-NFPA 70-2017 [Section No. 310.15(B)(7)]	Removal of the term "rated" as it pertains to ampacity

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich
Organization: Eaton Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Fri Aug 11 14:54:29 EDT 2017

Copyright Assignment

I, Thomas Domitrovich, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Thomas Domitrovich, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 2378-NFPA 70-2017 [Section No. 210.19(A) [Excluding any Sub-Sections]]

Informational Note No. 1: See 310.15 for ampacity ratings of conductors.

Informational Note No. 2: See Part II of Article 430 for minimum rating of motor branch-circuit conductors.

Informational Note No. 3: See 310.15(A)(3) for temperature limitation of conductors.

Informational Note No. 4: Conductors for branch circuits as defined in Article 100, sized to prevent a voltage drop exceeding 3 percent at the farthest outlet of power, heating, and lighting loads, or combinations of such loads, and where the maximum total voltage drop on both feeders and branch circuits to the farthest outlet does not exceed 5 percent, provide reasonable efficiency of operation. See Informational Note No. 2 of 215.2(A)(1)for voltage drop on feeder conductors.

Revise 210.19 (A) Informational Note No.4

Add a new code proposal as follows: A maximum of 5% voltage drop verification shall be required for all 120 volt branch circuit outlets installed in new and existing residential dwellings.

Statement of Problem and Substantiation for Public Input

The main issue appears to be the distance from the supply transformers in the public way to a home's point of attachment. This creates a greater share of the voltage drop further down the line on the consumer side of the demarcation. Beginning at the secondary side of the utility supply transformer cascading ends at the furthest outlet in the home. For reasonable efficiency, a maximum limit of five percent is recommended by the National Electrical Code. Most homes in this region far exceed this limit. To address these design issues, loaded voltage drop verification is needed at all 120 volt single phase receptacle outlets.

It appears in part to be a two-tiered design problem that has not been fully addressed. The utility side of the demarcation is the power company regulated by the Department of Public Utilities, and on the consumer side of demarcation is the home owner regulated by the authority having jurisdiction who enforces the Massachusetts and National Electrical Code for compliance.
On the consumer side of the demarcation, internal wiring issues can also contribute to additional high impedance connections that can cause voltage drop. The problem can be exacerbated by the unprofessional wiring activities that can be difficult to enforce. In many cases, the wiring is unsafe, non-code compliant and puts occupants at risk. In larger scale homes, this presents an even greater challenge as the wires would be run at a greater distance. There are many contributing factors such as the unlimited number of electrical outlets on a circuit and loose wiring which can all create voltage drop and potential fire hazards.

Currently inspections are carried out by the Authority having jurisdiction for code compliance and are mostly visual observations. Now, the voltage drop limit is not enforceable by the code. Therefore, the electrician installer is not required to check the installation in new or existing dwellings for excessive impedance that causes voltage drop.

Submitter Information Verification

Submitter Full Name: Philip Waters

Organization: [Philip Waters Electrician]

Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 17 11:11:14 EDT 2017

Copyright Assignment

I, Philip Waters, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Philip Waters, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 3250-NFPA 70-2017 [Section No. 210.19(A) [Excluding any Sub-Sections]]

Informational Note No. 1: See 310.15 for ampacity ratings of conductors.

Informational Note No. 2: See Part II of Article 430 for minimum rating of motor branch-circuit conductors.

Informational Note No. 3: See 310.15(A)(3) for temperature limitation of conductors.

Informational Note No. 4: Conductors for branch circuits as defined in Article 100, sized to prevent a voltage drop exceeding 3 percent at the farthest outlet of power, heating, and lighting loads, or combinations of such loads, and where the maximum total voltage drop on both feeders and branch circuits to the farthest outlet does not exceed 5 percent, provide reasonable efficiency of operation. See Informational Note No. 2 of 215.2(A)(1)for voltage drop on feeder conductors.

Informational Note 5: For information regarding circuit breakers, see IEEE 3004.5 IEEE Recommended Practice for the Application of Low-Voltage Circuit Breakers in Industrial and Commercial Power Systems

Statement of Problem and Substantiation for Public Input

The stronger the linkage between the NFPA and IEEE on electrical power technology the better. This document replaces ANSI/IEEE 142 -- the so-called "Red Book", which is now being sunsetted and superseded by 3004.5.

IEEE 3000 Standards Collection™ is the trademarked name of the family of industrial and commercial power systems standards formerly known as IEEE Color Books. The IEEE 3000 Standards Collection overall includes the same content as the Color Books that have been referenced into previous editions of the NEC but is now organized into approximately 70 IEEE "dot" standards that cover specific technical topics.

This method of development, of capturing and quickly conveying leading practice from transactions among academic experts and practitioners into our industry, supports the NFPA International mission of eliminating death, injury, property and economic loss due to fire, electrical and related hazards. My own experience with other international electrical standard developers suggests that closer coupling of the fire and electrical safety community in the US would be welcomed.

Details about this document is available at the link below:

https://standards.ieee.org/findstds/standard/3004.5-2014.html

Submitter Information Verification

Submitter Full Name: Michael Anthony
Organization: Standards Michigan
Street Address:

City:

State:

Zip:

Submittal Date: Mon Sep 04 18:47:39 EDT 2017

Copyright Assignment

I, Michael Anthony, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Michael Anthony, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 589-NFPA 70-2017 [Section No. 210.19(A) [Excluding any Sub-Sections]]

Informational Note No. 1: See 310.15 for ampacity ratings of conductors.

Informational Note No. 2: See Part II of Article 430 for minimum rating of motor branch-circuit conductors.

Informational Note No. ~~3: See 310.15(A)(3) for temperature limitation of conductors. Informational Note No.~~ 4: Conductors for branch circuits as defined in Article 100, sized to prevent a voltage drop exceeding 3 percent at the farthest outlet of power, heating, and lighting loads, or combinations of such loads, and where the maximum total voltage drop on both feeders and branch circuits to the farthest outlet does not exceed 5 percent, provide reasonable efficiency of operation. See Informational Note No. 2 of 215.2(A)(1) for voltage drop on feeder conductors.

Statement of Problem and Substantiation for Public Input

If I follow informational note 1, I've already read all of 310.15. Why do I then need to be reminded to read it again one sentence later?

Submitter Information Verification

Submitter Full Name: Ryan Jackson

Organization: Ryan Jackson

Street Address:

City:

State:

Zip:

Submittal Date: Mon Apr 24 17:21:10 EDT 2017

Public Input No. 1491-NFPA 70-2017 [Section No. 210.19(A)(1)]

(1) General.

Branch-circuit conductors shall have an ampacity not less than the maximum load to be served. Conductors shall be sized to carry not less than the larger of 210.19(A)(1)(a) or (b).

(a) Where a branch circuit supplies continuous loads or any combination of continuous and noncontinuous loads, the minimum branch-circuit conductor size shall have an allowable ampacity not less than the noncontinuous load plus 125 percent of the continuous load in accordance with 110 .14(C).

(b) The minimum branch-circuit conductor size shall have an allowable ampacity not less than the maximum load to be served after the application of any adjustment or correction factors in accordance with 310 .15(B).

Exception No. 1 : If the assembly, including the overcurrent devices protecting the branch circuit(s), is listed for operation at 100 percent of its rating, the allowable ampacity of the branch-circuit conductors shall be permitted to be not less than the sum of the continuous load plus the noncontinuous load.

Exception No. 2: Where a portion of a branch circuit is connected at both its supply and load ends to separately installed pressure connections as covered in 110.14(C)(2), it shall be permitted to have an allowable ampacity, in accordance with 310.15(B) not less than the sum of the continuous load plus the noncontinuous load. No portion of a branch circuit installed under the provisions of this exception shall extend into an enclosure containing either the branch circuit supply or the branch circuit load terminations.

Statement of Problem and Substantiation for Public Input

No. 1. Add Code references 110.14(C) and 310.15(B) to help the reader understand which rule applies.
No. 2. Add the same exception contained for Feeders in 215.2(A)(1)(a), if it's suitable for feeders, it's clearly suitable for branch circuits.

Submitter Information Verification

Submitter Full Name: Mike Holt

Organization: Mike Holt Enterprises Inc

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 01 10:45:00 EDT 2017

Copyright Assignment

Public Input No. 1666-NFPA 70-2017 [Section No. 210.19(A)(1)]

(1) General.

Branch-circuit conductors shall have an ampacity not less than the maximum load to be served. Conductors shall be sized to carry not less than the larger of 210.19(A)(1)(a) or (b).

(a) Where a branch circuit supplies continuous loads or any combination of continuous and noncontinuous loads, the minimum branch-circuit conductor size shall have an allowable ampacity not less than the noncontinuous load plus 125 percent of the continuous load.

(b) The minimum branch-circuit conductor size shall have an allowable ampacity not less than the maximum load to be served after the application of any adjustment or correction factors <u>in accordance with 310</u> .<u>15(B).</u>

Exception: If the assembly, including the overcurrent devices protecting the branch circuit(s), is listed for operation at 100 percent of its rating, the allowable ampacity of the branch-circuit conductors shall be permitted to be not less than the sum of the continuous load plus the noncontinuous load<u>, in accordance with 110</u> .<u>14(C).</u>

Statement of Problem and Substantiation for Public Input

No. 1 Reference to 310.15(B) provides the reader to know where they get the information for adjustment and correction.
No. 2 Add reference to 110.14(C) to the exception to help Code user better apply the requirements.

Submitter Information Verification

Submitter Full Name: Mike Holt

Organization: Mike Holt Enterprises Inc

Street Address:

City:

State:

Zip:

Submittal Date: Thu Aug 03 12:58:05 EDT 2017

Public Input No. 883-NFPA 70-2017 [Section No. 210.19(A)(1)]

(1) General.

Branch-circuit conductors shall have an ampacity not less than the

~~maximum load to be served. Conductors shall be sized to carry not less than the~~ larger of 210.19(A)(1)(a) or (b) and shall meet the equipment termination provisions of 110 . 14(C).

(a) Where a branch circuit supplies continuous loads or any combination of continuous and noncontinuous loads, the minimum branch-circuit conductor size shall have an ~~allowable~~ ampacity not less than the noncontinuous load plus 125 percent of the continuous load.

(b) The minimum branch-circuit conductor size, shall have an ~~allowable~~ ampacity not less than the maximum load to be served after the application of any adjustment or correction factors in accordance with 310 . 15 .

Exception: If the assembly, including the overcurrent devices protecting the branch circuit(s), is listed for operation at 100 percent of its rating, the ~~allowable~~ ampacity of the branch-circuit conductors shall be permitted to be not less than the sum of the continuous load plus the noncontinuous load.

Statement of Problem and Substantiation for Public Input

This public input is the work of an Ampacity Task Group. The task group consisted of the following members: Thomas Domitrovich, Dave Mercier, Christine Porter, Derrick Atkins, and Christel Hunter.

This PI makes the follow four modifications.

1. A new reference was added reminding the user of the NEC that equipment termination provisions must also be considered when establishing the minimum required conductor .

2. The parent text is modified to reflect the determinations of ampacity as part of (a) and (b) of this section. The ampacity of the conductor must not be less than the greater ampacity determined as part of (a) and (b) of this section.

3. The taskforce identified various areas of the NEC where the term "allowable" is used to describe ampacity. Ampacity is the maximum current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating. The term used in this section should be "ampacity" and not "allowable ampacity" as it is the intent for this section to determine the ampacity of the conductor based upon its conditions of use. The use of the word allowable does not add clarity.

4. "In accordance with 310.15" was added to improve usability and direct the user of the NEC to the section that governs ampacity of conductors.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 884-NFPA 70-2017 [Section No. 215.2(A)(1)]	Removal of the term "allowable" as it pertains to ampacity

Public Input No. 928-NFPA 70-2017 [Section No. 230.42(A)]	Removal of the term "allowable" as it pertains to ampacity
Public Input No. 929-NFPA 70-2017 [Section No. 230.90(A)]	Removal of the term "allowable" as it pertains to ampacity
Public Input No. 930-NFPA 70-2017 [Section No. 310.15(A)(3)]	Removal of the term "allowable" as it pertains to ampacity
Public Input No. 931-NFPA 70-2017 [Section No. 310.15(B) [Excluding any Sub-Sections]]	Removal of the term "allowable" as it pertains to ampacity
Public Input No. 932-NFPA 70-2017 [Section No. 310.15(B)(3)]	Removal of the term "allowable" as it pertains to ampacity
Public Input No. 933-NFPA 70-2017 [Section No. 334.80]	Removal of the term "allowable" as it pertains to ampacity
Public Input No. 934-NFPA 70-2017 [Section No. 370.23]	Removal of the term "allowable" as it pertains to ampacity
Public Input No. 935-NFPA 70-2017 [Section No. 392.80(A)(1)]	Removal of the term "allowable" as it pertains to ampacity
Public Input No. 936-NFPA 70-2017 [Section No. 392.80(A)(2)]	Removal of the term "allowable" as it pertains to ampacity
Public Input No. 937-NFPA 70-2017 [Section No. 392.80(B)(1)]	Removal of the term "allowable" as it pertains to ampacity
Public Input No. 938-NFPA 70-2017 [Section No. 400.5(A)]	Removal of the term "allowable" as it pertains to ampacity
Public Input No. 939-NFPA 70-2017 [Section No. 400.17]	Removal of the term "allowable" as it pertains to ampacity
Public Input No. 940-NFPA 70-2017 [Section No. 402.5]	Removal of the term "allowable" as it pertains to ampacity
Public Input No. 941-NFPA 70-2017 [Section No. 430.6 [Excluding any Sub-Sections]]	Removal of the term "allowable" as it pertains to ampacity
Public Input No. 942-NFPA 70-2017 [Section No. 727.8]	Removal of the term "allowable" as it pertains to ampacity

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich

Organization: Eaton Corporation

Street Address:

City:

State:

Zip:

Submittal Date: Fri Jun 02 14:38:24 EDT 2017

Copyright Assignment

I, Thomas Domitrovich, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Thomas Domitrovich, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 1495-NFPA 70-2017 [Section No. 210.19(A)(3)]

(3) Household Ranges and Cooking Appliances.

Branch-circuit conductors supplying household ranges, wall-mounted ovens, counter-mounted cooking units, and other household cooking appliances shall have an ampacity not less than the rating of the branch circuit and not less than the maximum load to be served. For ranges of 8¾ kW or more rating, the minimum branch-circuit rating shall be 40 amperes.

Exception No. 1: Conductors tapped from a branch circuit not exceeding 50-~~ampere branch circuit~~ amperes supplying electric ranges, wall-mounted electric ovens, and counter-mounted electric cooking units shall have an ampacity of not less than 20 amperes and shall be sufficient for the load to be served. These tap conductors include any conductors that are a part of the leads supplied with the appliance that are smaller than the branch-circuit conductors. The taps shall not be longer than necessary for servicing the appliance.

Exception No. 2: The neutral conductor of a 3-wire branch circuit supplying a household electric range, a wall-mounted oven, or a counter-mounted cooking unit shall be permitted to be smaller than the ungrounded conductors where the maximum demand of a range of 8¾-kW or more rating has been calculated according to Column C of Table 220.55, but such conductor shall have an ampacity of not less than 70 percent of the branch-circuit rating and shall not be smaller than 10 AWG.

Statement of Problem and Substantiation for Public Input

If we can make a tap with 20A conductors for a 50A range branch circuit, we should be able to do the same with a 30A or 40A circuit. Just saying...

Submitter Information Verification

Submitter Full Name: Mike Holt

Organization: Mike Holt Enterprises Inc

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 01 10:59:48 EDT 2017

Public Input No. 2660-NFPA 70-2017 [Section No. 210.21(A)]

(A) Lampholders.

Where connected to a branch circuit having a rating in excess of 20 amperes, lampholders shall be of the heavy-duty type. A heavy-duty lampholder shall have a rating of not less than 660 watts if of the admedium type, or not less than 750 watts if of any other type.

<u>Exception: Listed LED Luminaires shall be permitted on circuits in excess of 20 amperes. Large LED Luminaires are not equipped with lamp hoders and are comprised of multiple arrays that are mounted to the fixtures and wired to the driver for illumination.</u>

Statement of Problem and Substantiation for Public Input

LED Luminaires are utilized for retrofit/replacement of large wattage (250 and 400 W) fixtures on roadways and near the security fences. These fixtures required a traditional lamp holder and lamp arrangement. The lamp holders in these fixtures are heavy-duty allowing use of circuits larger than 20 amperes. The LED luminaires do not use traditional lamp holder and lamp arrangement. Instead the LED luminaires consist of one or many arrays of LED lights that are mounted and connected directly to the drivers to provide illumination and energy savings. Allowing direct replacement of existing luminaires with LED will provide tremendous energy savings.

Submitter Information Verification

Submitter Full Name: Daleep Mohla

Organization: DCM Electrical Consulting Serv

Street Address:

City:

State:

Zip:

Submittal Date: Thu Aug 24 13:06:14 EDT 2017

Public Input No. 2821-NFPA 70-2017 [Section No. 210.21(B)(1)]

(1) Single Receptacle on an Individual Branch Circuit.

A single receptacle installed on an individual branch circuit shall have an ampere rating not less than that of the branch circuit and not more than the values in Table 210 .21(B)(3)

Exception No. 1: A receptacle installed in accordance with 430.81(B).

Exception No. 2: A receptacle installed exclusively for the use of a cord-and-plug-connected arc welder shall be permitted to have an ampere rating not less than the minimum branch-circuit conductor ampacity determined by 630.11(A) for arc welders.

Informational Note: See the definition of *receptacle* in Article 100.

Statement of Problem and Substantiation for Public Input

Section 210.21 (B)(1) contradicts Table 210.21(B)(3) because it does not limit the receptacle size. (B)(1) alone, as written, allows a 30 amp single receptacle on a 20 amp circuit . I don't believe that was the intent so I added the words to direct the reader to Table 210.21(B)(3) which will limit the receptacle size.

Submitter Information Verification

Submitter Full Name: Dennis Alwon

Organization: Alwon Electric

Street Address:

City:

State:

Zip:

Submittal Date: Sun Aug 27 16:58:43 EDT 2017

Public Input No. 2786-NFPA 70-2017 [New Section after 210.22]

Smoke alarms on individual branch circuits

Smoke alarms shall not be permitted on individual branch circuits.

Statement of Problem and Substantiation for Public Input

I am an electrical contractor and 80% of my business is in residential. atleast 50% of my residential work is in government subsadized public housing and other government funded housing projects. 7 out of 10 properties I go to do not have operating smoke alarms due to missing batteries or batteries that are dead. With the way the code is written right now, 120 volt hardwired smoke alarms are permitted to be on individual branch circuits. This is a problem because if the battery is either dead or missing and if there was a fault on the circuit, then the protection device would open the circuit deeming the fire alarm inoperable and no one would ever know until the unfortunate occurs. Whereas if the smoke alarm(s) were on a general lighting circuit such as a bedroom, hallway, etc, then the homeowner or tenant would be forced to reset the protection device or seek professional help to minimize downtime without life safety.

Submitter Information Verification

Submitter Full Name: Emanuel Burgos

Organization: Rite Tech Services

Street Address:

City:

State:

Zip:

Submittal Date: Fri Aug 25 23:03:06 EDT 2017

Public Input No. 2984-NFPA 70-2017 [Section No. 210.23(A)(2)]

(2) Utilization Equipment Fastened in Place.

The total rating of utilization equipment fastened in place, other than luminaires, shall not exceed 50 percent of the branch-circuit ampere rating where lighting units, cord-and-plug-connected utilization equipment not fastened in place, or both, are also supplied.

Exception

(1) dwelling unit utilization equipment such as garage door openers, disposal and other intermittent equipment

Statement of Problem and Substantiation for Public Input

Intermittent equipment such as a garage door uses current for 5-10 secs. This load should not require complying with this section. Garages have had many changes over the years such that the requirement to wire a garage can use 3 or more circuits. It seems unnecessary since these doors are only on for short cycles. If there are 2 garage door openers it may very well require an entire circuit because of this section. This exception will cut back on the unnecessary need for extra circuits and still be a safe install.

Submitter Information Verification

Submitter Full Name: Dennis Alwon
Organization: Alwon Electric
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 30 08:16:17 EDT 2017

Public Input No. 237-NFPA 70-2017 [New Section after 210.25]

TITLE OF NEW CONTENT

Exception to A and B

If the branch circuits originate from a single metered sevice that is under single managment, The branch circuits shall be permitted to originate from any electrical equipment on the premises.

Statement of Problem and Substantiation for Public Input

this section does not take into account single metered services where the owner of the building includes utilities in the rent. such as heat, electric and water.

Submitter Information Verification

Submitter Full Name: Alfio Torrisi

Organization: Master electrician

Street Address:

City:

State:

Zip:

Submittal Date: Fri Feb 10 15:49:12 EST 2017

Public Input No. 2731-NFPA 70-2017 [Section No. 210.50 [Excluding any Sub-Sections]]

Receptacle outlets shall be installed as specified in 210.52 through 210.~~64~~ 65 .

Informational Note: See Informative Annex J for information regarding ADA accessibility design.

Statement of Problem and Substantiation for Public Input

See Public Input 782
If the change moves forward into the first revision to move Section 210.71 to new Section 210.65 then Section 210.50 needs to be revised as follows to include this Section.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 782-NFPA 70-2017 [Section No. 210.71]	

Submitter Information Verification

Submitter Full Name: Darryl Hill
Organization: Wichita Electrical JATC
Street Address:
City:
State:
Zip:

Submittal Date: Fri Aug 25 12:24:42 EDT 2017

Public Input No. 597-NFPA 70-2017 [Section No. 210.50 [Excluding any Sub-Sections]]

Receptacle outlets shall be installed as specified in 210.52 through 210.~~64~~ 65 .

Informational Note: See Informative Annex J for information regarding ADA accessibility design.

Statement of Problem and Substantiation for Public Input

This is a companion proposal to my suggestion of relocating 210.71 to 210.65. Because 210.71 requires receptacles outlets, it should be included in the opening statement of 210.50. It would be rather odd; however, to say that receptacles must be installed as specified in 210.52 through 210.64 and 210.71. Renumber that section and revising this one seems to make more sense and will hopefully increase usability ever so slightly.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 596-NFPA 70-2017 [Section No. 210.71]	Companion input

Submitter Information Verification

Submitter Full Name: Ryan Jackson

Organization: Ryan Jackson

Street Address:

City:

State:

Zip:

Submittal Date: Tue Apr 25 21:49:31 EDT 2017

Public Input No. 3768-NFPA 70-2017 [Section No. 210.52(A) [Excluding any Sub-Sections]]

In every kitchen, family room, dining room, living room, parlor, library, den, sunroom, bedroom, recreation room, or similar room or area of dwelling units, attached or detached garages and accessory buildings to dwelling units, receptacle outlets shall be installed in accordance with the general provisions specified in 210.52(A)(1) through (A)(4).

Statement of Problem and Substantiation for Public Input

Garages, both attached and detached, along with accessory buildings have evolved over time to include many similar areas as dwelling units. Many times one or more provisions are not present to allow full enforcement of the dwelling unit required receptacles. These rooms are set up no different than similar rooms in defined dwelling units. The popularity of "man caves", recreation rooms, wet bars, bathrooms, office/dens in these building types has become very popular. The intent of the receptacle spacing requirements in dwelling units is to limit the use of extension cords by providing an adequate number of receptacles along wall spaces, etc. When these spaces are being used as a space typically found in a dwelling unit, the requirements should be the same.

Submitter Information Verification

Submitter Full Name: Justin Lett
Organization: [Not Specified]
Street Address:
City:
State:
Zip:

Submittal Date: Wed Sep 06 20:59:13 EDT 2017

Public Input No. 38-NFPA 70-2017 [Section No. 210.52(A) [Excluding any Sub-Sections]]

In every kitchen, family room, dining room, living room, parlor, library, den, sunroom, bedroom, recreation room, laundry room*, or similar room or area of dwelling units, receptacle outlets shall be installed in accordance with the general provisions specified in 210.52(A)(1) through (A)(4).

* the remaining portion of a designated "laundry room" outside of the footprint of the "laundry area" 60 sqft. or greater in size.

Statement of Problem and Substantiation for Public Input

Clarity on definition and requirements for laundry in dwellings

Submitter Information Verification

Submitter Full Name: Dan Haruch

Organization: Brightwood Career Institute

Street Address:

City:

State:

Zip:

Submittal Date: Tue Jan 24 09:14:30 EST 2017

Public Input No. 4245-NFPA 70-2017 [New Section after 210.52(A)(2)]

TITLE OF NEW CONTENT

Exception to (1): Where multiple doorways and similar openings exist, the placement of a receptracle outlet shall not be required if there are receptacles outlets within 1.8 m (6 ft) of a required receptacle outlet.

Additional Proposed Changes

File Name	Description	Approved
EXHIBIT_1.pdf	Receptacles Example 1	✓
EXHIBIT_2.pdf	Receptacles Example 2	✓
EXHIBIT_3.pdf	Receptacles Example 3	✓
EXHIBIT_4.pdf	Receptacles Example 4	✓

Statement of Problem and Substantiation for Public Input

The exception would eliminate placement of receptacles in locations where are not needed (behind doors, within 3 feet across a doorway, consecutive short sections of walls larger than 2 feet, etc.) Common question from residential homeowners is: why is this receptacle in such odd location?.

Submitter Information Verification

Submitter Full Name: Lorenzo Adam

Organization: City Of Mason

Street Address:

City:

State:

Zip:

Submittal Date: Thu Sep 07 17:07:44 EDT 2017

EXHIBIT 1

Per 210.52(A)(2)(1).This room would have to have a receptacle in every space greater than 2 feet. Therefore, placing these receptacles in odd locations such as behind doors and sometimes more receptacles than the room or area, where they are located.

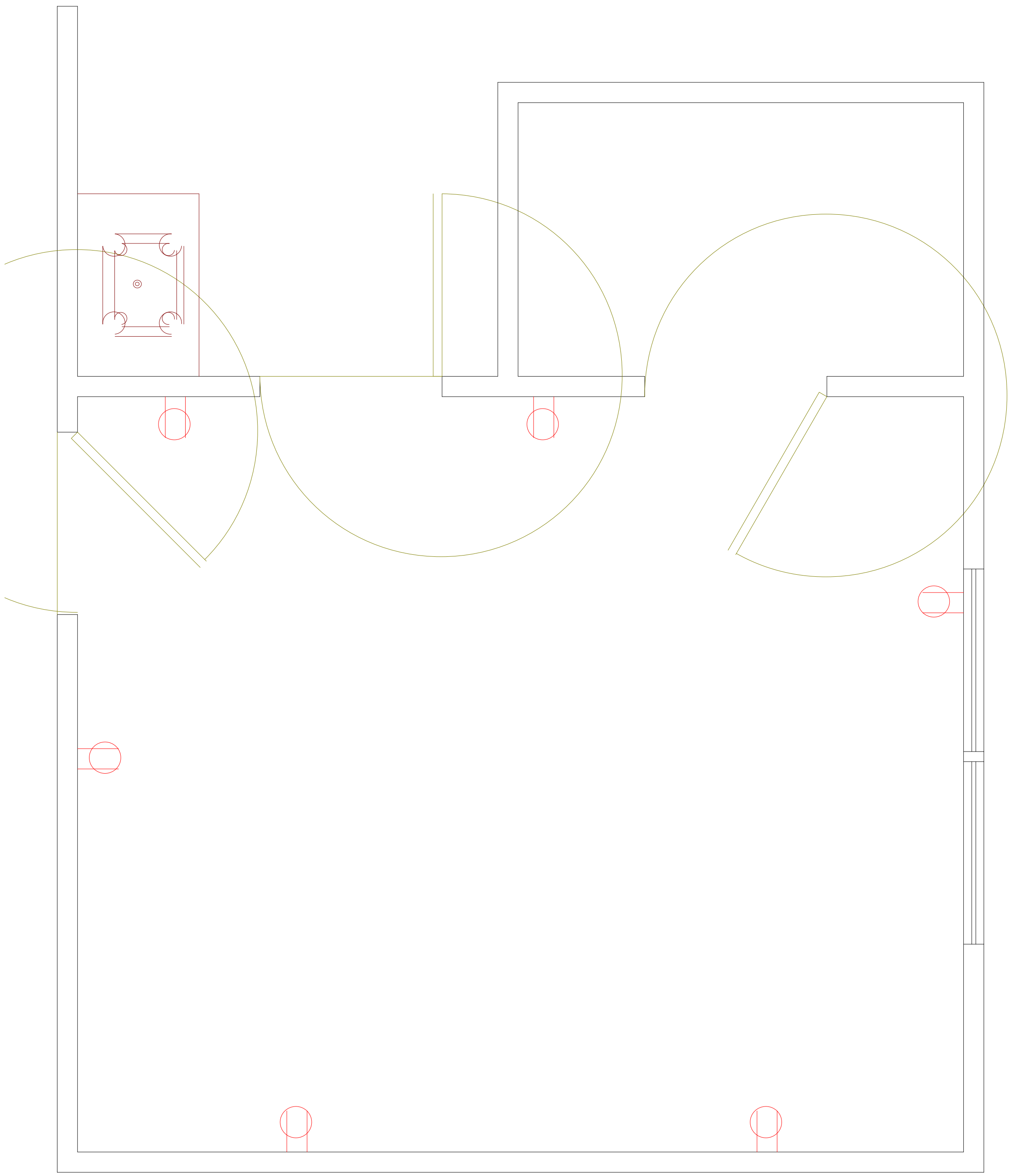


EXHIBIT 1

Applying the exception to this scenario, the receptacle behind the door will not be installed as there are other receptacles within 6 feet of that space.

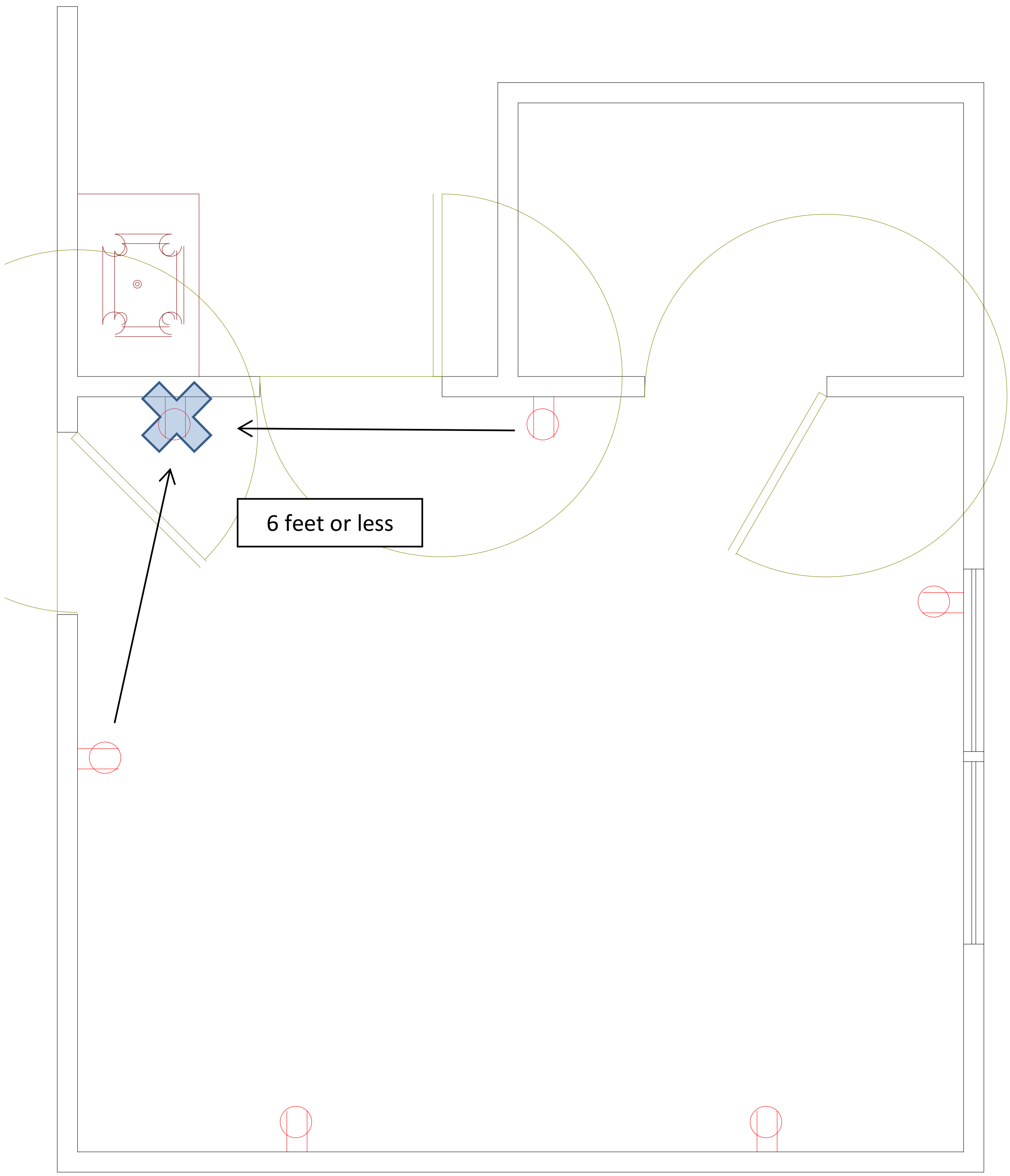


EXHIBIT 2

In this example, the receptacle by the entrance door would be required. The space is more than 2 feet and there is plenty of room to place the receptacle and comply with the code.

EXHIBIT 3

In this example, the entrance door swings in a different way and when placing the receptacle as required in 210.52(A)(2)(1), such receptacle will be behind the door. The purpose of the exception is to 1) eliminate receptacles behind doors and 2) limit the amount of receptacles in odd locations. With the exception you will not place a receptacle at this location if there is a receptacle outlet within 6 feet of the space.

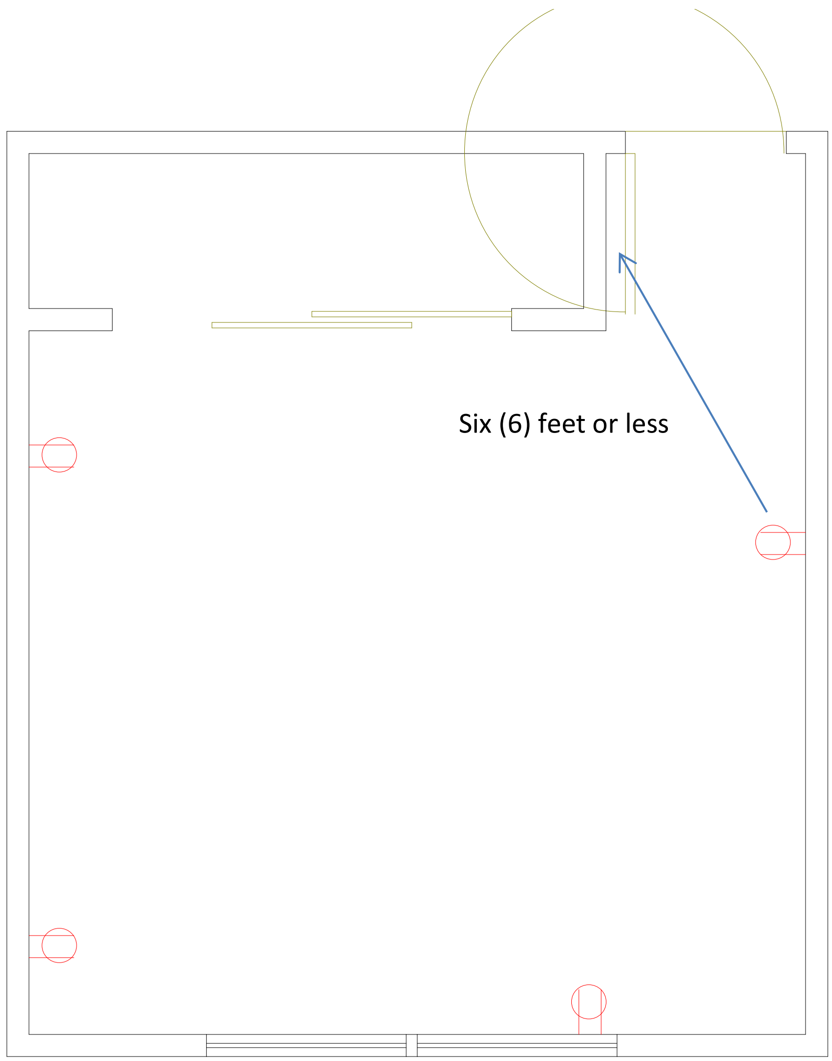


EXHIBIT 4

This is a good example where you have several doorways and openings and the space is more than 2 feet. Every wall space must have a receptacle. See Exhibit 5.

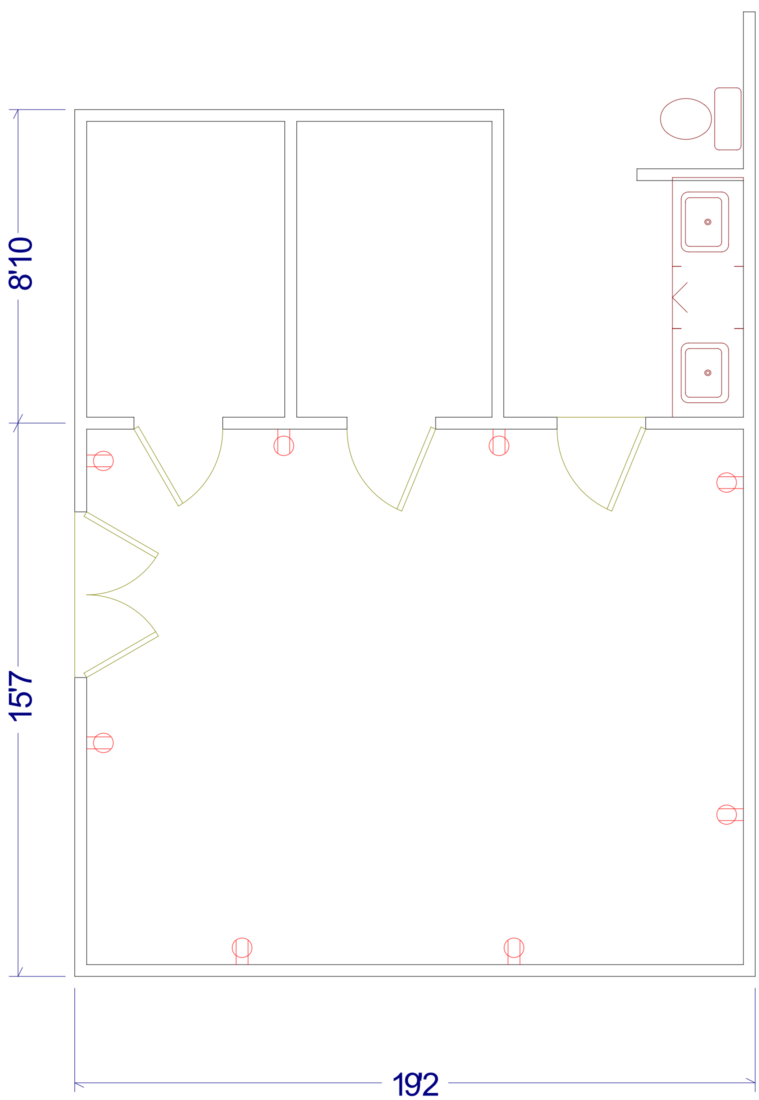
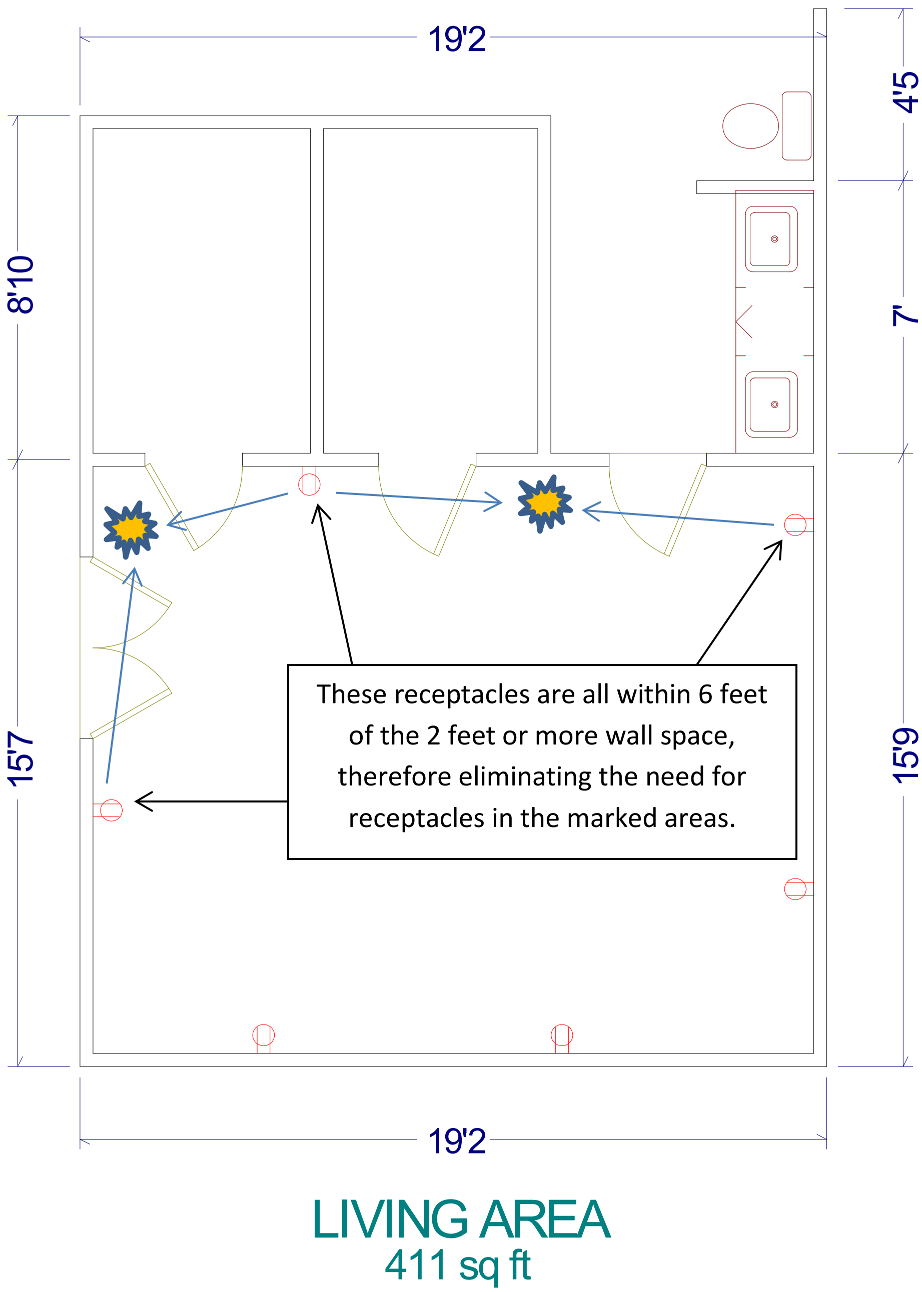


EXHIBIT 4

By looking at Exhibit, the placement of receptacles is as good as 210.52(A)(1) and you will not end up with receptacles in odd locations .



Public Input No. 202-NFPA 70-2017 [Section No. 210.52(A)(2)]

(2) Wall Space.

As used in this section, a wall space shall include the following:

(1) Any space 600 mm (2 ft) or more in width (including space measured around corners) and unbroken along the floor line by doorways and similar openings, fireplaces, and fixed cabinets

that do not have countertops or similar work surfaces

(2) The space occupied by fixed panels

in

walls, excluding sliding panels

(3) The space afforded by fixed room dividers, such as ~~freestanding bar-type counters or railings~~ partial height walls.

Additional Proposed Changes

File Name	Description	Approved
DSCF0560.JPG	Railing Sample	✓
DSCF0562.JPG	Railing Sample 1	✓
IMG_0522.JPG	Railing Sample 2	✓
IMG_0369_BAR_LIKE.jpg	Free Standing Bar-Type Counter	✓

Statement of Problem and Substantiation for Public Input

A "free standing bar-type counters" could be different pieces of cabinets, furniture, or perhaps an island with a sink in a basement. The kitchen island or peninsula could also divide a room, we do not count those as wall spaces, for the purpose of placing receptacles. Regarding the "railings", is the Code referring to guardrails or the decorative rails that divide the rooms in the split-level dwellings? There are guardrails to prevent fall into opening in the floor for stairs. Some of these stairs are located in areas that a placement of a receptacle is inconvenient and useless. The proposed change to "partial height wall" would cover most areas where a framed wall is constructed. That would include the areas for floor openings for stairs.

Submitter Information Verification

Submitter Full Name: Lorenzo Adam
Organization: City Of Mason
Street Address:
City:
State:
Zip:
Submittal Date: Mon Feb 06 13:00:13 EST 2017

Copyright Assignment

I, Lorenzo Adam, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Lorenzo Adam, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature


950A
WHITE / BLANCO
950A

Public Input No. 2384-NFPA 70-2017 [Section No. 210.52(A)(2)]

(2) Wall Space.

As used in this section, a wall space shall include the following:

(1) Any space 600 mm (2 ft) or more in width (including space measured around corners) and unbroken along the floor line by doorways and similar openings, fireplaces, and fixed cabinets that do not have countertops or similar work surfaces

(2) The space occupied by fixed panels in walls, excluding sliding panels

(3) The space afforded by fixed room dividers, such as freestanding bar-type counters or railings

Excepton: Wall space behind a door that swings against the wall shall not be measured as wall space as required by 210.52(A)(2)

Additional Proposed Changes

File Name	Description	Approved
8-17-2017_006.JPG	door	
8-17-2017_007.JPG	short wall	
8-17-2017_008.JPG	receptacle	
8-17-2017_009.JPG	closed door	

Statement of Problem and Substantiation for Public Input

See attached photo's
Cords install into a receptacle behind a door could get damage by the swinging door against the cord and the wall. This could become a fire hazard.
This measurement should start at the edge of the door when open at full swing for the wall space.

Submitter Information Verification

Submitter Full Name: John Plourde
Organization: CITY OF PORTSMOUTH NH
Affilliation: INSPECTION DEPARTMENT
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 17 15:07:09 EDT 2017

Copyright Assignment

I, John Plourde, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am John Plourde, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 257-NFPA 70-2017 [Section No. 210.52(A)(2)]

(2) Wall Space.

As used in this section, a wall space shall include the following:

(1) Any space 600 mm (2 ft) or more in width (including space measured around corners) and unbroken along the floor line by any of the following: doorways and ~~similar~~ similar openings, fireplaces, ~~and~~ fixed cabinets that do not have countertops or similar work surfaces , or spaces dedicated for the installation of appliances including but not limited to ranges and refrigerators.

(2) The space occupied by fixed panels

in

walls, excluding sliding panels

(3) The space afforded by fixed room dividers, such as freestanding bar-type counters or railings

Additional Proposed Changes

File Name	Description	Approved
DSC_0205.JPG	presently-wall space behind electric range requires receptacle on 20amp small appliance circuit	✓
IMG_0613.JPG	presently-wall space behind range requires receptacle on a 20amp small appliance circuit	✓
DSCF3155.JPG	presently-wall space behind range requires receptacle on 20amp small appliance circuit	✓
fridge_against_wall_1.JPG	presently-wall space behind fridge requires receptacle on 20amp small appliance circuit	✓
fridge_against_wall_2.JPG	presntly-wall space behind fridge requires receptacle on 20amp small appliance circuit	✓
210.52_A_2_.jpg	wall space behind range	✓

Statement of Problem and Substantiation for Public Input

The present wording in the code literally requires a 125volt 15amp or 20amp receptacle for the wall space occupied by large kitchen appliances such as electric ranges, or other large appliances that may need 250-volt circuits or 30-amp circuits, since this space is not broken along the floor line by a doorway, fireplace, or fixed cabinets. The photos I submitted will help make this point clear. There is simply no practical need for a 125v receptacle to be installed in the wall space behind the electric range or 250volt freezer in my kitchen. My proposal will help clarify this issue. It will also provide relief for the requirements of section 210.52(B)(1) exception 2 for example. The literal wording in that section presently always requires a 20-amp small appliance branch circuit to supply a receptacle for the wall space behind a refrigerator, since the exception says "in addition to the required receptacles'. My proposal makes it clear that a wall receptacle on a 20-amp small appliance circuit should not be "required" behind the refrigerator where a receptacle on an individual 15-amp circuit was installed.

Submitter Information Verification

Submitter Full Name: Russ Leblanc
Organization: Leblanc Consulting Services
Street Address:
City:
State:
Zip:
Submittal Date: Sat Feb 18 16:23:44 EST 2017

Copyright Assignment


11.26.2016


LEFT FRONT
LEFT REAR
OVEN TEMP
GENERAL ELECTRIC
RIGHT REAR
RIGHT FRONT


The wall space behind this
electric range is presently
included in the literal
wording of the requirements
in 210.52(A)(2)

Public Input No. 1415-NFPA 70-2017 [New Section after 210.52(A)(4)]

210.52(A)(5) USB Charging Outlet Devices and Combination USB Charging and Tamper-resistant Receptacle Outlet Devices

At least one of the receptacle outlet locations specified in Article 210.52(B)(3)(C)(1), 210.52(B)(3)(C)(2), 210.52(B)(3)(C)(3), or 210.52(B)(3)(C)(4) shall be a combination USB charging and tamper-resitant receptacle outlet device. The combination USB charging and tamper-resistant receptacle outlet device shall be a listed product.

Exception: In lieu of a combination USB charging and tamper-resitant receptacle outlet device, an individual USB charging outlet device may be installed to satisfy this requirement. The individual USB charging outlet device shall be a listed product.

Additional Proposed Changes

File Name	Description	Approved
receptacleChargerOverheat.pdf	Catastrophic-charger-failure-resulting-in-house-fire	✓

Statement of Problem and Substantiation for Public Input

The substantion for the proposed change is to help eliminate cords and unlisted plug-in type chargers, and also to provide added convenience to the consumer.

With today's ever increasing technology, the use of separate charging adapters has become the norm. In some cases, the external USB charging devices have been known to overheat and fail, leading to extreme loss of property caused by fire. We recently had a case in Wyoming whereby one of our very own electrical inspectors lost her entire home due to fire caused by one of these overheating devices. The fire report is attached.

If a combination receptacle outlet/USB device or individual USB charging device was required on new construction, in the event of overheating or catastrophic failure of the device, the failure would be contained INSIDE of a UL listed electrical box. This would greatly reduce any chance of property damage due to fire.

I see no downside to writing this requirement into the code. Added cost would be very minimal and probably go unnoticed. By requiring just one, it alerts the consumer to the fact that these devices are readily available and provides at least one convenience outlet for their ever-increasing use of mutiple electronic devices such as cell phones, tablets, mp3 devices, portable amplyfying speaker, etc., the list goes on and on. This would also provide the builder with the possiblity to showcase this new requirement to the consumer who may even request additional convenience devices in additional locations not mandated by NEC.

I see this as a win (consumer), win (home builder), win (manufacturer), and hope that you will consider adding this requirement to the code.

Submitter Information Verification

Submitter Full Name: Nick Sasso

Organization: State of Wyoming

Affilliation: www.electrical-code-expert.com
Street Address:
City:
State:
Zip:
Submittal Date: Fri Jul 28 12:20:40 EDT 2017

ORIGIN & CAUSE UPDATE

DATE PREPARED:	1/20/17
CLAIM #:	034924761
INSURED:	David Allred
LOSS LOCATION:	
DATE OF LOSS:	1/13/17
DATE OF INVESTIGATION:	1/18/17
INVESTIGATOR/COMPANY:	Dennis Jones / CASE Forensics / CASE File: 3000335
CONTACT INFORMATION:	P

INCIDENT SCENE DOCUMENTATION:

TYPE OF STRUCTURE:	A single-family residence
# OF STORIES:	One with an unfinished basement
AREA OF ORIGIN:	South living room wall
IGNITION SOURCE:	Failure in a Samsung® tablet charger
FIRST FUEL IGNITED:	The plastic housing of the charger and a sofa.
CAUSE CLASSIFICATION:	[X] **Accidental** (2014 edition N.F.P.A 921.20.1.1.) **Accidental Fire Cause.** Accidental fires involve all those for which the proven cause does not involve an intentional human act to ignite or spread fire into an area where the fire should not be. [ ] **Natural** (2014 edition N.F.P.A 921.20.1.2). **Natural Fire Cause.** Natural fire causes involve fires caused without direct human intervention or action, such as fires resulting from lightning, earthquake, and wind. [ ] **Incendiary** (2014 edition N.F.P.A 921.20.1.3). **Incendiary Fire Cause.** The incendiary fire is one intentionally ignited under circumstances in which the person igniting the fire knows the fire should not be ignited. [ ] **Undetermined** (2014 edition N.F.P.A 921.20.1.4). **Undetermined Fire Cause.** Whenever the cause cannot be proven to an acceptable level of certainty, the proper classification is undetermined. **(A)** Undetermined fire causes include those fires that have not yet been investigated or those that have been investigated, or are under investigation, and have insufficient information to classify further. However, the fire might still be under investigation and the cause may be determined later with the introduction or discovery of new information.

INVESTIGATION SUMMARY:

The origin of the fire was determined by use of the scientific method and through the coordination of witness statements, fire patterns, arc mapping and fire dynamics as set forth in NFPA 921.

Mr. David Allred (401-274-7474) and his wife Susan Allred (307-871-0035), the property owners and Liberty Mutual insureds, stated that they had owned the property for approximately 3 years. The house was built in 1940. Neither of them smoked tobacco. Mr. Allred is the Senior Building Inspector for Green River, Wyoming and Mrs. Allred is an Electrical Compliance Inspector for the State of Wyoming. Mrs. Allred stated that on the afternoon of January 13, 2017, sometime between 3:00 and 4:00 p.m. she plugged a Samsung® tablet charger into a duplex receptacle in the south living room wall and began charging her cell phone. At about 5:30 p.m. she retrieved her phone, but left the charger plugged into the receptacle. She and Mr. Allred then left and drove to Rock Springs. They returned home at approximately 7:30 p.m. Mr. Allred opened the front door and observed heavy black smoke in the house. He ran to the back door and opened it to air out. When the smoke had cleared a little he observed fire on the sofa in the living room. He attacked and extinguished the fire with two fire extinguishers. Mrs. Allred stated that she had purchased the Samsung® tablet and charger, about 10 years prior to the fire. Recently whenever she tried to charge the tablet she would get an error message stating that charging had ceased because the battery was too hot.

Examination of the fire scene revealed fire damage in the southeast corner of the living room. The burn patterns vectored to the area surrounding the heavily damaged duplex receptacle on the south living room wall. That was the receptacle that the tablet charger was plugged into. Both the charger and receptacle were heavily damaged. The lack of fire damage observed on the plastic receptacle box after the receptacle was removed from the wall indicated that the fire did not originate inside of the receptacle. The fire patterns established that the arm of the sofa had been against the south wall and the charger/receptacle at the time of the fire. The observed fire damage was consistent with the fire originating at the Samsung® tablet charger and spreading to the sofa. No other potential ignition source was located anywhere near the area of origin.

This is a summary of findings at the above loss. It is not intended to replace a full report that would be submitted under the guidelines of NFPA 921 or ASTM Standards. A complete investigation has been conducted; however, should additional information become available at a later date, CASE reserves the right to evaluate that new information. A report is available upon request.

If you have any questions or comments please contact the undersigned at (801) 372-8126 or djones@CASE4N6.COM.

Respectfully Submitted:	Reviewed by:
Dennis Jones	Craig Rice, PE, CFI
Senior Fire Investigator	Senior Electrical Engineer
CASE Forensics Corporation	CASE Forensics Corporation

Photograph 1. 1-18-17 DLJ, IMG_0002: The front (south) elevation of the residence.

Photograph 2. 1-18-17 DLJ, IMG_0011: Looking east at the fire damage in the living room.

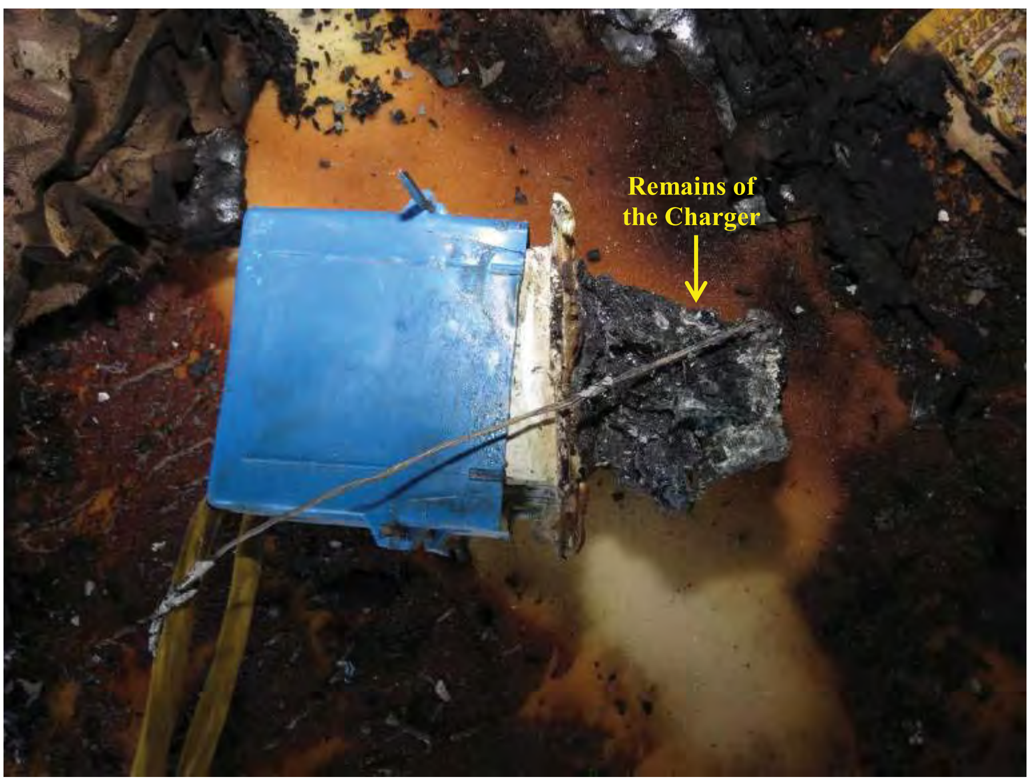
Photograph 3. 1-18-17 DLJ, IMG_0041: Fire damage in the southeast corner of the living room.


Photograph 4. 1-18-17 DLJ, IMG_0044: The area of origin of the fire.

Photograph 5. 1-18-17 DLJ, IMG_0048: The receptacle and remains of the charger.

Photograph 6. 1-18-17 DLJ, IMG_0052: A closer view of the damaged receptacle and charger.

Photograph 7. 1-18-17 DLJ, IMG_0053: An additional image of the outlet and charger.



Photograph 8. 1-18-17 DLJ, IMG_0068: The undamaged receptacle box seen after the receptacle was removed from the wall.

Public Input No. 1649-NFPA 70-2017 [New Section after 210.52(C)]

Section 210.52(C)(6)

(6) Countertops and Work Surfaces Without Walls. A receptacle outlet shall be installed at each countertop and work surface that is 300 mm (12 in.) or wider. Receptacle outlets shall be installed so that no point along the countertop or work surface is more than 600 mm (24 in.) measured horizontally from a receptacle outlet in that space. Receptacle outlets shall be l ocated on or above, but not more than 500 mm (20 in.) above, the countertop or work surface and shall not be installed greater than 150 mm (6 in.) below the countertop(s) or work surface(s).

Statement of Problem and Substantiation for Public Input

Some kitchens these days are designed using modern architecture and exposed warehouse looks. Some kitchens have only islands with no walls in the kitchen area, just large islands with significant countertop spaces. To apply the single receptacle outlet rule to these kitchen designs would be insufficient. There are many types of equipment and devices that can be installed to meet the receptacle outlet requirement without creating a hardship or an eye sore. It's time for the NEC to close this gap and provide rules that reflect the needs of kitchen both modern and traditional designs. A companion public input deletes 210.52(C)(2) as this rule would cover the previous island receptacle outlet requirements and be more adequate relative to the number of receptacles necessary. One receptacle outlet is not enough at an island, in many cases.

Submitter Information Verification

Submitter Full Name: Agnieszka Golriz

Organization: NECA

Street Address:

City:

State:

Zip:

Submittal Date: Thu Aug 03 10:48:33 EDT 2017

Public Input No. 258-NFPA 70-2017 [Section No. 210.52(B)(1)]

(1) Receptacle Outlets Served.

In the kitchen, pantry, breakfast room, dining room, or similar area of a dwelling unit, the two or more 20-ampere small-appliance branch circuits required by 210.11(C)(1) shall serve all wall and floor receptacle outlets covered by 210.52(A), all countertop outlets covered by 210.52(C), and receptacle outlets for refrigeration equipment.

Exception No. 1: In addition to the required receptacles specified by 210.52, switched receptacles supplied from a general-purpose branch circuit rated 15 amperes or greater as defined in 210.70(A)(1), Exception No. 1, shall be permitted.

Exception No. 2:

In addition to the required receptacles specified by 210.52 , a receptacle outlet to serve a specific appliance

shall be permitted to be supplied from an individual branch circuit rated 15 amperes or greater.

Statement of Problem and Substantiation for Public Input

Many lighting circuits are 15 amp circuits. The present wording in this exception does not specify the rating of the circuit and as such, many installers and inspectors are unsure if 15 amp circuits would be permitted for this purpose or if 20-amp circuits would still be needed. My proposal makes it clear that 15-amp or 20-amp circuits would be permitted per this exception.

Submitter Information Verification

Submitter Full Name: Russ Leblanc

Organization: Leblanc Consulting Services

Street Address:

City:

State:

Zip:

Submittal Date: Sat Feb 18 16:54:05 EST 2017

Public Input No. 455-NFPA 70-2017 [Section No. 210.52(B)(1)]

(1) Receptacle Outlets Served.

In the kitchen, pantry, breakfast room, dining room, or similar area of a dwelling unit, the two or more 20-ampere small-appliance branch circuits required by 210.11(C)(1) shall serve all wall and floor receptacle outlets covered by 210.52(A), all countertop outlets covered by 210.52(C), and receptacle outlets for refrigeration equipment.

Exception No. 1: In addition to the required receptacles specified by 210.52, switched receptacles supplied from a general-purpose branch circuit ~~as defined in 210.70(A)(1), Exception No. 1,~~ shall be permitted.

Exception No. 2: In addition to the required receptacles specified by 210.52, a receptacle outlet to serve a specific appliance shall be permitted to be supplied from an individual branch circuit rated 15 amperes or greater.

Statement of Problem and Substantiation for Public Input

210.70(A)(1) contains no definitions. Furthermore, including the reference to that exception doesn't appear to add anything to the allowance.

Submitter Information Verification

Submitter Full Name: Ryan Jackson

Organization: Ryan Jackson

Street Address:

City:

State:

Zip:

Submittal Date: Fri Mar 31 14:44:54 EDT 2017

Public Input No. 513-NFPA 70-2017 [Section No. 210.52(B)(1)]

(1) Receptacle Outlets Served.

In the kitchen, pantry, breakfast room, dining room, or similar area of a dwelling unit, the two or more 20-ampere small-appliance branch circuits required by 210.11(C)(1) shall serve all wall and floor receptacle outlets covered by 210.52(A), all countertop outlets covered by 210.52(C), and receptacle outlets for refrigeration equipment.

Exception No. 1: ~~In~~ In addition to the required receptacles specified by 210.52, ~~switched receptacles supplied from~~ a ~~general-purpose branch circuit as defined in~~ ~~210.70(A)(1)~~ ~~,~~ ~~Exception No. 1, shall be permitted. Exception No. 2: In addition to the required receptacles specified by~~ ~~210.52~~ ~~, a~~ receptacle outlet to serve a specific appliance shall be permitted to be supplied from an individual branch circuit rated 15 amperes or greater.

Statement of Problem and Substantiation for Public Input

This seems to be unnecessary exception in the code. The additional switched receptacle is confusing for the electrician and certainly for the homeowner. It leave a situation that a homeowner could use the 15 amp circuit in the area when a 20 amp is available.
We entertain in our kitchens and dinning area with warmers, crock pots and other cooking equipment placed on tables that are best suited for a 20 amp circuit. The switched receptacle could easily be achieved by half switching a duplex receptacle on a 20 amp circuit that is already in the area and could be used for a portable lamp. I believe that this would simplify things and avoid the possibility of overloading a general lighting circuit with appliances that are intended to be use on a 20 amp branch circuit.

Submitter Information Verification

Submitter Full Name: Martin Vaughan

Organization: Metro Community College

Street Address:

City:

State:

Zip:

Submittal Date: Tue Apr 11 15:12:44 EDT 2017

Public Input No. 1647-NFPA 70-2017 [Section No. 210.52(C)]

(C) Countertops and Work Surfaces.

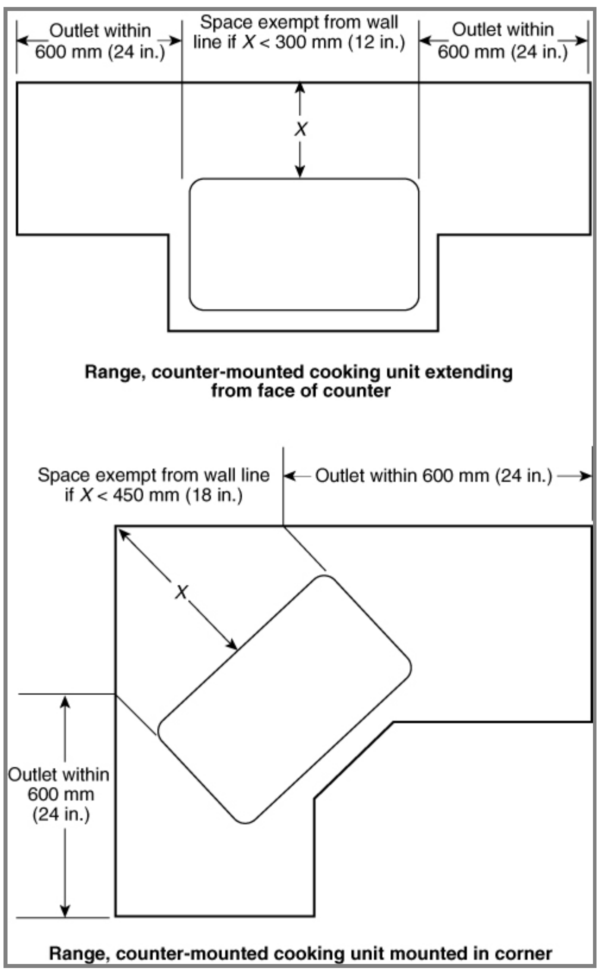
In kitchens, pantries, breakfast rooms, dining rooms, and similar areas of dwelling units, receptacle outlets for countertop and work surfaces shall be installed in accordance with 210.52(C)(1) through (C)(5) ~~.~~

(1) ~~Wall~~ Countertop and Work Surface.

A receptacle outlet shall be installed at each ~~wall~~ countertop and work surface that is 300 mm (12 in.) or wider. Receptacle outlets shall be installed so that no point along the ~~wall line~~ coutertop or work surface is more than 600 mm (24 in.) measured horizontally from a receptacle outlet in that space.

Exception: Receptacle outlets shall not be required ~~on a wall~~ directly behind a range, counter-mounted cooking unit, or sink in the installation described in Figure 210.52(C)(1).

Figure 210.52(C)(1) Determination of Area Behind a Range, Counter-Mounted Cooking Unit, or Sink.



~~**(2)** Island Countertop Spaces.~~

~~At least one receptacle shall be installed at each island countertop space with a long dimension of 600 mm (24 in.) or greater and a short dimension of 300 mm (12 in.) or greater.~~

~~**(3)** Peninsular Countertop Spaces.~~

~~At least one receptacle outlet shall be installed at each peninsular countertop long dimension space with a long dimension of 600 mm (24 in.) or greater and a short dimension of 300 mm (12 in.) or greater. A peninsular countertop is measured from the connected perpendicular wall.~~

~~**(4)** Separate Spaces.~~

~~Countertop spaces separated by rangetops, refrigerators, or sinks shall be considered as separate countertop spaces in applying the requirements of 210.52(C)(1). If a range, counter-mounted cooking unit, or sink is installed in an island or peninsular countertop and the depth of the countertop behind the range, counter-mounted cooking unit, or sink is less than 300 mm (12 in.), the range, counter-mounted cooking unit, or sink shall be considered to divide the countertop space into two separate countertop spaces. Each separate countertop space shall comply with the applicable requirements in 210.52(C).~~

~~(5)~~

Receptacle Outlet Location.

Receptacle outlets shall be located on or above, but not more than 500 mm (20 in.) above, the countertop or work surface. Receptacle outlet assemblies listed for use in countertops or work surfaces shall be permitted to be installed in countertops or work surfaces. Receptacle outlets rendered not readily accessible by appliances fastened in place, appliance garages, sinks, or rangetops as covered in 210.52(C)(1), Exception, or appliances occupying dedicated space shall not be considered as

~~these~~

required outlets

~~.~~

> ~~Informational Note: See 406.5(E) and 406.5(G) for requirements for installation of receptacles in countertops and 406.5(F) and 406.5(G) for requirements for installation of receptacles in work surfaces.~~

~~Exception to (5): To comply with the following conditions (1) and (2), receptacle outlets~~

for countertop and work surfaces.

Receptacle outlets required by this section shall be permitted to be installed ~~mounted~~ not more than

~~300 mm~~

300 mm (

~~12 in~~

12 in .) below the countertop or work surface. Receptacles installed ~~mounted~~ below a countertop or work surface ~~in accordance~~ ~~with this exception~~ shall not be located where the countertop or work surface extends more than

~~150 mm~~

150 mm (

~~6 in On island and peninsular countertops or work surface where the surface is flat across its entire surface (no backsplashes, dividers, etc.) and there are no means to mount a receptacle within 500 mm (20 in.) above the countertop or work surface, such as an overhead cabinet~~

6 in .) beyond its support base.

- ~~Construction for the physically impaired~~

> Informational Note: See Annex J for information ADA Standards for Accessibility Designs and ANSI/ICC A117.1-2009

Statement of Problem and Substantiation for Public Input

This section seems to have grown over several cycles in a fashion that has resulted in unnecessary confusion and complexity in some cases. This does not have to be as complicated as it has become. Simplify the requirements and remove the insanity. Everything in the sections proposed for deletion can be covered by the reduced text. Many kitchen designs today don't include counters that have walls. Contractors are talented enough to be able to satisfy the simplified requirements as proposed with a multitude of materials and products available in the market today to support compliance with the section as revised. It's simple. Install receptacle outlets to serve kitchen countertop and work surfaces in a manner that results in a receptacle every 4 feet of countertop or work surface and that no point along the countertop or work surface is more than two feet without a receptacle outlet in that space. The requirement applies to peninsulas, islands, and all countertops and work surfaces period. The goal is to provide receptacles to serve those locations at the spacing required in the driving text of this section. The proposed revision would be clear, practical, easy to understand, and enforceable. It would allow jurisdictions to more easily apply the requirements and contractors the flexibility to use their expertise to meet the requirements. There is no reason to continue this practice of making this simple rule more complicated every cycle. The continuing need for more receptacles in dwelling more than justifies any receptacle outlet requirement that is in addition to receptacles that are currently required in this rule. The informational note referring to Sections of Article 406 is unnecessary and redundant as these are general requirements for receptacle installation. If the Code panel does not accept this proposed revision that simplifies and provides clear requirements for receptacles in these locations, then it is highly recommended that the committee revise the section as it sees fit to accomplish a similar and necessary result.

Submitter Information Verification

Submitter Full Name: Agnieszka Golriz
Organization: NECA
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 03 10:24:11 EDT 2017

Public Input No. 1765-NFPA 70-2017 [Section No. 210.52(C) [Excluding any Sub-Sections]]

In kitchens, pantries, breakfast rooms, dining rooms, and similar areas of dwelling units, receptacle outlets for countertop and work surfaces shall be installed in accordance with 210.52(C)(1) through (C)(5) and shall not be considered as the receptacle outlets required by 210 . 52(A).

Statement of Problem and Substantiation for Public Input

Receptacle outlet installations covered in (C) are separate from those covered by requirements in 210.52(A). This change makes it clear that the receptacle outlets installed for the countertop or work surfaces are not permitted to satisfy the requirement for receptacle outlet placement as provided in 210.52(A).

Submitter Information Verification

Submitter Full Name: Agnieszka Golriz
Organization: NECA
Street Address:
City:
State:
Zip:
Submittal Date: Fri Aug 04 12:01:39 EDT 2017

Public Input No. 2119-NFPA 70-2017 [Section No. 210.52(C)(1)]

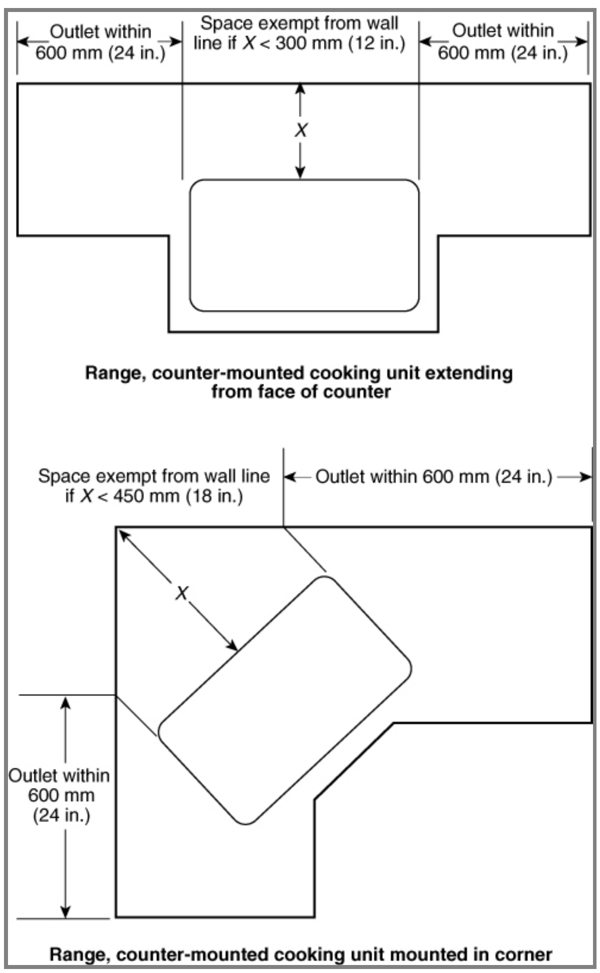
(1) Wall Countertop and Work Surface.

A receptacle outlet shall be installed at each wall countertop and work surface that is 300 mm (12 in.) or wider. Receptacle outlets shall be installed so that no point along the wall line is more than 600 mm (24 in.) measured horizontally from a receptacle outlet in that space.

Exception No. 1 :- - Receptacle outlets shall not be required on a wall directly behind a range, counter-mounted cooking unit, or sink in the installation described in Figure 210.52(C)(1).

Exception No. 2: Receptacle outlets shall not be required where there is no wall space, or backspash between the countertop and a pass through in the inside or outside of a delling unit. The requirement of 210.52(C)(1) shall not be required along this space.

Figure 210.52(C)(1) Determination of Area Behind a Range, Counter-Mounted Cooking Unit, or Sink.



Additional Proposed Changes

File Name	Description	Approved
july_4_pics_180.JPG	pass thru to screen porch	✓
july_4_pics_178.JPG	pass thru	✓

july_4_pics_174.JPG	windows	✓
july_4_pics_183.JPG	from inside screen porch	✓
july_4_pics_181.JPG	from porch to kitchen	✓
july_4_pics_184.JPG	closed windows	✓
july_4_pics_252.JPG	pop ups receptacles	✓
july_4_pics_253.JPG	pop ups lowered	✓

Statement of Problem and Substantiation for Public Input

Due to the problems of a counter top pass through in kitchens, the spacing describe in 210.52(C) could not be code compliant if the opening is larger than 42 inches due to the double jack studs on each side of the opening. Flush mounted receptacles could cause a problem with hot dishes passing through the pass through and hitting the flush mounted receptacles or pop up type receptacles to the dinning room or other areas, even outside, see the photo's attached. This pass through in the photo is on one of my inspection in Portsmouth NH with a 8 foot pass through into a screen porch area.
Food will be prepared in the kitchen and slide across the granite pass through to the outside dinning area. This installation is not a normal home in the State of NH, but pass through from kitchens to breakfast areas, or dinning rooms are very common in the City of Portsmouth NH. This is a hard ship to the homeowners and it is a safety issue as well.
I had to enforce this 210.52(C) section on this dwelling unit, and could not use 90.4 in the NEC.
This would clarify a lot of issues when it comes to pass though from the kitchen to other areas.

Submitter Information Verification

Submitter Full Name:	John Plourde
Organization:	CITY OF PORTSMOUTH ELECTRICAL INSPECTION DEPARTMENT
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Fri Aug 11 08:39:42 EDT 2017


WOLF
OPEN THIS END
17631566


Scrimshaw


RH

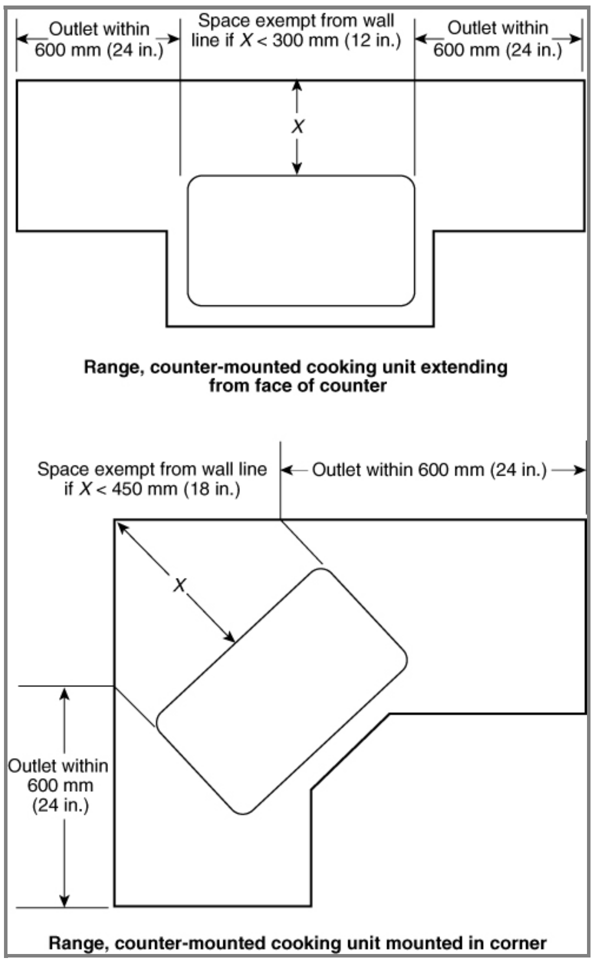
Public Input No. 3766-NFPA 70-2017 [Section No. 210.52(C)(1)]

(1) Wall Countertop and Work Surface.

A receptacle outlet shall be installed at each wall countertop and work surface that is 300 mm (12 in.) or wider. Receptacle outlets shall be installed so that no point along the wall line is more than 600 mm (24 in.) measured horizontally from a receptacle outlet in that space.

Exception: Receptacle outlets shall not be required on a wall directly behind a range, counter-mounted cooking unit, or sink in the installation described in Figure 210.52(C)(1).

Figure 210.52(C)(1) Determination of Area Behind a Range, Counter-Mounted Cooking Unit, or Sink.



Additional Proposed Changes

File Name	Description	Approved
210.52_C_1_Fig_2020_NEC.jpg	Replace the existing Figure 210.52(C)(1) with the figure provided	✓

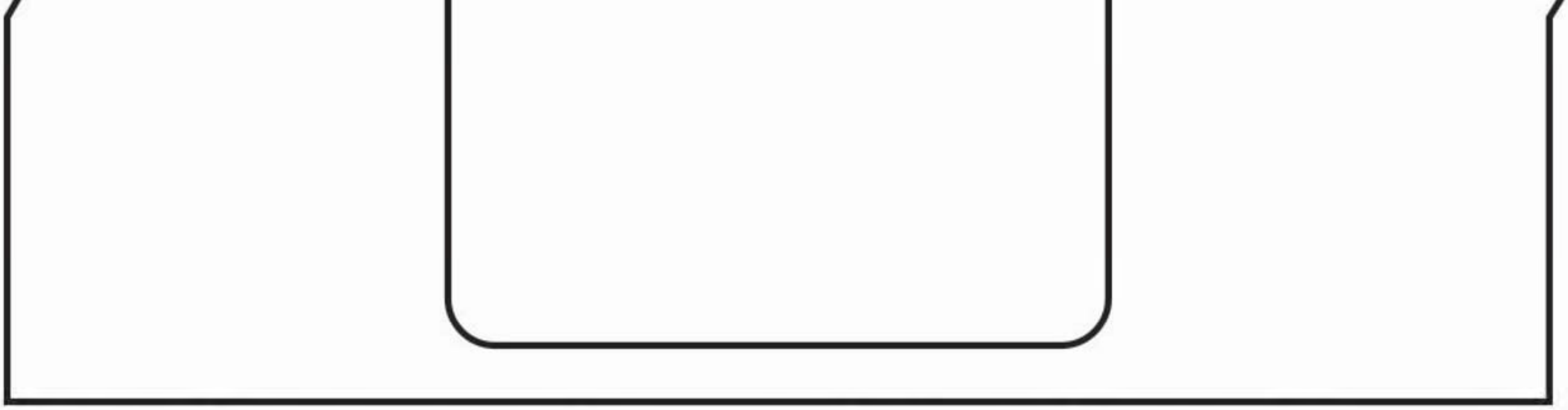
Statement of Problem and Substantiation for Public Input

My intention is to replace Figure 210.52(C)(1) with the figure provided as a graphic. The caption for the

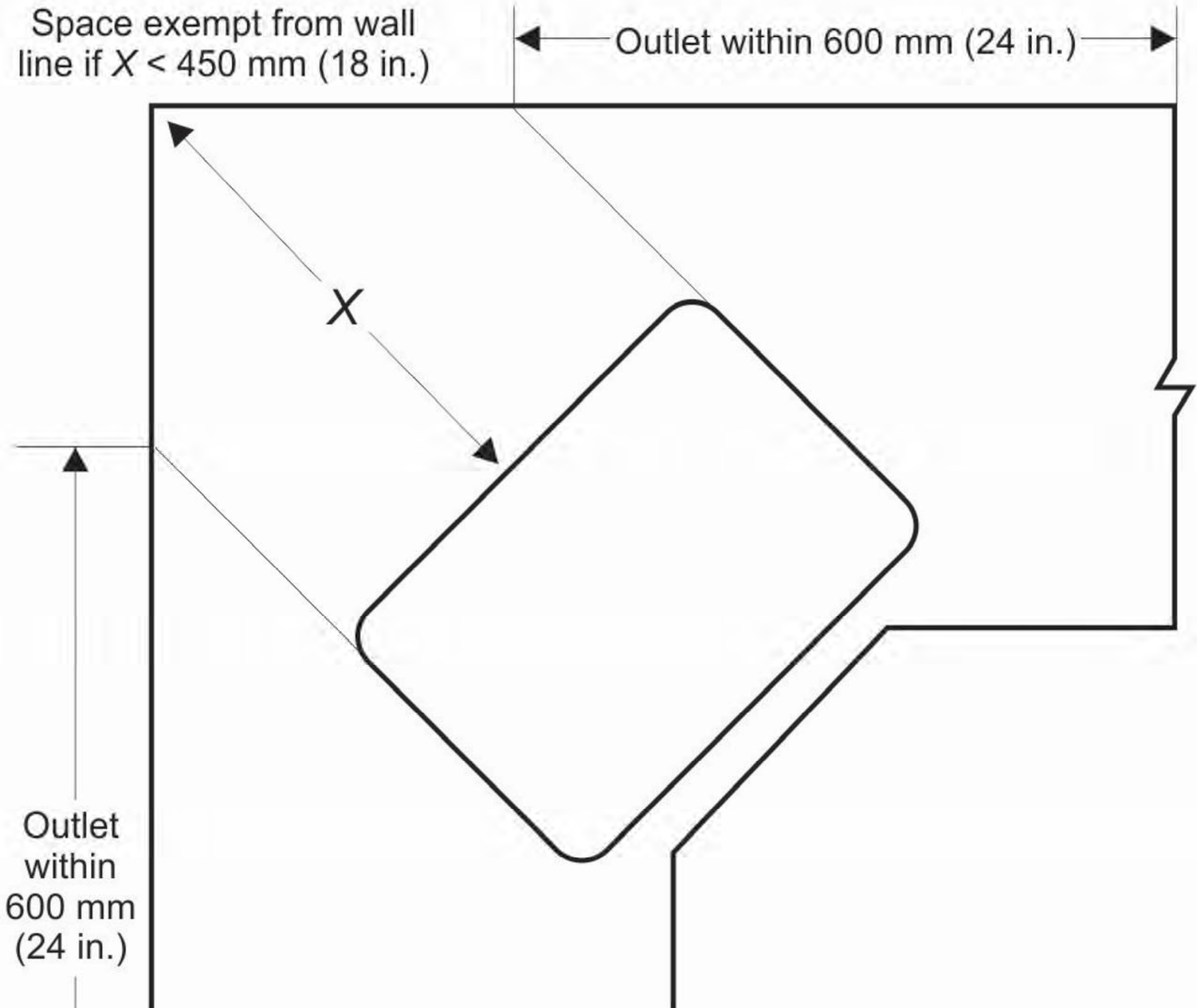
figure appears to be correct.
The upper drawing in Figure 210.52(C)(1) needs to be revised as shown as most commonly, counter-mounted cooking units, rangetops and sinks do not extend from the face of kitchen counters. And, that is not the issue being addressed. This section addresses whether or not a receptacle outlet is needed for a wall space. It is not uncommon for a range to extend beyond the face of the lower cabinet but that feature is not shown in either drawing. The figure should also be used for 210.52(C)(4) to illustrate "Separate Spaces". The appliance or sink create a separation of the counter top for the purpose of determining the appropriate placement of receptacle outlets. If there is less than the prescribed distance shown at the "X", a receptacle is not required.
In addition, the inner caption for both drawings should be replaced to include "sink" because "sink" is included in both 210.52(C)(1) Exception and in 210.52(C)(4) as an object that can create a separate counter space or .

Submitter Information Verification

Submitter Full Name: Phil Simmons
Organization: Simmons Electrical Services
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 06 20:55:49 EDT 2017



Range, counter-mounted cooking unit or sink in counter space



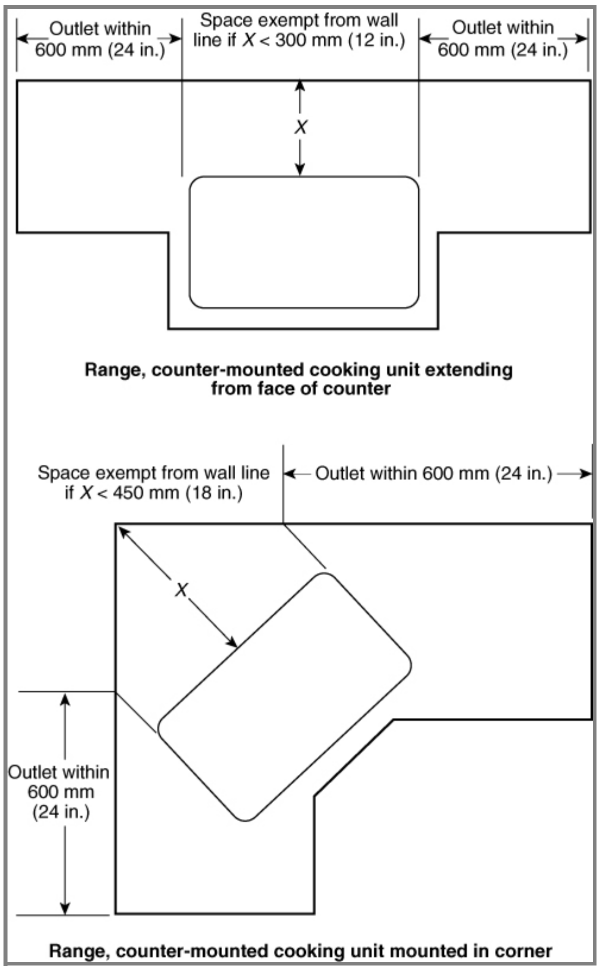
Public Input No. 3809-NFPA 70-2017 [Section No. 210.52(C)(1)]

(1) Wall Countertop and Work Surface.

A receptacle outlet shall be installed at each wall countertop and work surface that is 300 mm (12 in.) or wider. Receptacle outlets shall be installed so that no point along the wall line is more than 600 mm (24 in.) measured horizontally from a receptacle outlet in that space.

Exception: Receptacle outlets shall not be ~~required~~ allowed on a wall directly behind a range ~~,~~ or counter-mounted cooking unit, or required behind a sink in the installation described in Figure 210.52(C)(1).

Figure 210.52(C)(1) Determination of Area Behind a Range, Counter-Mounted Cooking Unit, or Sink.



Statement of Problem and Substantiation for Public Input

Where the space behind a range or counter-mounted cooking unit is too small for the appliance to also be placed in that space, cords are carried across the top of the burners. 12 inches is an appropriate number for the definition of "too small" as that is also used in 210.52(C)(4) for the definition of separate countertop spaces.

Submitter Information Verification

Submitter Full Name: Douglas Hansen
Organization: Code Check
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 06 22:34:03 EDT 2017

Copyright Assignment

I, Douglas Hansen, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Douglas Hansen, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 1648-NFPA 70-2017 [Section No. 210.52(C)(2)]

~~**(2)** Island Countertop Spaces.~~

~~At least one receptacle shall be installed at each island countertop space with a long dimension of 600 mm (24 in.) or greater and a short dimension of 300 mm (12 in.) or greater.~~

Statement of Problem and Substantiation for Public Input

Some kitchens these days are designed using modern architecture and exposed warehouse looks. Some kitchens have only islands with no walls in the kitchen area, just large islands with significant countertop spaces. To apply the single receptacle outlet rule to these kitchen designs would be insufficient. There are many types of equipment and devices that can be installed to meet the receptacle outlet requirement without creating a hardship or an eye sore. It's time for the NEC to close this gap and provide rules that reflect the needs of kitchen both modern and traditional designs. A companion public input deletes 210.52(C)(2) as this rule would cover the previous island receptacle outlet requirements and be more adequate relative to the number of receptacles necessary. One receptacle outlet is not enough at an island, in many cases.

Submitter Information Verification

Submitter Full Name: Agnieszka Golriz

Organization: NECA

Street Address:

City:

State:

Zip:

Submittal Date: Thu Aug 03 10:42:03 EDT 2017

Public Input No. 1877-NFPA 70-2017 [Section No. 210.52(C)(2)]

(2) Island Countertop Spaces.

At least one receptacle shall be installed at each island countertop space with a long dimension of 600 mm (24 in.) or greater and a short dimension of 300 mm (12 in.) or greater. Unless there is a double, or raised counter top with a wall built behind the base cabinets to support the countertop, requirement for receptacles shall be as for countertops and work surfaces accordance to 210.52(C)(1)

Additional Proposed Changes

File Name	Description	Approved
july_4_pics_135.JPG	double top island	✓

Statement of Problem and Substantiation for Public Input

Double countertops that are raised 6 to 12 inches above the island supported by a wall should have wall spacing the same as the kitchen counter tops.
The wall mounted receptacle can serve both countertops. Two counter tops I would consider two islands and would require 2 receptacles.

Submitter Information Verification

Submitter Full Name: John Plourde
Organization: JP ELECTRICAL ENTERPRISES
Affilliation: JP ELECTRICAL ENTERPRISES
Street Address:
City:
State:
Zip:
Submittal Date: Mon Aug 07 18:12:39 EDT 2017

Public Input No. 1878-NFPA 70-2017 [Section No. 210.52(C)(3)]

(3) Peninsular Countertop Spaces.

At least one receptacle outlet shall be installed at each peninsular countertop long dimension space with a long dimension of 600 mm (24 in.) or greater and a short dimension of 300 mm (12 in.) or greater. A peninsular countertop is measured from the connected perpendicular wall. If a double or rised countertop is installed on top of a kneewall the requiremnts of 210.52(C)(1) shall apply.

Additional Proposed Changes

File Name	Description	Approved
july_4_pics_137.JPG	double countertop	✓
july_4_pics_138.JPG	double counter	✓

Statement of Problem and Substantiation for Public Input

Raised countertops that have a 6 inch to 12 wall above the lower countertop to support the upper counter top shall comply with 210.52(C)(1)

Submitter Information Verification

Submitter Full Name: John Plourde

Organization: JP ELECTRICAL ENTERPRISES

Street Address:

City:

State:

Zip:

Submittal Date: Mon Aug 07 18:41:01 EDT 2017


SCHLAGE


GRK

Public Input No. 2283-NFPA 70-2017 [Section No. 210.52(C)(3)]

(3) Peninsular Countertop Spaces.

At least one receptacle outlet shall be installed at each peninsular countertop ~~long dimension space with a long dimension of 600 mm (24 in.) or greater and a short dimension of 300 mm (12 in.) or greater. A peninsular~~ measuring 6' or longer. The peninsular countertop is measured from the connected perpendicular wall.

Exception to (3): If the peninslar countertop has no base construction which would allow a receptacle to be mounted. A receptacle installed on the conneced perpendicular wall meeting the installation requiremets of 210.52(C)(1) shall be permitted.

Statement of Problem and Substantiation for Public Input

As stated in the substantiation on Public Input No. 3605-NFPA 70-2014. "Many peninsulas are really attached kitchen tables, and present significant construction difficulties in providing a receptacle if the wall is not an eligible for placement".

However, once a peninsular counter exceeds 6 ft in distance from the wall, a receptacle should be required somewhere at its more distant margin to comply with 210.52(A)(2)(3). The new exception would allow for the wall receptacle, to be the required receptacle, in the event that there are no cabinets or construction to allow the receptacle to be installed under the countertop surface.

Submitter Information Verification

Submitter Full Name: Dean Hunter
Organization: Minnesota Department of Labor
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 15 19:27:05 EDT 2017

Public Input No. 2694-NFPA 70-2017 [Section No. 210.52(C)(3)]

(3) Peninsular Countertop Spaces.

At least one receptacle outlet shall be installed at each peninsular countertop long dimension space with a long dimension of 600 mm (24 in.) or greater and a short dimension of 300 mm (12 in.) or greater. A peninsular countertop is measured from the connected perpendicular wall. Receptacles installed for countertop and similar work surfaces as specified in 210.52(C)(1) and (C)(2) shall not be considered as the receptacle outlets required by (C)(3).

Statement of Problem and Substantiation for Public Input

As revised in the 2017 cycle, this requirement has created confusion. Clarity is needed.

Due to the manner in which this was revised, some have interpreted that a receptacle installed in accordance with 210.52(C)(1) could also serve as a receptacle required by 210.52(C)(3). That is incorrect. Each second level subdivision is a "stand alone" requirement.

The suggested text is just one idea to provide clarity.

Submitter Information Verification

Submitter Full Name: James Dollard
Organization: IBEW Local Union 98
Street Address:
City:
State:
Zip:
Submittal Date: Fri Aug 25 09:47:03 EDT 2017

Public Input No. 3057-NFPA 70-2017 [Section No. 210.52(C)(3)]

(3) Peninsular Countertop Spaces.

At least one receptacle outlet shall be installed on at each peninsular countertop ~~long dimension space~~ space with a long dimension of 600 mm (24 in.) or greater and a short dimension of 300 mm (12 in.) or greater. A peninsular countertop is measured from the connected perpendicular wall. A wall receptacle over the peninsular will fulfill this requirement provided that the peninsular is not longer than 4'. Receptacle outlets required on the peninsular shall be installed either at the end of the island or along the long dimension.

Statement of Problem and Substantiation for Public Input

The term long dimension means the receptacle outlet must be installed on the long sides of the peninsular. In most cases these peninsular's have a large over hang on one side for sitting and cabinets and draws on the opposite side making it virtually impossible to install a receptacle. The end of the peninsular has always been a reliable place to install an outlet. Pop up receptacles are unsightly and expensive.

The 4' dimension was a bit arbitrary but if a peninsular is only 4' long it seems that the wall outlet will suffice.

Submitter Information Verification

Submitter Full Name: Dennis Alwon

Organization: Alwon Electric

Street Address:

City:

State:

Zip:

Submittal Date: Thu Aug 31 11:25:56 EDT 2017

Public Input No. 3134-NFPA 70-2017 [Section No. 210.52(C)(3)]

(3) Peninsular Countertop ~~Spaces~~ And Pass Through Spaces .

At least one receptacle outlet shall be installed at each peninsular countertop long dimension space with a long dimension of 600 mm (24 in.) or greater and a short dimension of 300 mm (12 in.) or greater. A peninsular countertop is measured from the connected perpendicular wall.

Statement of Problem and Substantiation for Public Input

Pass through spaces or break through spaces are subject to a work surface without a back wall and walls on both sides of the long dimension with many different lengths of counter used for many purposes serving food, preparation of food, dining, entertainment, home work etc. laying out these countertop spaces with many pop up or trap door type of receptacles outlets seems to be more of a nuisance on the counter top as if the peninsular and island was treated with the same 24 in. wall rule to comply with 210.52(C)(1) and should be left to the discretion of the installer if more than one receptacle outlet is needed.

Submitter Information Verification

Submitter Full Name: Mark Rochon
Organization: [Not Specified]
Street Address:
City:
State:
Zip:

Submittal Date: Fri Sep 01 13:24:20 EDT 2017

Public Input No. 3188-NFPA 70-2017 [Section No. 210.52(C)(3)]

(3) Peninsular Countertop Spaces.

At least one receptacle outlet shall be installed at each peninsular countertop ~~long dimension space with a long dimension of 600 mm (24 in.) or greater and a short dimension of 300 mm (12 in.) or greater. A~~ space. A wall receptacle outlet shall serve the peninsular unless the peninsular is divide by a sink, cooktop or oother appliance. A peninsular countertop is measured from the connected perpendicular wall.

Statement of Problem and Substantiation for Public Input

Since the 24" does not apply to islands or peninsular it seems appropriate that a wall receptacle outlet should suffice for the peninsular space. In fact, many believe that is the intent unless the peninsular is divided. I did not include the 12" rule behind an appliance as I have written another proposal to changhe that also so that any appliance separates the spaces...

Submitter Information Verification

Submitter Full Name: Dennis Alwon

Organization: Alwon Electric

Street Address:

City:

State:

Zip:

Submittal Date: Sun Sep 03 11:09:52 EDT 2017

Public Input No. 3301-NFPA 70-2017 [Section No. 210.52(C)(3)]

(3) Peninsular Countertop Spaces.

At least one receptacle outlet shall be installed at each peninsular countertop ~~long dimension~~ space with a long dimension of 600 mm (24 in.) or greater and a short dimension of 300 mm (12 in.) or greater. A peninsular countertop is measured from the ~~connected perpendicular wall~~ connecting edge .

Additional Proposed Changes

File Name	Description	Approved
Figure_210.52_C_3_2020_FD_NEC_.jpg	Figure 210.52(C)(3) 2020 FD NEC PI	✓

Statement of Problem and Substantiation for Public Input

I urge the committee to revert back to the 2014 NEC language at 210.52(C)(3). This language worked with no problems for 24 years (beginning with the 1993 NEC) in the NEC until the 2017 NEC. A quick history lesson will show that a public input (PI 3605) resulted in a First Draft revision (FR 356) to the 2017 NEC. This FR was going to result in allowing a receptacle outlet at the connecting wall (which serves the base countertop) to also serve the peninsular countertop. The end of the peninsular countertop could be as far away from the wall receptacle as 1.8 m (6 ft). Under the 2014 NEC, a peninsular countertop that measures 600 mm (24 in.) by 900 mm (36 in.) (measured from the connecting edge) would require at least one receptacle outlet (located at the peninsular countertop) to serve that peninsular countertop. Under the proposed text of the 2017 NEC, this same peninsular countertop would require ZERO receptacles at the peninsular countertop as the countertop could be served by the wall receptacle [that could be up to 1.8 m (6 ft) away from the end of said countertop].

This submitter submitted a public comment (PC 572) pointing out the fact that if accepted as proposed in the 2017 NEC First Draft, the Code was going to require less receptacles (if any) than that required by the previous edition of the Code with the potential safety for the user (typically the homeowner) lessened from the previous requirements for a receptacle at a peninsular countertop.

Whither intended or not, this section is being interpreted as to REQUIRE a receptacle outlet to be installed only at the long dimension of the peninsular countertop. A receptacle outlet installed at the perpendicular wall or at the end of the peninsular countertop would not meet this requirement as the latter receptacle outlets would not be installed "at each peninsular countertop long dimension." A literal reading of 210.52(C)(3) in the 2017 NEC would concur with this interpretation.

For the 2017 NEC, this appeared to be a case of trying to fix something that was not broken. Let's do installers and inspectors alike a great service and take the language back to the 1993 through the 2014 NEC language where it worked and was not broken.

Submitter Information Verification

Submitter Full Name: L. Keith Lofland

Organization: IAEI

Affilliation: Self

Street Address:

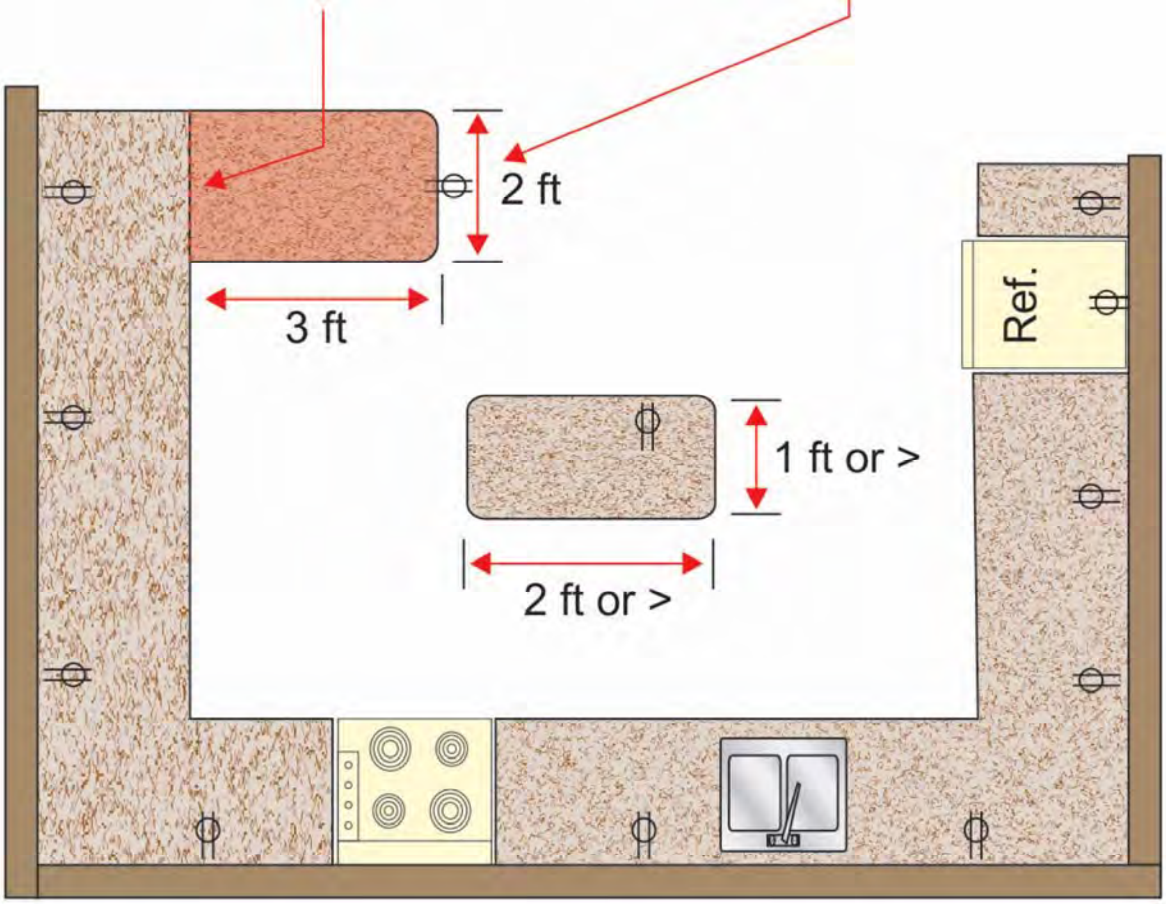
City:

State:

Zip:

Submittal Date: Tue Sep 05 11:38:49 EDT 2017

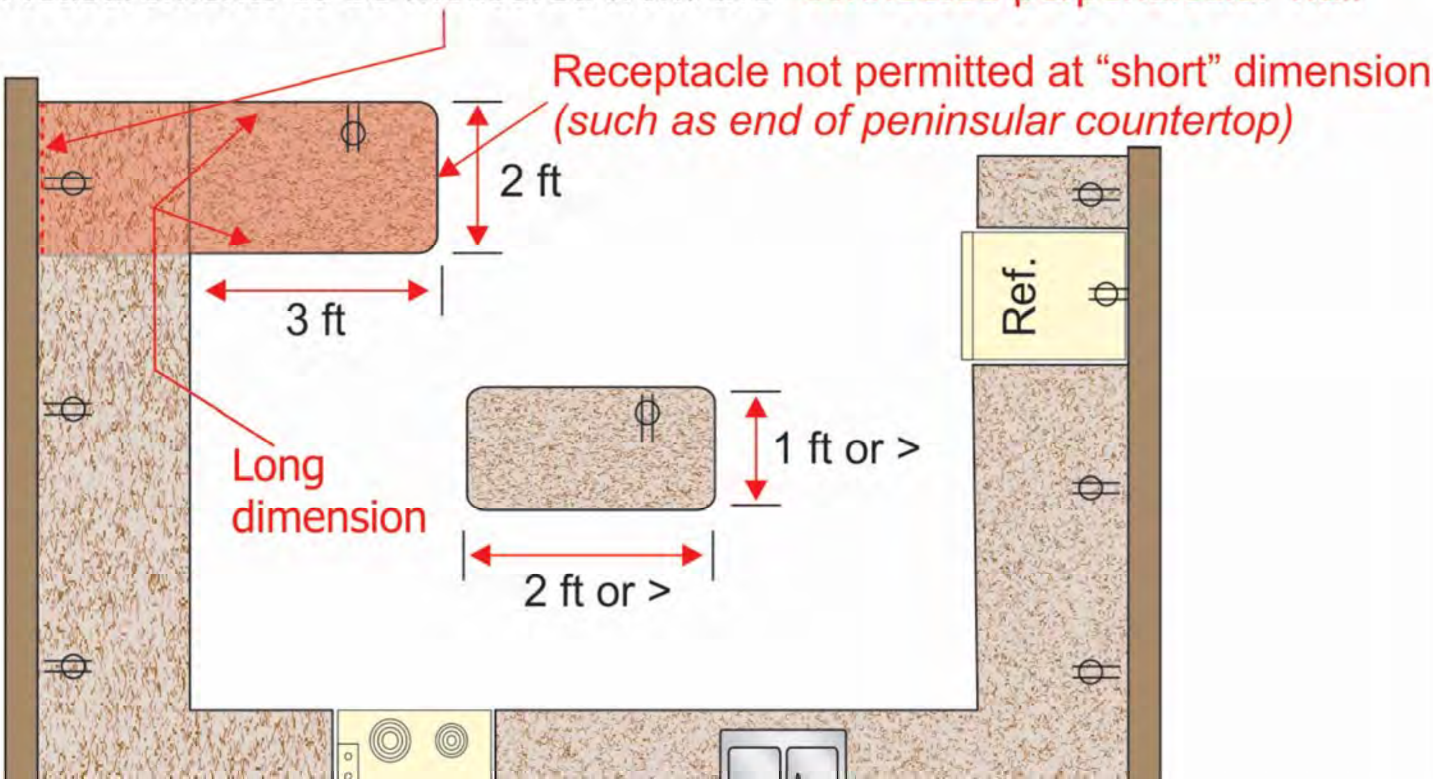
Copyright Assignment



2017 *NEC* :

At least one receptacle outlet to be installed at each peninsular countertop long dimension space with a long dimension of 600 mm (24 in.) or greater and a short dimension of 300 mm (12 in.) or greater

Measurements to be measured from the "connected perpendicular wall"



Public Input No. 3640-NFPA 70-2017 [Section No. 210.52(C)(3)]

(3) Peninsular Countertop Spaces.

At least one receptacle outlet shall be installed at each peninsular countertop long dimension space with a long dimension of 600 mm (24 in.) or greater and a short dimension of 300 mm (12 in.) or greater. A peninsular countertop is measured from the ~~connected perpendicular wall~~ connecting edge .

Additional Proposed Changes

File Name	Description	Approved
210.52_C_3_1.png	210.52(C)(3) #Picture 1	
210.52_C_3_2.png	210.52(C)(3) #Picture 2	

Statement of Problem and Substantiation for Public Input

A peninsular is not always connected to a perpendicular wall, but will always have a connecting edge. Otherwise it would be an island and covered by 210.52(C)(2).

Submitter Information Verification

Submitter Full Name: Richard Hollander
Organization: City of Tucson
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 06 15:48:42 EDT 2017

Public Input No. 3682-NFPA 70-2017 [Section No. 210.52(C)(3)]

(3) Peninsular Countertop Spaces.

At least one receptacle outlet shall be installed at each peninsular countertop long dimension space with a long dimension of 600 mm (24 in.) or greater and a short dimension of 300 mm (12 in.) or greater. For peninsular countertops with a long diminsion space greater than 1.8m (6 ft) at least one additional receptacle shall be installed in accordance with 210.52(C)(5). A peninsular countertop is measured from the connected perpendicular wall.

Statement of Problem and Substantiation for Public Input

Greetings CMP 2,

As many of you know the use of the receptacle located on the wall space of a countertop that is also part of the perpendicular wall (in a kitchen) that is connected to a peninsular can meet the receptacle requirements of section 210.52(C)(3). However, there is no length limitation placed on this rule that would prohibit a long (for argument sake) 10 ft. peninsular that would result in to receptacle. This encourages the use of extension cords where the previous definition of a connecting edge would have required a receptacle on the peninsular in addition to the normal wall counter space receptacle as long as the peninsular met the size requirements (24x12). This seems to be a step backwards in trying to reduce the use of cords for applications where we all know that during holidays and family gatherings the peninsular is going to be used to cook plates, crock pots, blenders, etc. This public input attempts to bring a length requirement to trigger an additional receptacle for these long peninsular and to correct an potential hazard in the making.

Submitter Information Verification

Submitter Full Name: Paul Abernathy

Organization: Encore Wire Corporation

Street Address:

City:

State:

Zip:

Submittal Date: Wed Sep 06 17:05:37 EDT 2017

Public Input No. 3837-NFPA 70-2017 [Section No. 210.52(C)(3)]

(3) Peninsular Countertop Spaces.

At least one receptacle outlet shall be installed at each peninsular countertop long dimension space with a long dimension of 600 mm (24 in.) or greater and a short dimension of 300 mm (12 in.) or greater. A peninsular countertop is measured from the ~~connected~~ perpendicular wall if there is no base cabinet or from the connecting edge of a base cabinet if it exists or will be present .

Statement of Problem and Substantiation for Public Input

In reality, a peninsular cabinet originates at the perpendicular wall only if no base cabinet exists. If a base cabinet exists or will be installed at that phase of construction, the peninsular cabinet originates at the juncture of the base cabinet and the peninsular cabinet.
This Public Input clarifies the distinction and should be accepted.

Submitter Information Verification

Submitter Full Name: Phil Simmons
Organization: Simmons Electrical Services
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 07 00:18:09 EDT 2017

Public Input No. 4314-NFPA 70-2017 [Section No. 210.52(C)(3)]

(3) Peninsular Countertop Spaces.

At least one receptacle outlet shall be installed at each peninsular countertop long dimension space with a long dimension of 600 mm (24 in.) or greater and a short dimension of 300 mm (12 in.) or greater. A peninsular countertop is measured from the ~~connected perpendicular wall~~ connecting edge .

Statement of Problem and Substantiation for Public Input

The change in the 2014 code cycle had the effect of reducing the number of counter top receptacles required. The net result was that a peninsular counter top space essentially does not require a receptacle outlet like the remainder of the counter space does.

Submitter Information Verification

Submitter Full Name: Matt Hermanson

Organization: A And A Electric Inc

Street Address:

City:

State:

Zip:

Submittal Date: Thu Sep 07 20:05:25 EDT 2017

Public Input No. 774-NFPA 70-2017 [Section No. 210.52(C)(3)]

(3) Peninsular Countertop Spaces.

At least one receptacle outlet shall be installed at each fixed in place peninsular countertop ~~long dimension space~~ with a long dimension of 600 mm (24 in.) or greater and a short dimension of 300 mm (12 in.) or greater ~~. A peninsular countertop is measured from the connected perpendicular wall~~ extening from a connecting wall or front edge of the attached perpendicular counter top. The wall receptacle outlet shall be permitted to sever as the peninsular countertop .

Statement of Problem and Substantiation for Public Input

the has been a lot of controversy in this section, one, is the wall receptacle permitted to serve the countertop or not? if the peninsular is attached directly to a wall the wall receptacle is acceptable so why not when it is attached to a perpendicular countertop. there are also retractable peninsular making it impracticable to have a receptacle on the peninsular

Submitter Information Verification

Submitter Full Name: Alfio Torrisi
Organization: Master Electrician
Street Address:
City:
State:
Zip:
Submittal Date: Sat May 20 08:39:34 EDT 2017

Public Input No. 87-NFPA 70-2017 [Section No. 210.52(C)(3)]

(3) Peninsular Countertop ~~Spaces~~ and Work Surfaces .

At least one receptacle outlet shall be installed at each ~~peninsular countertop~~ long dimension ~~space with a~~ of a peninsular countertop or work surface having a long dimension of 600 mm (24 in.) or greater and a short dimension of 300 mm (12 in.) or greater. ~~A peninsular countertop is~~ Peninsular countertop and work surfaces are measured from the

connected perpendicular walls.

A receptacle serving a wall countertop that directly faces a peninsular countertop or work surface shall be permitted to serve as the receptacle for that peninsular countertop or work surface where the peninsular surfaces are horizontally contiguous to the wall countertop, and the receptacle is located within 1.8 m (6 ft) of the most distant edge of the peninsular countertop or work space surface.

.

Statement of Problem and Substantiation for Public Input

Reinstate what Code-Making Panel 2 had accepted at the 2017 NEC® Second Revision Ballot for a length limitation on peninsulas served by receptacles also serving wall countertops but had been deleted by Second Correlating Revision No 67. This Public Input addresses the concerns expressed in Second Correlating Revision No 67 regarding the introduction of the term "workspace" that resulted in that paragraph being deleted on this important safety requirement for peninsulas served by receptacles. The reinstated requirement here avoids the use of long extension cords to serve the outlying portions of peninsulas, particularly with regard to countertop appliances having short power supply cords.

Submitter Information Verification

Submitter Full Name: Brian Rock

Organization: Hubbell Incorporated

Street Address:

City:

State:

Zip:

Submittal Date: Sat Jan 28 13:32:14 EST 2017

Public Input No. 3184-NFPA 70-2017 [Section No. 210.52(C)(4)]

(4) Separate Spaces.

Countertop spaces separated by rangetops, refrigerators, or sinks shall be considered as separate countertop spaces in applying the requirements of 210.52(C)(1). ~~If a range, counter-mounted cooking unit, or sink is installed in an island or peninsular countertop and the depth of the countertop behind the range, counter-mounted cooking unit, or sink is less than 300 mm (12 in.), the range, counter-mounted cooking unit, or sink shall be considered to divide the countertop space into two separate countertop spaces. Each separate countertop space shall comply with the applicable requirements in 210.52(C) .~~

Statement of Problem and Substantiation for Public Input

I am not sure why the requirement for one receptacle is allowed if the 12" behind an appliance or sink is present . With appliances it would seem both ends of an separate island should have access to a receptacle regardless if there if 12" of counter behind a separator.

Submitter Information Verification

Submitter Full Name: Dennis Alwon
Organization: Alwon Electric
Street Address:
City:
State:
Zip:
Submittal Date: Sun Sep 03 10:57:25 EDT 2017

Public Input No. 3834-NFPA 70-2017 [Section No. 210.52(C)(4)]

(4) Separate Spaces.

Countertop spaces separated by ~~rangetops, refrigerators, or sinks~~ a range, counter-mounted cooking unit, refrigerator, or sink shall be considered as a separate countertop ~~spaces~~ space in applying the requirements of 210.52(C)(1). ~~If~~ As shown in the upper drawing of Figure 210.52(C)(1), if a range, counter-mounted cooking unit, or sink is installed in an island or peninsular countertop and the depth of the countertop behind the range, counter-mounted cooking unit, or sink is less than 300 mm (12 in.), the range, counter-mounted cooking unit, or sink shall be considered to divide the countertop space into two separate countertop spaces. Each separate countertop space shall comply with the applicable requirements in 210.52(C).

Statement of Problem and Substantiation for Public Input

This section needs to refer to the revised upper figure of Figure 210.52(C)(1) for clarity. The revised figure is directly applicable the this section as it illustrates the dimension when a separate counter space is created.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3766-NFPA 70-2017 [Section No. 210.52(C)(1)]	

Submitter Information Verification

Submitter Full Name: Phil Simmons
Organization: Simmons Electrical Services
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 07 00:05:20 EDT 2017

Public Input No. 2802-NFPA 70-2017 [Section No. 210.52(D)]

(D) Bathrooms.

At least one receptacle outlet shall be installed in bathrooms within 900 mm (3 ft) of the outside edge of each basin. This measurement shall be made without crossing a basin. The receptacle outlet shall be located on a wall or partition that is adjacent to the basin or basin countertop, located on the countertop, or installed on the side or face of the basin cabinet. In no case shall the receptacle be located more than 300 mm (12 in.) below the top of the basin or basin countertop. Receptacle outlet assemblies listed for use in countertops shall be permitted to be installed in the countertop.

Informational Note: See 406.5(E)and 406.5(G)for requirements for installation of receptacles in countertops.

Statement of Problem and Substantiation for Public Input

When there is a double sink it is possible, by not usual, for a receptacle to be placed on one side of a double basin vanity and still be within 3' of both basins. This, I hope, will clear up this issue of measuring across the basins.

Submitter Information Verification

Submitter Full Name: Dennis Alwon

Organization: Alwon Electric

Street Address:

City:

State:

Zip:

Submittal Date: Sat Aug 26 19:46:14 EDT 2017

Public Input No. 1138-NFPA 70-2017 [Section No. 210.52(E)(3)]

(3) Balconies, Decks, and Porches.

Balconies, decks, and porches ~~that~~ accessible from inside of the dwelling unit that are attached to the dwelling ~~unit and~~ unit or are ~~accessible~~ directly accessible from inside the dwelling unit shall have at least one receptacle outlet accessible from the balcony, deck, or porch. The receptacle outlet shall not be located more than 2.0 m (6½ ft) above the balcony, deck, or porch walking surface.

Statement of Problem and Substantiation for Public Input

Many decks are installed in a cantilevered manor where connection to the actual dwelling is not made at any point generally leaving an air gap to promote drainage and prevent wood decay at the building band board and siding. A literal reading of the existing text would suggest that a receptacle is not required as the deck is unattached. The proposed text would close this loophole and require the receptacle on this deck" unattached by one inch or less" to have the receptacle intended by this section.

Submitter Information Verification

Submitter Full Name: David Humphrey

Organization:

Street Address:

City:

State:

Zip:

Submittal Date: Thu Jul 13 11:26:16 EDT 2017

Public Input No. 299-NFPA 70-2017 [Section No. 210.52(F)]

(F) Laundry Areas.

In dwelling units, at least one receptacle outlet shall be ~~installed in areas designated for~~ installed for the installation of laundry equipment in designated areas .

Exception No. 1: A receptacle for laundry equipment shall not be required in a dwelling unit of a multifamily building where laundry facilities are provided on the premises for use by all building occupants.

Exception No. 2: A receptacle for laundry equipment shall not be required in other than one-family dwellings where laundry facilities are not to be installed or permitted.

Statement of Problem and Substantiation for Public Input

The present wording is being interpreted by builders for single family homes or townhouses for example, as meaning if they don't "designate " areas for laundry equipment, then no receptacle or circuit is needed, which then means no 1500va load calculation either , which then leads to a smaller feeder or service. I don't believe that is the intent of the wording, but unfortunately the present wording allows this interpretation. My revised wording would help clarify this issue.

Submitter Information Verification

Submitter Full Name: Russ Leblanc

Organization: Leblanc Consulting Services

Street Address:

City:

State:

Zip:

Submittal Date: Fri Feb 24 19:23:07 EST 2017

Public Input No. 35-NFPA 70-2017 [Section No. 210.52(F)]

(F) Laundry Areas.

In dwelling units, at least one receptacle outlet shall be installed in areas designated for the installation of laundry equipment.

<u>This outlet is intended for the laundry appliances and is in addition to the outlet required in 210.11(C)(2).</u>

Exception No. 1: A receptacle for laundry equipment shall not be required in a dwelling unit of a multifamily building where laundry facilities are provided on the premises for use by all building occupants.

Exception No. 2: A receptacle for laundry equipment shall not be required in other than one-family dwellings where laundry facilities are not to be installed or permitted.

Statement of Problem and Substantiation for Public Input

Clarity on definition and requirements for laundry in dwellings

Submitter Information Verification

Submitter Full Name: Dan Haruch
Organization: Brightwood Career Institute
Street Address:
City:
State:
Zip:
Submittal Date: Tue Jan 24 08:34:25 EST 2017

Public Input No. 3136-NFPA 70-2017 [Section No. 210.52(E)(3)]

(3) Balconies, Decks, and Porches.

Balconies, decks, and porches that are attached to the dwelling unit and are accessible from inside the dwelling unit shall have at least one receptacle outlet accessible from the balcony, deck, or porch. The receptacle outlet shall not be located more than 2.0 m (6½ ft) above the balcony, deck, or porch walking surface.

<u>Exception No. 1: An accessible outlet is not required at a juliet balcony.</u>

Statement of Problem and Substantiation for Public Input

Juliet balconies as defined in the building code do not extend beyond the building surface and are not large enough to stand on or to place objects on. Some inspectors require an outlet which is difficult or impossible to install and which serves no reasonable purpose. Installers need a clear statement from the panel as to whether these outlets are required or not required.

Submitter Information Verification

Submitter Full Name:	Nathan Philips
Organization:	Integrated Electronic Systems
Affilliation:	NECA
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Fri Sep 01 13:44:18 EDT 2017

Public Input No. 4080-NFPA 70-2017 [Section No. 210.52(G)]

(G) Basements, Garages, and Accessory Buildings.

For one- ~~and~~ , two- family,and multi-family dwellings, at least one receptacle outlet shall be installed in the areas specified in 210.52(G)(1) through (3). These receptacles shall be in addition to receptacles required for specific equipment.

(1) Garages.

In each attached garage and in each detached garage with electric power, at least one receptacle outlet shall be installed in each vehicle bay and not more than 1.7 m (5½ ft) above the floor.

(2) Accessory Buildings.

In each accessory building with electric power.

(3) Basements.

In each separate unfinished portion of a basement.

Statement of Problem and Substantiation for Public Input

WHEN INSPECTING MULTI-FAMILY APARTMENT BUILDINGS WHERE RENTORS HAVE GREATER THAN A SINGLE STALL DETACHED GARAGE THE REQUIREMENT WOULD BE THE SAME. I HAVE SEEN 1 OUTLET AND THEN MULTIPLE USE OF EXTENSION CORDS ETC.

Submitter Information Verification

Submitter Full Name: RICHARD WOLFE
Organization: NDSEB
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 07 13:41:07 EDT 2017

Public Input No. 1013-NFPA 70-2017 [Section No. 210.52(G) [Excluding any Sub-Sections]]

For one- and two- family dwellings, at least one receptacle outlet shall be installed in the areas specified in 210.52(G)(1) through (3). These receptacles shall be in addition to receptacles required for specific equipment.

Proposed change:

210.52

(G) Basements, Garages, and Accessory Buildings. For one and two- family dwellings, ***and multi-family dwellings of more than two units with attached individual garage space accessible only to owner or occupant*** , at least one receptacle outlet shall be installed in the areas specified in 210.52(G)(1) through (3). These receptacles shall be in addition to receptacles required for specific equipment.

Exception 1: Shall not apply to multi-family dwellings with attached or detached common parking areas or garages.

Additional Proposed Changes

File Name	Description	Approved
210.52_G_Proposed_change.docx	Supporting proposed change to 210.52(G)	✓

Statement of Problem and Substantiation for Public Input

There are many instances of multi-family dwellings, greater than 2, built on top of individual garage space accessible only to the individual owner or occupant. The article as written implies that such construction of more than two units would not require theses outlets.

Submitter Information Verification

Submitter Full Name: Dan Haruch

Organization: Brightwood Career Institute

Street Address:

City:

State:

Zip:

Submittal Date: Sat Jun 10 14:56:00 EDT 2017

Copyright Assignment

I, Dan Haruch, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Dan Haruch, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Proposed change:

210.52

(G) Basements, Garages, and Accessory Buildings. For one and two- family dwellings, ***and multi-family dwellings of more than two units with attached individual garage space accessible only to owner or occupant***, at least one receptacle outlet shall be installed in the areas specified in 210.52(G)(1) through (3). These receptacles shall be in addition to receptacles required for specific equipment.

Exception 1: Shall not apply to multi-family dwellings with attached or detached common parking areas or garages.

Example: 12 unit attached townhouse multi-family structure.

Public Input No. 2963-NFPA 70-2017 [Section No. 210.52(G) [Excluding any Sub-Sections]]

For one-~~- and~~ , two- family dwellings and multifamily dwellings with individual garages , accessory buildings or basements, at least one receptacle outlet shall be installed in the areas specified in 210.52(G)(1) through (3). These receptacles shall be in addition to receptacles required for specific equipment.

Additional Proposed Changes

File Name	Description	Approved
PI_No._2963_-_210.52_G_.pdf	Multi-Family with individual attached and detached garages.	✓

Statement of Problem and Substantiation for Public Input

In the 2017 NEC, 201.52(G) was expanded, from one-family, to include two-family dwelling units. It did not include multifamily dwellings. This could be a potential safety hazard, in that an occupant of a multi-family dwelling unit could resort to utilizing an extension cord if a receptacle outlet is not readily available. This same level of safety should be made available to multi-family dwelling units. In some cases multi-family dwelling units are available with individual garages and/or accessory buildings.

Submitter Information Verification

Submitter Full Name: Edward Rodriguez

Organization: Walker Engineering Inc

Affilliation: Independent Electrical Contractors

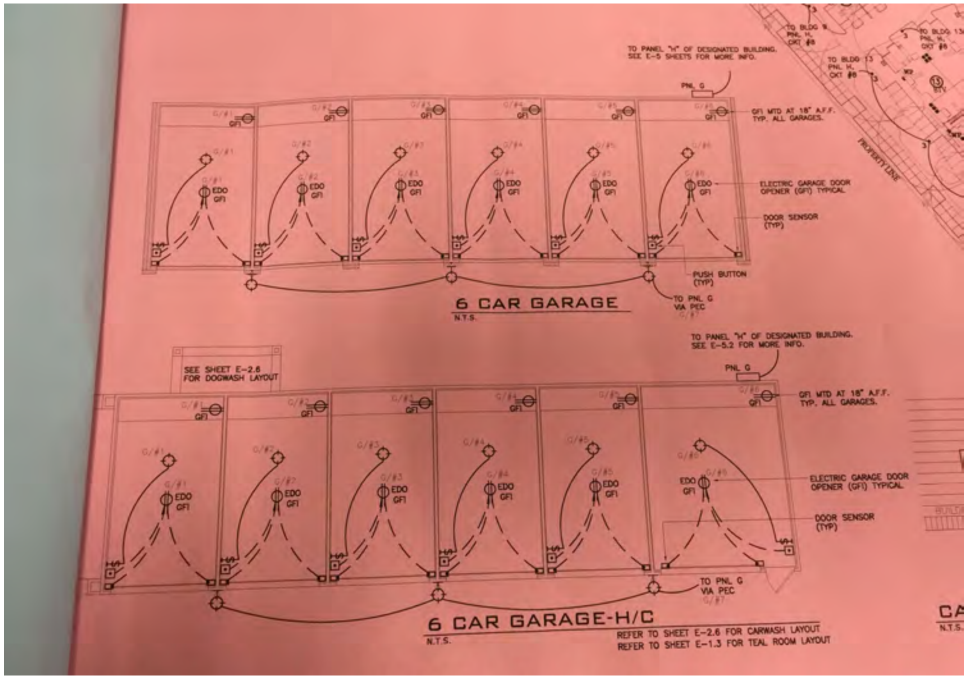
Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 29 16:25:52 EDT 2017


6 CAR GARAGE
N.T.S.
6 CAR GARAGE-H/C
N.T.S.
SEE SHEET E-2.6 FOR DOGWASH LAYOUT
ELECTRIC GARAGE DOOR OPENER (GFI) TYPICAL
DOOR SENSOR (TYP)
PUSH BUTTON (TYP)
REFER TO SHEET E-2.6 FOR CARWASH LAYOUT
REFER TO SHEET E-1.3 FOR TEAL ROOM LAYOUT


Tyvek
Tyvek




Public Input No. 1438-NFPA 70-2017 [Section No. 210.52(G)(1)]

(1) Garages.

In each attached garage and in each detached garage with electric power, ~~at least one receptacle outlet shall be installed in each vehicle bay and~~ receptacles shall be installed such that no point measured horizontally along the floor line of any wall space is more than 3.04m (10ft) from a receptacle outlet and not more than 1.7 m (5½ ft) above the floor.

Statement of Problem and Substantiation for Public Input

The proposed wording would put the spacing of receptacles in the garage in line with other wording found int he NEC (see section 252.10 (A)(1)). The term "Vehicle bay" is not defined in the NEC. Many homes will have an extra bay in the garage that is never intended to hold a motor vehicle (i.e. a space for working or storage).

Submitter Information Verification

Submitter Full Name: Brandon Lackey
Organization: Lackey LLC
Street Address:
City:
State:
Zip:
Submittal Date: Sun Jul 30 20:16:30 EDT 2017

Public Input No. 3472-NFPA 70-2017 [Section No. 210.52(G)(1)]

(1) Garages.

In each attached garage and in each detached garage with electric power, ~~at least one receptacle outlet shall be installed in each vehicle bay~~ receptacles shall be installed such that no point measured horizontally along the floor line of any wall space is more than 1.8 m (6 ft.) from a receptacle outlet and not more than 1.~~7 m~~ 7 m (5 1⁄2 ~~ft~~ ft.) above the floor.

Statement of Problem and Substantiation for Public Input

The proposed text addresses the number of receptacles found in a garage and the issue pertaining to the placement and confusion of receptacles installed in a vehicle bay or what a vehicle bay is. This Public Input encourages the panel to have a discussion on this subject. The actual spacing requirement can be adjusted by the panel.

Submitter Information Verification

Submitter Full Name: David Kendall
Organization: Thomas Betts Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 06 11:16:44 EDT 2017

Public Input No. 907-NFPA 70-2017 [Section No. 210.52(G)(1)]

(1) Garages.

In each attached garage and in each detached garage with electric power, at least one receptacle outlet shall be installed in each vehicle bay and not more than 1.7 m (5½ ft) above the floor in accordance with 210 .11 (C) (4).

Statement of Problem and Substantiation for Public Input

210.11(C) (4) only allows a 20 amp branch circuit to supply only the garage receptacle(s) with one exception. this would update this section

Submitter Information Verification

Submitter Full Name: Alfio Torrisi

Organization: master electrician

Street Address:

City:

State:

Zip:

Submittal Date: Tue Jun 06 19:54:42 EDT 2017

Public Input No. 2807-NFPA 70-2017 [Section No. 210.60]

210.60 Guest Rooms, Guest Suites, ~~Dormitories~~ Dormitory Units , and Similar Occupancies.

(A) General.

Guest rooms or guest suites in hotels, motels, sleeping rooms in ~~dormitories~~ dormitory units , and similar occupancies shall have receptacle outlets installed in accordance with 210.52(A) and (D). Guest rooms or guest suites provided with permanent provisions for cooking shall have receptacle outlets installed in accordance with all of the applicable rules in 210.52.

(B) Receptacle Placement.

In applying the provisions of 210.52(A), the total number of receptacle outlets shall not be less than the minimum number that would comply with the provisions of that section. These receptacle outlets shall be permitted to be located conveniently for permanent furniture layout. At least two receptacle outlets shall be readily accessible. Where receptacles are installed behind the bed, the receptacle shall be located to prevent the bed from contacting any attachment plug that may be installed or the receptacle shall be provided with a suitable guard.

Statement of Problem and Substantiation for Public Input

Edit the text to match the public input term Dormitory Unit to be added to Article 100.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2806-NFPA 70-2017 [New Definition after Definition: Disconnecting Means.]	

Submitter Information Verification

Submitter Full Name: Mike Holt

Organization: Mike Holt Enterprises Inc

Street Address:

City:

State:

Zip:

Submittal Date: Sat Aug 26 20:04:24 EDT 2017

Public Input No. 1178-NFPA 70-2017 [New Section after 210.60(A)]

Exterior Receptacle

An exterior receptacle will be provided for a balcony, patio or deck that is greater than 15 square feet and is accessible from the inside of a guest room.

Statement of Problem and Substantiation for Public Input

Guest rooms that do not meet the definition of a dwelling unit, but have a exterior balcony or deck suitable for the placement of furniture should have an available receptacle.

Submitter Information Verification

Submitter Full Name: William Buterbaugh
Organization: City of SeaTac
Street Address:
City:
State:
Zip:
Submittal Date: Tue Jul 18 14:55:39 EDT 2017

Public Input No. 775-NFPA 70-2017 [Section No. 210.63]

210.63 Heating, Air-Conditioning, and Refrigeration Equipment Outlet.

A 125-volt, single-phase, 15- or 20-ampere-rated receptacle outlet shall be installed at an accessible location for the servicing of heating, air-conditioning, and refrigeration equipment. The receptacle shall be located on the same level and within 7.5 m (25 ft) of the heating, air-conditioning, and refrigeration equipment. The receptacle outlet shall not be connected to the load side of the equipment disconnecting means.

Informational Note: See 210.8 for ground-fault circuit-interrupter requirements.

~~*Exception: A receptacle outlet shall not be required at one- and two-family dwellings for the service of evaporative coolers.*~~

Statement of Problem and Substantiation for Public Input

the maintenance person servicing this equipment under any occupancy, should have access to a receptacle and seeing that a single family is required to have one front and back it would not be a stretch to comply with the general rule.

Submitter Information Verification

Submitter Full Name: Alfio Torrisi

Organization: Master Electrician

Street Address:

City:

State:

Zip:

Submittal Date: Sat May 20 09:10:58 EDT 2017

Public Input No. 1085-NFPA 70-2017 [Section No. 210.64]

210.~~64~~ 64 Indoor Electrical Service Areas.

At least one 125-volt, single-phase, 15- or 20-ampere-rated receptacle outlet shall be installed in an accessible location within 7.5 m (25 ft) of the indoor electrical service equipment. The required receptacle outlet shall be located within the same room or area as the service equipment.

Exception No. 1: The receptacle outlet shall not be required to be installed in one- and two-family dwellings.

Exception No. 2: Where the service voltage is greater than 120 volts to ground, a receptacle outlet shall not be required for services dedicated to equipment covered in Articles 675 and 682.

Statement of Problem and Substantiation for Public Input

I don't know why it crossed out "64," terra seems to be glitchy today.

The change is just to add "Indoor" in the title. It is for clarity.

Submitter Information Verification

Submitter Full Name: Nick Sasso
Organization: State of Wyoming, www.electrical-code-expert.com
Street Address:
City:
State:
Zip:
Submittal Date: Wed Jun 28 15:43:02 EDT 2017

Public Input No. 1397-NFPA 70-2017 [Section No. 210.64]

210.64 Electrical Service Areas.

At least one 125-volt, single-phase, 15- or 20-ampere-rated receptacle outlet shall be installed in an accessible location within 7.5 m (25 ft) of the indoor electrical service equipment. The required receptacle outlet shall be located within the same room or area as the service equipment and have GFCI protection .

Exception No. 1: The receptacle outlet shall not be required to be installed in one- and two-family dwellings.

Exception No. 2: Where the service voltage is greater than 120 volts to ground, a receptacle outlet shall not be required for services dedicated to equipment covered in Articles 675 and 682.

Statement of Problem and Substantiation for Public Input

It is now the norm that National Electrical Code provide GFCI protection for service people that have to work on electrical equipment. For instance, Article 511.12 requires that all 125-volt, single-phase, 15- and 20-ampere receptacles installed in areas where electrical diagnostic equipment, electrical hand tools, or portable lighting equipment are to be used shall have ground-fault circuit-interrupter protection for personnel.

This requirement is for other than dwelling units where the floors in these buildilngs are usually concrete (a grounded surface) and as you know NEC considers concrete, brick, or tile to be a grounded surface. I feel that the GFCI protection is needed.

Requiring GFCI protection for the duplex receptacle in this location will also not significantly impact any costs.

Submitter Information Verification

Submitter Full Name: Nick Sasso
Organization: State of Wyoming
Affilliation: www.electrical-code-expert.com
Street Address:
City:
State:
Zip:
Submittal Date: Fri Jul 28 11:29:09 EDT 2017

Copyright Assignment

I, Nick Sasso, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Nick Sasso, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 3699-NFPA 70-2017 [Section No. 210.64]

210.64 Electrical Service Areas.

At least one 125-volt, single-phase, 15- or 20-ampere-rated receptacle outlet shall be installed in an accessible location within 7.5 m (25 ft) of the indoor electrical service equipment. The required receptacle outlet shall be located within the same room or area as the service equipment.

Exception No. 1: The receptacle outlet shall not be required to be installed in one- and two-family dwellings.

~~*Exception No. 2: Where the service voltage is greater than 120 volts to ground, a receptacle outlet shall not be required for services dedicated to equipment covered in Articles 675 and 682.*~~

Statement of Problem and Substantiation for Public Input

this section was revised for only indoor locations the exceptions are for outdoor locations and is no longer needed

Submitter Information Verification

Submitter Full Name: Alfio Torrisi
Organization: master electrician
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 06 17:36:16 EDT 2017

Public Input No. 664-NFPA 70-2017 [Section No. 210.64]

210.64 Electrical Service Areas.

At least one 125-volt, single-phase, 15- or 20-ampere-rated receptacle outlet shall be installed in an accessible location within 7.5 m (25 ft) of ~~the indoor electrical service equipment.~~ all switchboards, switchgear, panelboards, and motor control centers, located in dedicated equipment spaces. The required receptacle outlet shall be located within the same room or area as the ~~service~~ electrical equipment.

Exception No. 1: The receptacle outlet shall not be required to be installed in one- and two-family dwellings.

Exception No. 2: Where the service voltage is greater than 120 volts to ground, a receptacle outlet shall not be required for services dedicated to equipment covered in Articles 675 and 682.

Doesn't this sound better????

At least one 125-volt, single-phase, 15- or 20-ampere-rated receptacle outlet shall be installed in an accessible location within 7.5 m (25 ft) of the indoor electrical service equipment. Where dedicated equipment spaces exist that do not house service equipment a t least one 125-volt, single-phase, 15- or 20-ampere-rated receptacle outlet shall also be installed .

Statement of Problem and Substantiation for Public Input

The original intent for this provision was to have a 15 or 20 amp 120v receptacle outlet in each “electrical room” for servicing, metering and recording equipment. "Dedicated equipment space" is described in 110.26(E). Servicing, metering and recording equipment is used on more than just service equipment.

Submitter Information Verification

Submitter Full Name:	David Hittinger
Organization:	Independent Electrical Contractors
Affilliation:	Independent Electrical Contractors Codes and Standard
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Sat May 06 13:19:20 EDT 2017

Public Input No. 916-NFPA 70-2017 [Section No. 210.64]

210.64 Electrical Service Areas.

~~At~~ For other than one and two famly dwellings at least one 125-volt, single-phase, 15- or 20-ampere-rated receptacle outlet shall be installed in an accessible location within 7.5 m (25 ft) of the indoor electrical service equipment. The required receptacle outlet shall be located within the same room or area as the service equipment.

~~Exception No. 1: The receptacle outlet shall not be required to be installed in one- and two-family dwellings.~~

~~Exception No. 2:~~ Exception: Where the service voltage is greater than 120 volts to ground, a receptacle outlet shall not be required for services dedicated to equipment covered in Articles 675 and 682.

Statement of Problem and Substantiation for Public Input

If CMP 2 agrees the deletion of the first exception may be facilitated by including the exclusion of the general rule to one and two family dwellings as indicated. This PI is submitted IAW the NEC style manual section 3.1.4 titled "Exceptions" which states "Exceptions to NEC rules shall be used sparingly. If used, exceptions shall convey alternatives or differences to a basic code rule. It is the responsibility of the Code-Making Panel to determine whether the principle can be expressed most effectively as a separate positive code rule or as an exception to a rule This format is used universally throughout the document It appears as it may serve this section well and eliminate an exception.

Submitter Information Verification

Submitter Full Name: Charles Palmieri

Organization: Town of Norwell

Street Address:

City:

State:

Zip:

Submittal Date: Wed Jun 07 12:02:30 EDT 2017

Public Input No. 2011-NFPA 70-2017 [Section No. 210.70 [Excluding any Sub-Sections]]

Lighting outlets shall be installed where specified in 210.70(A), (B), and (C). Locking support and mounting receptacle outlets shall be recognized as lighting outlets.

Statement of Problem and Substantiation for Public Input

Locking support and mounting receptacle outlets are utilized to supply luminaires or fan/light combinations. The receptacle can be installed in the ceiling with a centerpiece installed in the faceplate turning into a coverplate, with the expectation of the later addition of the utilization equipment (luminaire or fan/light combination). This text insures there's no requirement to add another lighting outlet since the locking support and mounting receptacle, even without the utilization equipment installed, is a lighting outlet.

Submitter Information Verification

Submitter Full Name:	Amy Cronin
Organization:	Strategic Code Solutions Llc
Affilliation:	SQL Technologies (formerly Safety Quick Lighting and Fans Corp)
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Wed Aug 09 14:23:09 EDT 2017

Public Input No. 4199-NFPA 70-2017 [Section No. 210.70(A)(1)]

(1) Habitable Rooms.

At least one ~~wall switch–controlled~~ lighting outlet controlled by a wall switch or wall mounted remote-control device shall be installed in every habitable room, kitchen, and bathroom. The wall switch or wall mounted remote-control device shall be located near an entrance to the room on a wall.

Exception No. 1: In other than kitchens and bathrooms, one or more receptacles controlled by a wall switch or wall mounted remote-control device shall be permitted in lieu of lighting outlets.

Exception No. 2: Lighting outlets shall be permitted to be controlled by occupancy sensors that are (1) in addition to wall switches or wall mounted remote-control devices or (2) located at a customary wall switch location and equipped with a manual override that will allow the sensor to function as a wall switch.

Statement of Problem and Substantiation for Public Input

The National Electrical Code requires "wall switch–controlled" lighting and receptacles. The common enforcement understanding due to the definition of a switch is that a hard-wired switch is required. The technology for controlling lighting and receptacles continues to evolve with further automation and control. Voice control via Alexa and manual remote devices located on the wall are able to communicate via control wire or wirelessly with the controllers for operating lighting outlets and receptacles at the receptacle outlet or lighting outlet.

Numerous manufacturers offer remote devices that wirelessly communicate with controllers that control the lighting outlet or the receptacle outlet. They are being installed today across the country as code compliant to serve as a "wall switch," when in fact they would not meet the definition of a "switch" with a voltage rating or interrupting rating.

The proposed revise language will permit lighting and receptacle control technology that is currently available and being installed in dwellings and commercial buildings today. Permitting wireless communication to a controller for lighting in the NEC would also align with the permitted application of wireless communication for life safety fire alarms permitted in NFPA 72.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 4154-NFPA 70-2017 [New Definition after Definition: Remote-Control Circuit.]	Definition to support new language

Submitter Information Verification

Submitter Full Name: Alan Manche

Organization: Schneider Electric

Street Address:

City:

State:

Zip:

Submittal Date: Thu Sep 07 16:23:09 EDT 2017

Copyright Assignment

I, Alan Manche, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Alan Manche, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 4342-NFPA 70-2017 [Section No. 210.70(A)(1)]

(1) Habitable Rooms.

At least one wall switch–controlled lighting outlet shall be installed in every habitable room, kitchen, and bathroom.

Exception No. 1: In other than kitchens, breakfast rooms, dining rooms, and bathrooms, one or more receptacles controlled by a wall switch shall be permitted in lieu of lighting outlets.

Exception No. 2: Lighting outlets shall be permitted to be controlled by occupancy sensors that are (1) in addition to wall switches or (2) located at a customary wall switch location and equipped with a manual override that will allow the sensor to function as a wall switch.

Statement of Problem and Substantiation for Public Input

Correlation of the rooms excluded in NEC® 210.71(A)(1) Exception No. 1 with those rooms required to have 20-ampere branch circuits in NEC® 210.52(B)(1). Receptacle outlets in "the kitchen, pantry, breakfast room, dining room, or similar area of a dwelling unit" are required to be served by 20-ampere branch circuits. However, without any restriction beyond being controlled by a wall switch, receptacles outlets serving dining rooms and breakfast rooms that are supplied from 15-ampere branch circuits intended to providing lighting outlets. Appliances, particularly heating appliances, used in dining rooms and breakfast rooms, draw significant amerage that all branch circuits serving receptacle outlets in those rooms should be rated for 20 amperes.

Submitter Information Verification

Submitter Full Name: Brian Rock

Organization: Hubbell Incorporated

Street Address:

City:

State:

Zip:

Submittal Date: Thu Sep 07 23:11:48 EDT 2017

Public Input No. 183-NFPA 70-2017 [Section No. 210.70(A)(2)]

(2) Additional Locations.

Additional lighting outlets shall be installed in accordance with

the following:

(1) At least one wall switch–controlled lighting outlet shall be installed in hallways, stairways, attached garages, and detached garages with electric power.

(2) For dwelling units, attached garages, and detached garages with electric power, at least one wall switch–controlled lighting outlet shall be installed to provide illumination on the exterior side of outdoor entrances or exits with grade-level access. A vehicle door in a garage shall not be considered as an outdoor entrance or exit.

(3) Where one or more lighting outlet(s) are installed for interior stairways, there shall be a wall switch at each floor level, and landing level that includes an entryway, to control the lighting outlet(s) where the stairway between floor levels has six risers or more. A stairway with a bulkhead shall have the swich located at the lower level.

Exception to (A)(2)(1), (A)(2)(2), and (A)(2)(3): In hallways, in stairways, and at outdoor entrances, remote, central, or automatic control of lighting shall be permitted.

(4)

Lighting outlets controlled in accordance with

210.70(A) ? (2) ? (3) shall not be controlled by use of dimmer switch

es unless they provide the full range of dimming control at each location

.

Statement of Problem and Substantiation for Public Input

basement interior stairway leading to the outside with a bulkhead is not an entry way an would not require the switch at both levels. Or a interior stairway leading to a bulk head / hatch on a roof is not an entry way an would not require the switch at both levels

Submitter Information Verification

Submitter Full Name: Alfio Torrisi

Organization: Master

Street Address:

City:

State:

Zip:

Submittal Date: Sun Feb 05 14:34:05 EST 2017

Copyright Assignment

I, Alfio Torrisi, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Alfio Torrisi, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 4193-NFPA 70-2017 [Section No. 210.70(A)(2)]

(2) Additional Locations.

Additional lighting outlets shall be installed in accordance with the following:

(1) At least one ~~wall switch–controlled~~ lighting outlet controlled by a wall switch or wall mounted remote- control device shall be installed in hallways, stairways, attached garages, and detached garages with electric power.

(2) For dwelling units, attached garages, and detached garages with electric power, at least one ~~wall switch–controlled~~ lighting outlet controlled by a wall switch or wall mounted remote-control device shall be installed to provide illumination on the exterior side of outdoor entrances or exits with grade-level access. A vehicle door in a garage shall not be considered as an outdoor entrance or exit.

(3) Where one or more lighting outlet(s) are installed for interior stairways, there shall be a wall switch or wall mounted remote-control device at each floor level, and landing level that includes an entryway, to control the lighting outlet(s) where the stairway between floor levels has six risers or more.

Exception to (A)(2)(1), (A)(2)(2), and (A)(2)(3): In hallways, in stairways, and at outdoor entrances, remote, central, or automatic control of lighting shall be permitted.

(4) Lighting outlets controlled in accordance with210.70(A)(2)(3) shall not be controlled by use of dimmer switches or controllers unless they provide the full range of dimming control at each location.

Statement of Problem and Substantiation for Public Input

The National Electrical Code requires “wall switch–controlled” lighting and receptacles. The common enforcement understanding due to the definition of a switch is that a hard-wired switch is required. The technology for controlling lighting and receptacles continues to evolve with further automation and control. Voice control via Alexa and manual remote devices located on the wall are able to communicate via control wire or wirelessly with the controllers for operating lighting outlets and receptacles at the receptacle outlet or lighting outlet.

Numerous manufacturers offer remote devices that wirelessly communicate with controllers that control the lighting outlet or the receptacle outlet. They are being installed today across the country as code compliant to serve as a “wall switch,” when in fact they would not meet the definition of a “switch” with a voltage rating or interrupting rating.

The proposed revise language will permit lighting and receptacle control technology that is currently available and being installed in dwellings and commercial buildings today. Permitting wireless communication to a controller for lighting in the NEC would also align with the permitted application of wireless communication for life safety fire alarms permitted in NFPA 72.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 4154-NFPA 70-2017 [New Definition after Definition: Remote-Control Circuit.]	Definition for new language

Public Input No. 4199-NFPA 70-2017 [Section No. 210.70(A)(1)] Alignment

Submitter Information Verification

Submitter Full Name: Alan Manche
Organization: Schneider Electric
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 07 16:18:07 EDT 2017

Copyright Assignment

I, Alan Manche, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Alan Manche, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 222-NFPA 70-2017 [Section No. 210.70(A)(3)]

~~**(3)** Storage or Equipment Spaces.~~

~~For attics, underfloor spaces, utility rooms, and basements, at least one lighting outlet containing a switch or controlled by a wall switch shall be installed where these spaces are used for storage or contain equipment requiring servicing. At least one point of control shall be at the usual point of entry to these spaces. The lighting outlet shall be provided at or near the equipment requiring servicing.~~

delete

Statement of Problem and Substantiation for Public Input

please delete this section as it is now addressed in 210.70 (C)

Submitter Information Verification

Submitter Full Name: Alfio Torrisi

Organization: Master

Street Address:

City:

State:

Zip:

Submittal Date: Thu Feb 09 13:06:30 EST 2017

Public Input No. 369-NFPA 70-2017 [Section No. 210.70(A)(3)]

~~(3) Storage or Equipment Spaces.~~

~~For attics, underfloor spaces, utility rooms, and basements, at least one lighting outlet containing a switch or controlled by a wall switch shall be installed where these spaces are used for storage or contain equipment requiring servicing. At least one point of control shall be at the usual point of entry to these spaces. The lighting outlet shall be provided at or near the equipment requiring servicing.~~

-

Statement of Problem and Substantiation for Public Input

This section can safely be deleted. It is redundant and no longer needed since the revisions made to section 210.70(C) in the last revision cycle. The identical requirements found in section 210.70(C) are for ALL occupancies, including dwelling units.

Submitter Information Verification

Submitter Full Name: Russ Leblanc

Organization: Leblanc Consulting Services

Street Address:

City:

State:

Zip:

Submittal Date: Sun Mar 26 07:42:56 EDT 2017

Public Input No. 4208-NFPA 70-2017 [Section No. 210.70(A)(3)]

(3) Storage or Equipment Spaces.

For attics, underfloor spaces, utility rooms, and basements, at least one lighting outlet ~~containing a switch or~~ controlled by a wall switch <u>or mounted remote-control device</u> shall be installed where these spaces are used for storage or contain equipment requiring servicing. At least one point of control shall be at the usual point of entry to these spaces. The lighting outlet shall be provided at or near the equipment requiring servicing.

Statement of Problem and Substantiation for Public Input

The National Electrical Code requires "wall switch–controlled" lighting and receptacles. The common enforcement understanding due to the definition of a switch is that a hard-wired switch is required. The technology for controlling lighting and receptacles continues to evolve with further automation and control. Voice control via Alexa and manual remote devices located on the wall are able to communicate via control wire or wirelessly with the controllers for operating lighting outlets and receptacles at the receptacle outlet or lighting outlet.

Numerous manufacturers offer remote devices that wirelessly communicate with controllers that control the lighting outlet or the receptacle outlet. They are being installed today across the country as code compliant to serve as a "wall switch," when in fact they would not meet the definition of a "switch" with a voltage rating or interrupting rating.

The proposed revise language will permit lighting and receptacle control technology that is currently available and being installed in dwellings and commercial buildings today. Permitting wireless communication to a controller for lighting in the NEC would also align with the permitted application of wireless communication for life safety fire alarms permitted in NFPA 72.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 4154-NFPA 70-2017 [New Definition after Definition: Remote-Control Circuit.]	Definition
Public Input No. 4199-NFPA 70-2017 [Section No. 210.70(A)(1)]	Related
Public Input No. 4193-NFPA 70-2017 [Section No. 210.70(A)(2)]	Related

Submitter Information Verification

Submitter Full Name: Alan Manche
Organization: Schneider Electric
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 07 16:28:10 EDT 2017

Copyright Assignment

I, Alan Manche, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Alan Manche, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 4219-NFPA 70-2017 [Section No. 210.70(B)]

(B) Guest Rooms or Guest Suites.

In hotels, motels, or similar occupancies, guest rooms or guest suites shall have at least one ~~wall switch–controlled~~ lighting outlet controlled by a wall switch or wall mounted remote-control device installed in every habitable room and bathroom.

Exception No. 1: In other than bathrooms and kitchens where provided, one or more receptacles controlled by a wall switch or wall mounted remote-controlled device shall be permitted in lieu of lighting outlets.

Exception No. 2: Lighting outlets shall be permitted to be controlled by occupancy sensors that are (1) in addition to wall switches or wall mounted lighting remote-control device, or (2) located at a customary wall switch location and equipped with a manual override that allows the sensor to function as a wall switch.

Statement of Problem and Substantiation for Public Input

The National Electrical Code requires “wall switch–controlled” lighting and receptacles. The common enforcement understanding due to the definition of a switch is that a hard-wired switch is required. The technology for controlling lighting and receptacles continues to evolve with further automation and control. Voice control via Alexa and manual remote devices located on the wall are able to communicate via control wire or wirelessly with the controllers for operating lighting outlets and receptacles at the receptacle outlet or lighting outlet.

Numerous manufacturers offer remote devices that wirelessly communicate with controllers that control the lighting outlet or the receptacle outlet. They are being installed today across the country as code compliant to serve as a “wall switch,” when in fact they would not meet the definition of a “switch” with a voltage rating or interrupting rating.

The proposed revise language will permit lighting and receptacle control technology that is currently available and being installed in dwellings and commercial buildings today. Permitting wireless communication to a controller for lighting in the NEC would also align with the permitted application of wireless communication for life safety fire alarms permitted in NFPA 72.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 4154-NFPA 70-2017 [New Definition after Definition: Remote-Control Circuit.]	Definition for new term used
Public Input No. 4199-NFPA 70-2017 [Section No. 210.70(A)(1)]	
Public Input No. 4193-NFPA 70-2017 [Section No. 210.70(A)(2)]	
Public Input No. 4208-NFPA 70-2017 [Section No. 210.70(A)(3)]	

Submitter Information Verification

Submitter Full Name: Alan Manche

Organization: Schneider Electric

Street Address:

City:

State:

Zip:

Submittal Date: Thu Sep 07 16:39:10 EDT 2017

Copyright Assignment

I, Alan Manche, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Alan Manche, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 4213-NFPA 70-2017 [Section No. 210.70(C)]

(C) All Occupancies.

For attics and underfloor spaces, utility rooms, and basements, at least one lighting outlet containing a switch or controlled by a wall switch or wall mounted lighting remote-control device shall be installed where these spaces are used for storage or contain equipment requiring servicing. At least one point of control shall be at the usual point of entry to these spaces. The lighting outlet shall be provided at or near the equipment requiring servicing.

Statement of Problem and Substantiation for Public Input

The National Electrical Code requires “wall switch–controlled” lighting and receptacles. The common enforcement understanding due to the definition of a switch is that a hard-wired switch is required. The technology for controlling lighting and receptacles continues to evolve with further automation and control. Voice control via Alexa and manual remote devices located on the wall are able to communicate via control wire or wirelessly with the controllers for operating lighting outlets and receptacles at the receptacle outlet or lighting outlet.

Numerous manufacturers offer remote devices that wirelessly communicate with controllers that control the lighting outlet or the receptacle outlet. They are being installed today across the country as code compliant to serve as a “wall switch,” when in fact they would not meet the definition of a “switch” with a voltage rating or interrupting rating.

The proposed revise language will permit lighting and receptacle control technology that is currently available and being installed in dwellings and commercial buildings today. Permitting wireless communication to a controller for lighting in the NEC would also align with the permitted application of wireless communication for life safety fire alarms permitted in NFPA 72.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 4154-NFPA 70-2017 [New Definition after Definition: Remote-Control Circuit.]	Definition
Public Input No. 4199-NFPA 70-2017 [Section No. 210.70(A)(1)]	
Public Input No. 4193-NFPA 70-2017 [Section No. 210.70(A)(2)]	
Public Input No. 4208-NFPA 70-2017 [Section No. 210.70(A)(3)]	
Public Input No. 4219-NFPA 70-2017 [Section No. 210.70(B)]	

Submitter Information Verification

Submitter Full Name: Alan Manche
Organization: Schneider Electric
Street Address:
City:
State:
Zip:

Submittal Date: Thu Sep 07 16:33:34 EDT 2017

Copyright Assignment

I, Alan Manche, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Alan Manche, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 4318-NFPA 70-2017 [Section No. 210.70(C)]

(C) All Occupancies.

For attics and underfloor spaces, utility rooms, and basements, at least one lighting outlet containing a switch or controlled by a wall switch shall be installed where these spaces are used for storage or contain equipment requiring servicing. At least one point of control shall be at the usual point(s) of entry to these spaces. The lighting outlet shall be provided at or near the equipment requiring servicing.

Statement of Problem and Substantiation for Public Input

It is possible that there could be more than one point of entry.

Submitter Information Verification

Submitter Full Name: Matt Hermanson

Organization: A And A Electric Inc

Street Address:

City:

State:

Zip:

Submittal Date: Thu Sep 07 20:26:12 EDT 2017

Public Input No. 2700-NFPA 70-2017 [Section No. 210.71]

210.71 Meeting Rooms.

(A) General.

Each meeting room of not more than 93 m^2 (1000 ft^2) in other than dwelling units shall have outlets for nonlocking-type, 125-volt, 15- or 20-ampere receptacles. The outlets shall be installed in accordance with 210.71(B). Where a room or space is provided with movable partition(s), each room size shall be determined with the partition in the position that results in the smallest size meeting room.

Informational Note No. 1: For the purposes of this section, meeting rooms are typically designed or intended for the gathering of seated occupants for such purposes as conferences, deliberations, or similar purposes, where portable electronic equipment such as computers, projectors, or similar equipment is likely to be used.

Informational Note No. 2: Examples of rooms that are not meeting rooms include auditoriums, schoolrooms, and coffee shops.

(B) Receptacle Outlets Required.

The total number of receptacle outlets, including floor outlets and receptacle outlets in fixed furniture, shall not be less than as determined in (1) and (2). These receptacle outlets shall be permitted to be located as determined by the designer or building owner.

(1) Receptacle Outlets in Fixed Walls.

~~Receptacle~~

The required number of receptacle outlets shall be

~~installed~~

determined in accordance with 210.52(A)(1) through (A)(4).

(2) Floor Receptacle Outlets.

A meeting room that is at least 3.7 m (12 ft) wide and that has a floor area of at least 20 m^2 (215 ft^2) shall have at least one receptacle outlet located in the floor at a distance not less than 1.8 m (6 ft) from any fixed wall for each 20 m^2 (215 ft^2) or major portion of floor space.

Informational Note No. 1: See Section 314.27(B) for floor boxes used for receptacles located in the floor.

Informational Note No. 2: See Article 518 for assembly occupancies designed for 100 or more persons.

Statement of Problem and Substantiation for Public Input

There has been confusion in the field whether it is necessary to meet the location and spacing requirements of 210.52(A) as stated in 210.71(B) (1). This is to clarify that 210.52 is used only to determine the quantity of receptacles and the location is determined by the designer or building owner as stated in 210.71(B) above.

Submitter Information Verification

Submitter Full Name: Vince Baclawski
Organization: Nema
Street Address:
City:
State:
Zip:
Submittal Date: Fri Aug 25 10:34:32 EDT 2017

Copyright Assignment

Public Input No. 596-NFPA 70-2017 [Section No. 210.71]

210. ~~71~~ 65 Meeting Rooms.

(A) General.

Each meeting room of not more than 93 m^2 (1000 ft^2) in other than dwelling units shall have outlets for nonlocking-type, 125-volt, 15- or 20-ampere receptacles. The outlets shall be installed in accordance with 210.~~71~~ 65 (B). Where a room or space is provided with movable partition(s), each room size shall be determined with the partition in the position that results in the smallest size meeting room.

Informational Note No. 1: For the purposes of this section, meeting rooms are typically designed or intended for the gathering of seated occupants for such purposes as conferences, deliberations, or similar purposes, where portable electronic equipment such as computers, projectors, or similar equipment is likely to be used.

Informational Note No. 2: Examples of rooms that are not meeting rooms include auditoriums, schoolrooms, and coffee shops.

(B) Receptacle Outlets Required.

The total number of receptacle outlets, including floor outlets and receptacle outlets in fixed furniture, shall not be less than as determined in (1) and (2). These receptacle outlets shall be permitted to be located as determined by the designer or building owner.

(1) Receptacle Outlets in Fixed Walls.

Receptacle outlets shall be installed in accordance with 210.52(A)(1) through (A)(4).

(2) Floor Receptacle Outlets.

A meeting room that is at least 3.7 m (12 ft) wide and that has a floor area of at least 20 m^2 (215 ft^2) shall have at least one receptacle outlet located in the floor at a distance not less than 1.8 m (6 ft) from any fixed wall for each 20 m^2 (215 ft^2) or major portion of floor space.

Informational Note No. 1: See Section 314.27(B) for floor boxes used for receptacles located in the floor.

Informational Note No. 2: See Article 518 for assembly occupancies designed for 100 or more persons.

Statement of Problem and Substantiation for Public Input

This input seeks to relocate 210.71 to 210.65. It is a companion proposal to a change I am proposing to 210.50.

Submitter Information Verification

Submitter Full Name: Ryan Jackson

Organization: Ryan Jackson

Street Address:

City:

State:

Zip:

Submittal Date: Tue Apr 25 21:46:16 EDT 2017

Copyright Assignment

Public Input No. 782-NFPA 70-2017 [Section No. 210.71]

210.~~71~~ 65 Meeting Rooms.

(A) General.

Each meeting room of not more than 93 m^2 (1000 ft^2) in other than dwelling units shall have outlets for nonlocking-type, 125-volt, 15- or 20-ampere receptacles. The outlets shall be installed in accordance with 210.71(B). Where a room or space is provided with movable partition(s), each room size shall be determined with the partition in the position that results in the smallest size meeting room.

> Informational Note No. 1: For the purposes of this section, meeting rooms are typically designed or intended for the gathering of seated occupants for such purposes as conferences, deliberations, or similar purposes, where portable electronic equipment such as computers, projectors, or similar equipment is likely to be used.

> Informational Note No. 2: Examples of rooms that are not meeting rooms include auditoriums, schoolrooms, and coffee shops.

(B) Receptacle Outlets Required.

The total number of receptacle outlets, including floor outlets and receptacle outlets in fixed furniture, shall not be less than as determined in (1) and (2). These receptacle outlets shall be permitted to be located as determined by the designer or building owner.

(1) Receptacle Outlets in Fixed Walls.

Receptacle outlets shall be installed in accordance with 210.52(A)(1) through (A)(4).

(2) Floor Receptacle Outlets.

A meeting room that is at least 3.7 m (12 ft) wide and that has a floor area of at least 20 m^2 (215 ft^2) shall have at least one receptacle outlet located in the floor at a distance not less than 1.8 m (6 ft) from any fixed wall for each 20 m^2 (215 ft^2) or major portion of floor space.

> Informational Note No. 1: See Section 314.27(B) for floor boxes used for receptacles located in the floor.

> Informational Note No. 2: See Article 518 for assembly occupancies designed for 100 or more persons.

Statement of Problem and Substantiation for Public Input

Meeting Room receptacle outlet requirements should be more appropriately located before Section 210.70 in Part III of Article 210. Section 210.50 requires receptacle outlets to be installed as specified in 210.52 through 210.64.
Then at 210.70 it switches to lighting outlets. But with the addition of 210.71 for Meeting rooms the language is back to receptacle outlets.
Relocating the requirements for Meeting room receptacle outlets to a new Section number 210.65 and changing Section 210.50 to include this section would clean this up.

Related Public Inputs for This Document

Related Input	Relationship

Public Input No. 2731-NFPA 70-2017 [Section No. 210.50 [Excluding any Sub-Sections]]

Submitter Information Verification

Submitter Full Name: Darryl Hill
Organization: Wichita Electrical JATC
Street Address:
City:
State:
Zip:
Submittal Date: Mon May 22 14:41:07 EDT 2017

Copyright Assignment

Public Input No. 1650-NFPA 70-2017 [Section No. 210.71(A)]

(A) General.

Each meeting room of not more than 93 m^2 (1000 ft^2) in other than dwelling units shall have outlets for nonlocking-type, 125-volt, 15- or 20-ampere receptacles. The quantity of outlets shall be ~~installed~~ determined in accordance with 210.71(B). Where a room or space is provided with movable partition(s), each room size shall be determined with the partition in the position that results in the smallest size meeting room.

Informational Note No. 1: For the purposes of this section, meeting rooms are typically designed or intended for the gathering of seated occupants for such purposes as conferences, deliberations, or similar purposes, where portable electronic equipment such as computers, projectors, or similar equipment is likely to be used.

Informational Note No. 2: Examples of rooms that are not meeting rooms include auditoriums, schoolrooms, and coffee shops.

Statement of Problem and Substantiation for Public Input

Editorial revisions to clarify and differentiate between requirements for installing receptacles and methods of determining the minimum quantity of receptacles.

Submitter Information Verification

Submitter Full Name: Agnieszka Golriz
Organization: NECA
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 03 10:53:23 EDT 2017

Public Input No. 1651-NFPA 70-2017 [Section No. 210.71(B)]

(B) Receptacle Outlets Required.

The total number of receptacle outlets, including floor outlets and receptacle outlets in fixed furniture, shall not be less than as determined in (1) and (2). These receptacle outlets shall be permitted to be located as determined by the designer or building owner.

(1) Receptacle Outlets in Fixed Walls.

~~Receptacle~~ The quantity of receptacle outlets shall be ~~installed~~ determined in accordance with 210.52(A)(1) through (A)(4).

(2) Floor Receptacle Outlets.

A meeting room that is at least 3.7 m (12 ft) wide and that has a floor area of at least 20 m^2 (215 ft^2) shall have at least one receptacle outlet located in the floor at a distance not less than 1.8 m (6 ft) from any fixed wall for each 20 m^2 (215 ft^2) or major portion of floor space.

Informational Note No. 1: See Section 314.27(B) for floor boxes used for receptacles located in the floor.

Informational Note No. 2: See Article 518 for assembly occupancies designed for 100 or more persons.

Statement of Problem and Substantiation for Public Input

Editorial revisions to clarify and differentiate between requirements for installing receptacles and methods of determining the minimum quantity of receptacles.

Submitter Information Verification

Submitter Full Name: Agnieszka Golriz
Organization: NECA
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 03 10:54:54 EDT 2017

Public Input No. 224-NFPA 70-2017 [Section No. 210.71(B)]

(B) Receptacle Outlets Required.

The total number of receptacle outlets, including floor outlets and receptacle outlets in fixed furniture, shall not be less than as determined in (1) and (2).

~~These receptacle outlets shall be permitted to be located as determined by the designer or building owner.~~

(1) Receptacle Outlets in Fixed Walls.

Receptacle outlets shall be installed in accordance with 210.52(A)(1) through (A)(4).

(2) Floor Receptacle Outlets.

A meeting room that is at least 3.7 m (12 ft) wide and that has a floor area of at least 20 m^2 (215 ft^2) shall have at least one receptacle outlet located in the floor at a distance not less than 1.8 m (6 ft) from any fixed wall for each 20 m^2 (215 ft^2) or major portion of floor space. These receptacles outlets shall be permitted to be located as determined by the designer or building owner

> Informational Note No. 1: See Section 314.27(B) for floor boxes used for receptacles located in the floor.
>
> Informational Note No. 2: See Article 518 for assembly occupancies designed for 100 or more persons.

Statement of Problem and Substantiation for Public Input

the fix wall receptacle outlets have mandatory language that contradicts the designer locating them and so the designer should only be allowed to locate the floor receptacles

Submitter Information Verification

Submitter Full Name: Alfio Torrisi
Organization: Master
Street Address:
City:
State:
Zip:
Submittal Date: Thu Feb 09 13:24:22 EST 2017

Copyright Assignment

I, Alfio Torrisi, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Alfio Torrisi, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 3676-NFPA 70-2017 [Section No. 210.71(B)]

(B) Receptacle Outlets Required.

The total number of receptacle outlets, including floor outlets and receptacle outlets in fixed furniture, shall not be less than as determined in (1) and (2). These receptacle outlets shall be permitted to be located as determined by the designer or building owner and not as referenced in 210 .52(A)(1) through (A)(4).

(1) Receptacle Outlets in Fixed Walls.

~~Receptacle outlets~~ The sum of the total receptacle outlets required shall be ~~installed~~ determined in accordance with 210.52(A)(1) through (A)(4).

(2) Floor Receptacle Outlets.

A meeting room that is at least 3.7 m (12 ft) wide and that has a floor area of at least 20 m^2 (215 ft^2) shall have at least one receptacle outlet located in the floor at a distance not less than 1.8 m (6 ft) from any fixed wall for each 20 m^2 (215 ft^2) or major portion of floor space.

Informational Note No. 1: See Section 314.27(B) for floor boxes used for receptacles located in the floor.

Informational Note No. 2: See Article 518 for assembly occupancies designed for 100 or more persons.

Statement of Problem and Substantiation for Public Input

Greetings CMP 2 Members,

In speaking with many of the CMP members there appears to be an oversight in the published edition of the 2017 NEC with regards to section 210.71(B). The way the language is expressed in section 210.71(B)(1) is that the installation of the required receptacles had to meet 210.52(A)(1) and (2) which are confuses NEC users that the spacing requirements come into play. Clearly the intent was to use these values in determining the sum of the receptacles needed. The use of the word "installed" in 210.71(B)(1) creates the confusion.

My submittal is simply cleaning up that language to make it clear that it is the sum of the required receptacles that we are after and not the spacing and overall payout requirements of the requirement as clearly 210.71(B) addresses. I was told by a few CMP members that remain anonymous that what was put in print was not actually what they thought was being added. This change is only to clarify and is open to friendly modification by the committee.

Submitter Information Verification

Submitter Full Name: Paul Abernathy

Organization: Encore Wire Corporation

Street Address:

City:

State:

Zip:

Submittal Date: Wed Sep 06 16:54:35 EDT 2017

Copyright Assignment

Public Input No. 1942-NFPA 70-2017 [Section No. 210.71(B)(1)]

(1) Receptacle Outlets in Fixed Walls.

Receptacle outlets shall ~~be installed~~ be determned in accordance with 210.52(A)(1) through (A)(4).

Statement of Problem and Substantiation for Public Input

There has been some confusion created by the use of the phrase "installed in accordance with 210.52(A)(1) through (A)(4)" which has resulted in different interpretations of the requirement. In some cases it has been determined that the receptacles have to be located in accordance with 210.52(A)(1) through (A)(4) as opposed to the number of required receptacle outlets being determined in this manner.

Changing "installed" to "determined" will make it clear to readers of the NEC the number of receptacles of is determined in accordance with 210.52(A)(1) through (A)(4) but the actual physical location can be selected by the building owner or the designer.

Submitter Information Verification

Submitter Full Name: David Clements

Organization: Intl Assoc Elec Insp

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 09 09:16:45 EDT 2017

Public Input No. 2252-NFPA 70-2017 [Section No. 210.71(B)(1)]

(1) Receptacle Outlets in Fixed Walls.

~~Receptacle~~ The minimum number of receptacle outlets shall be ~~installed~~ calculated in accordance with 210.52(A)(1) through (A)(4).

Statement of Problem and Substantiation for Public Input

This modification is in line with the parent text requirement which states that these receptacle outlets shall be permitted to be located as determined by the designer or building owner. The goal of this requirement was not to tell where the receptacles were required to be located but rather the total number of receptacles that are required for this space.

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich

Organization: Eaton Corporation

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 15 15:01:27 EDT 2017

Public Input No. 3172-NFPA 70-2017 [Section No. 210.71(B)(1)]

(1) Receptacle Outlets in Fixed Walls.

~~Receptacle~~ The number of receptacle outlets shall be ~~installed~~ calculated in accordance with 210.52(A)(1) through (A)(4).

Statement of Problem and Substantiation for Public Input

The main rule in 210.71(B) tells us that the placement of the receptacle outlets is permitted to be determined by the building designer or owner, but 210.71(B)(1) tell us that the receptacle outlets must be installed in accordance with the rules in 210.52(A)(1) through (A)(4). If the receptacle outlets must be installed per the rules in 210.52(A)(1) through (A)(4) the placement of these receptacle outlets is determined by those rules and not by the building owner or designer as stated in 210.71(B). These two sections are in conflict with each other.

Submitter Information Verification

Submitter Full Name: Don Ganiere
Organization: [Not Specified]
Street Address:
City:
State:
Zip:
Submittal Date: Sat Sep 02 14:15:01 EDT 2017

Public Input No. 1943-NFPA 70-2017 [Section No. 210.71(B)(2)]

(2) Floor Receptacle Outlets.

A meeting room that is at least 3.7 m (12 ft) wide in any direction and that has a floor area of at least 20 m^2 (215 ft^2) shall have at least one receptacle outlet located in the floor at a distance not less than 1.8 m (6 ft) from any fixed wall for each 20 m^2 (215 ft^2) or major portion of floor space.

Informational Note No. 1: See Section 314.27(B) for floor boxes used for receptacles located in the floor.

Informational Note No. 2: See Article 518 for assembly occupancies designed for 100 or more persons.

Statement of Problem and Substantiation for Public Input

This eliminates the possibility of arguments about length versus width and also addresses non-rectangular meeting rooms, such as round ones.

Submitter Information Verification

Submitter Full Name: David Clements

Organization: Intl Assoc Elec Insp

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 09 09:19:13 EDT 2017

Public Input No. 598-NFPA 70-2017 [Section No. 210.71(B)(2)]

(2) Floor Receptacle Outlets.

A meeting room that is at least 3.7 m (12 ft) wide and that has a floor area of at least 20 m^2 (215 ft^2) shall have at least one receptacle outlet located in the floor at a distance not less than 1.8 m (6 ft) from any fixed wall for each 20 m^2 (215 ft^2) or major portion of floor space.

Informational Note ~~No. 1~~ : See Section 314.27(B) for floor boxes used for receptacles located in the floor.

~~Informational Note No. 2: See Article 518 for assembly occupancies designed for 100 or more persons.~~

Statement of Problem and Substantiation for Public Input

An occupant load of over 100 people in a 1,000 square foot room seems very unlikely.

Submitter Information Verification

Submitter Full Name: Ryan Jackson

Organization: Ryan Jackson

Street Address:

City:

State:

Zip:

Submittal Date: Tue Apr 25 22:46:01 EDT 2017

Public Input No. 660-NFPA 70-2017 [Section No. 210.71(B)(2)]

(2) Floor Receptacle Outlets.

A meeting room that is at least 3.7 m (12 ft) wide and that has a floor area of at least 20 m^2 (215 ft^2) shall have at least one receptacle outlet located in the floor at a distance not less than 1.8 m (6 ft) from any fixed wall for each 20 m^2 (215 ft^2) or major portion of floor space.

(3) Equivalency.

The outlets required in 210.71(B)(2) shall be permitted to be located either flush or surface mounted on the floor or shall be permitted to be located within furniture that is centrally located within the room.

Informational Note No. 1: See Section 314.27(B) for floor boxes used for receptacles located in the floor.

Informational Note No. 2: See Article 518 for assembly occupancies designed for 100 or more persons.

Statement of Problem and Substantiation for Public Input

The present wording for Section 210.71 infers that the floor receptacle outlet must be located in the floor. These editorial changes will clarify that the meeting room outlet requirement can be satisfied by either a surface or flush outlet and may also be satisfied by outlets located within furniture such as a table top outlet.

Submitter Information Verification

Submitter Full Name: David Hittinger

Organization: Independent Electrical Contractors

Affilliation: Independent Electrical Contractors Codes and Standard

Street Address:

City:

State:

Zip:

Submittal Date: Sat May 06 12:58:22 EDT 2017

Public Input No. 3213-NFPA 70-2017 [New Article after 210]

210.72 Smoke Alarms

(A) **Locations.** Smoke alarms shall be provided in dwelling units in the following locations:

1. Sleeping rooms

2. Outside each separate sleeping area in the immediate vicinity of the bedroom

3. On each additional story of the dwelling, including basements and habitable attics and not including crawl spaces and uninhabitable attics. In dwellings or dwelling units with split levels and without an intervening door between the adjacent levels, a smoke alarm installed on the upper level shall suffice for the adjacent lower level provided that the lower level is less than one full story below the upper level.

(B) **Interconnection.** Where more than one smoke alarm is required to be installed within an individual dwelling unit, the alarm devices shall be interconnected in such a manner that the actuation of one alarm will activate all of the alarms in the individual dwelling unit. Physical interconnection of smoke alarms shall not be required where listed wireless alarms are installed and all alarms sound upon activation of one alarm.

(C) **Power source.** Smoke alarms shall receive their primary power from the building wiring where such wiring is served from a commercial source and, where primary power is interrupted, shall receive power from a battery. Wiring shall be permanent and without a disconnecting switch other than those required for overcurrent protection.

Exception: Interconnection of smoke alarms in existing areas shall not be required where alterations or repairs do not result in removal of interior wall or ceiling finishes exposing the structure, unless there is an attic, crawl space or basement available that could provide access for interconnection without the removal of interior finishes.

Informational Note No. 1: See the International Residential Code (IRC), Section R314 for additional information regarding smoke alarm requirements.

Informational Note No. 2: Combination smoke and carbon monoxide alarms shall be permitted to be used in lieu of smoke alarms.

Informational Note No. 3: Fire alarm systems shall be permitted to be used in lieu of smoke alarms. See International Residential Code R314.7 for additional information.

210.73 Carbon Monoxide Alarms

Carbon monoxide alarms shall be provided for dwelling units that contain a fuel-fired appliance or has an attached garage with an opening from the dwelling unit to the garage.

(A) **Location.** Carbon monoxide alarms in dwelling units shall be installed outside of each separate sleeping area in the immediate vicinity of the bedrooms. Where a fuel-burning appliance is located within a bedroom or its attached bathroom, a carbon monoxide alarm shall be installed within the bedroom.

(B) **Power source.** Carbon monoxide alarms shall receive their primary power from the building wiring where such wiring is served from a commercial source and, where primary power is interrupted, shall receive power from a battery. Wiring shall be permanent and without a disconnecting switch other than those required for overcurrent protection.

Informational Note No. 1: See the International Residential Code (IRC), Section R315 for additional information regarding carbon monoxide alarm requirements.

Informational Note No. 2: Combination carbon monoxide and smoke alarms shall be permitted to be used in lieu of carbon monoxide alarms.

Informational Note No. 3: Carbon monoxide detection systems shall be permitted to be used in lieu of carbon monoxide alarms. See International Residential Code R315.6 for additional information.

Statement of Problem and Substantiation for Public Input

The electrical installer is responsible for the installation of smoke alarms and carbon monoxide alarms when roughing in single family dwelling units. These devices are tied to branch circuits within these units. Several questions arise from installers and electrical inspectors as to where this information is located within the NEC. This information is not found within the NEC and has to be referenced in the International Residential Code (IRC).

This information would prove to be very beneficial to the electrician if referenced in the NEC. The NEC references other documents such as NFPA 99, The Health Care Facilities Code, so as to bring information to the attention of the electrician as it pertains to hospitals, doctors offices, and nursing homes. This request would be no different except it would be referencing the IRC to provide guidance to electricians of the requirements governing smoke alarms and carbon dioxide alarms.

An article was written for the IAEI Magazine addressing this problem and alerting the electricians and inspectors to where this information was located. This information was very well received within the electrical industry as it provided valuable information to the industry concerning these devices. This would see to be very beneficial to the user of the Code to be able to reference these requirements within the NEC. The addition of this information would provide guidance to the installer as to the locations for alarms to help assure compliance and public safety.

Submitter Information Verification

Submitter Full Name: Joseph Wages

Organization:

Street Address:

City:

State:

Zip:

Submittal Date: Mon Sep 04 08:59:51 EDT 2017

Public Input No. 1076-NFPA 70-2017 [New Section after 220.1]

220.2 Definitions

Demonstrated Load. Historical demand watt information recorded over at least a 24-month period for the same type of facility as the one in question, equated to watts/square foot (watts/square meter)

Additional Proposed Changes

File Name	Description	Approved
CSA-Groups-CEC-Section-8-Circuit-loading-and-demand-factors.pdf		

Statement of Problem and Substantiation for Public Input

This is a correlating and necessary definition to accompany a proposal for demonstrated load in a new proposal in Section 220.86.

Submitter Information Verification

Submitter Full Name: Michael Anthony
Organization: Standards Michigan
Affilliation: www.standardsmichigan.com
Street Address:
City:
State:
Zip:
Submittal Date: Mon Jun 26 06:27:56 EDT 2017

Origin (from sources other than the submitter)

Arkady Tssiserev, Lorne Clark (University of Alberta), Jim Harvey

Public Input No. 3288-NFPA 70-2017 [New Section after 220.10]

220.11 Floor Area Calculation

The floor area for each floor shall be calculated from the outside dimensions of the building, dwelling unit, or other area involved. For dwelling units, the calculated floor area shall not include open porches, garages, or unused or unfinished spaces not adaptable for future use.

Additional Proposed Changes

File Name	Description	Approved
LARRY_AYER_ATTACHMENT_PI_3288_3282.pdf		✓

Statement of Problem and Substantiation for Public Input

The Correlating Committee identified the need to establish an Energy Task Group to review the NEC® and identify areas where industry achievements in the reduction of energy use have not been reflected in the NEC. Identified areas would then be reviewed and public inputs submitted where agreed upon enhancements will provide appropriate alignment while preserving appropriate safety and operational provisions. NEC Article 220 addressing calculations for sizing electrical infrastructure is one area the task group identified. The initial focus for the 2020 NEC public inputs is on alignment of the lighting load calculations more closely with industry technology and practice. The Correlating Committee Energy Task Group, includes: Larry Ayer (Co-Chair), Alan Manche (Co-Chair), Donny Cook, Eric Richman Ashrae 90.1, John McCamish, Ken Boyce, Mike Weaver, Richard Holub, Steve Douglas; Tom Domitrovich, Tim Croushore, and Tim Pope.

This is a companion public input to PI-3282 which made changes to section 220.12 and deleted a certain part with regard to floor area calculations used to determine the minimum lighting load.
This specific public input relocates the floor area information to a new section, 220.11.

The Energy Task Group has removed unit loads for dwelling units from 220.12 and relocated this information to 220.14(J). As a result the floor area determination needs to address both 220.12 for non-dwelling occupancies and 220.14(J) for dwelling units. The proposed new 220.11 will now allow both 220.12 and 220.14(J) to reference a separate independent section for clarity.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3147-NFPA 70-2017 [Section No. 220.14(J)]	
Public Input No. 3153-NFPA 70-2017 [Section No. 220.42]	
Public Input No. 3282-NFPA 70-2017 [Section No. 220.12]	
Public Input No. 3300-NFPA 70-2017 [Section No. 220.16]	

Submitter Information Verification

Submitter Full Name: Lawrence Ayer
Organization: Biz Com Electric, Inc.

Affilliation: IEC
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 05 10:20:39 EDT 2017

Copyright Assignment

I, Lawrence Ayer, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Lawrence Ayer, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Part II. Branch-Circuit Load Calculations
220.10 General.

Branch-circuit loads shall be calculated as shown in 220.12, 220.14, and 220.16.

220.11 Floor Area (PI-3288)

The floor area for each floor shall be calculated from the outside dimensions of the building, dwelling unit, or other area involved. For dwelling units, the calculated floor area shall not include open porches, garages, or unused or unfinished spaces not adaptable for future use.

220.12 Lighting Load for Specified Occupancies. (PI-3282)

(A) General. A unit load of not less than that specified in Table 220.12 for non-dwelling occupancies specified shall be used to calculate ~~constitute~~ the minimum lighting load. ~~The floor area for each floor shall be calculated from the outside dimensions of the building, dwelling unit, or other area involved. For dwelling units, the calculated floor area shall not include open porches, garages, or unused or unfinished spaces not adaptable for future use.~~ The minimum lighting load shall be determined using the minimum unit load and the floor area as determined in 220.11.

> Informational Note: The unit values of Table 220.12 are based on minimum load conditions and 80~~100~~ percent power factor and may not provide sufficient capacity for the installation contemplated.

(B). Energy Code. ~~Exception No. 1:~~ Where the building is designed and constructed to comply with an energy code adopted by the local authority, the lighting load shall be permitted to be calculated using the unit~~at the~~ values specified in the energy code where the following conditions are met:

- *(1) A power monitoring system is installed that will provide continuous information regarding the total general lighting load of the building.*
- *(2) The power monitoring system will be set with alarm values to alert the building owner or manager if the lighting load exceeds the values set by the energy code.*
- *(3) The demand factors specified in 220.42 are not applied to the general lighting load.*

~~Exception No. 2: Where a building is designed and constructed to comply with an energy code adopted by the local authority and specifying an overall lighting density of less than 13.5 volt-amperes/13.5 m² (1.2 volt-amperes/1.2 ft²), the unit lighting loads in Table 220.12 for office and bank areas within the building shall be permitted to be reduced by 11 volt-amperes/11 m² (1 volt-amperes/1 ft²).~~

Table 220.12 General Lighting Loads by Non-Dwelling Occupancy

~~Type of Occupancy~~	~~Unit Load~~	
	~~Volt-amperes/m²~~	~~Volt-amperes/ft²~~
~~Armories and auditoriums~~	~~11~~	~~1~~
~~Banks~~	~~39[b]~~	~~3½[b]~~

~~Type of Occupancy~~	~~Unit Load~~	
	~~Volt-amperes/m²~~	~~Volt-amperes/ft²~~
~~Barber shops and beauty parlors~~	~~33~~	~~3~~
~~Churches~~	~~11~~	~~1~~
~~Clubs~~	~~22~~	~~2~~
~~Courtrooms~~	~~22~~	~~2~~
~~Dwelling units[a]~~	~~33~~	~~3~~
~~Garages — commercial (storage)~~	~~6~~	~~½~~
~~Hospitals~~	~~22~~	~~2~~
~~Hotels and motels, including apartment houses without provision for cooking by tenants[a]~~	~~22~~	~~2~~
~~Industrial commercial (loft) buildings~~	~~22~~	~~2~~
~~Lodge rooms~~	~~17~~	~~1½~~
~~Office buildings~~	~~39[b]~~	~~3½[b]~~
~~Restaurants~~	~~22~~	~~2~~
~~Schools~~	~~33~~	~~3~~
~~Stores~~	~~33~~	~~3~~
~~Warehouses (storage)~~	~~3~~	~~¼~~
~~In any of the preceding occupancies except one-family dwellings and individual dwelling units of two-family and multifamily dwellings:~~	~~-~~	~~-~~
~~Assembly halls and auditoriums~~	~~11~~	~~1~~
~~Halls, corridors, closets, stairways~~	~~6~~	~~½~~
~~Storage spaces~~	~~3~~	~~¼~~

~~[a]See 220.14(J).~~

~~[b]See 220.14(K).~~

Cross references for the 2017 NEC occupancies are provided in the notes to Table 220.12.

Type of Occupancy	Unit Load	
	Volt-amperes/m²	Volt-amperes/ft²
Automotive facility	16	1.5
Convention center	15	1.4
Courthouse	15	1.4
Restaurants[4]	16	1.5

Dormitory	16	1.5
Exercise center	15	1.4
Fire station	14	1.3
Gymnasium[3]	18	1.7
Health-care clinic	17	1.6
Hospital	17	1.6
Hotels and motels, including apartment houses without provision for cooking by tenants[6]	18	1.7
Library	16	1.5
Manufacturing facility	24	2.2
Motion picture theater	17	1.6
Museum	17	1.6
Office[1]	14	1.3
Parking garage[8]	3	0.3
Penitentiary	13	1.2
Performing arts theater	16	1.5
Police station	14	1.3
Post office	17	1.6
Religious facility	24	2.2
Retail[5, 7]	20	1.9
School/university	16	1.5
Sports arena	16	1.5
Town hall	15	1.4
Transportation	13	1.2
Warehouse	13	1.2
Workshop	18	1.7

220.14(K).

Notes:

1. **Banks are office type occupancies.**
2. **Industrial Commercial loft buildings are considered manufacturing type occupancies.**
3. **Armories and Auditoriums are considered Gymnasium type occupancies.**
4. **Clubs are considered restaurant occupancies.**
5. **Barber shops and beauty parlors are considered retail occupancies.**
6. **Lodge rooms are similar to hotel and motel**
7. **Stores are considered retail occupancies.**
8. **Garages – Commercial (storage) are considered Parking Garage occupancies.**

220.14 Other Loads — All Occupancies.
In all occupancies, the minimum load for each outlet for general-use receptacles and outlets not used for general illumination shall not be less than that calculated in 220.14(A) through (L), the loads shown being based on nominal branch-circuit voltages.
Exception: The loads of outlets serving switchboards and switching frames in telephone exchanges shall be waived from the calculations.

(A) Specific Appliances or Loads.
An outlet for a specific appliance or other load not covered in 220.14(B) through (L) shall be calculated based on the ampere rating of the appliance or load served.

(B) Electric Dryers and Electric Cooking Appliances in Dwellings and Household Cooking Appliances Used in Instructional Programs.
Load calculations shall be permitted as specified in 220.54 for electric dryers and in 220.55 for electric ranges and other cooking appliances.

(C) Motor Outlets.
Loads for motor outlets shall be calculated in accordance with the requirements in 430.22, 430.24, and 440.6.

(D) Luminaires.
An outlet supplying luminaire(s) shall be calculated based on the maximum volt-ampere rating of the equipment and lamps for which the luminaire(s) is rated.

(E) Heavy-Duty Lampholders.
Outlets for heavy-duty lampholders shall be calculated at a minimum of 600 volt-amperes.

(F) Sign and Outline Lighting.
Sign and outline lighting outlets shall be calculated at a minimum of 1200 volt-amperes for each required branch circuit specified in 600.5(A).

(G) Show Windows.
Show windows shall be calculated in accordance with either of the following:

(1) The unit load per outlet as required in other provisions of this section

(2) At 200 volt-amperes per linear 300 mm (1 ft) of show window

(H) Fixed Multioutlet Assemblies.
Fixed multioutlet assemblies used in other than dwelling units or the guest rooms or guest suites of hotels or motels shall be calculated in accordance with (H)(1) or (H)(2). For the purposes of this section, the calculation shall be permitted to be based on the portion that contains receptacle outlets.

(1) Where appliances are unlikely to be used simultaneously, each 1.5 m (5 ft) or fraction thereof of each separate and continuous length shall be considered as one outlet of not less than 180 volt-amperes.

(2) Where appliances are likely to be used simultaneously, each 300 mm (1 ft) or fraction thereof shall be considered as an outlet of not less than 180 volt-amperes.

(I) Receptacle Outlets.
Except as covered in 220.14(J) and (K), receptacle outlets shall be calculated at not less than 180 volt-amperes for each single or for each multiple receptacle on one yoke. A single piece of equipment consisting of a multiple receptacle comprised of four or more receptacles shall be calculated at not less than 90 volt-amperes per receptacle. This provision shall not be applicable to the receptacle outlets specified in 210.11(C)(1) and (C)(2).

(J) Dwelling Occupancies. (PI-3147)
In one-family, two-family, and multifamily dwellings and in guest rooms or guest suites of hotels and motels, the unit load shall be not less than the 33-VA/m^2 (3 VA/ft2). The lighting and receptacle outlets specified in (J)(1), (J)(2), and (J)(3) ~~-~~are included in the minimum unit load ~~general lighting load calculations of 220.12~~. No additional load calculations shall be required for such outlets. The minimum lighting load shall be determined using the minimum unit load and the floor area as determined in 220.11 for dwelling occupancies.

(1) All general-use receptacle outlets of 20-ampere rating or less, including receptacles connected to the circuits in 210.11(C)(3)

(2) The receptacle outlets specified in 210.52(E) and (G)

(3) The lighting outlets specified in 210.70(A) and (B)

(K) ~~Banks and~~ Office Buildings.
In ~~banks or~~ office buildings, the receptacle loads shall be calculated to be the larger of (1) or (2):

(1) The calculated load from 220.14(I)

(2) 11 volt-amperes/m^2 or 1 volt-ampere/ft^2

(L) Other Outlets.

Other outlets not covered in 220.14(A) through (K) shall be calculated based on 180 volt-amperes per outlet.

220.16 Loads for Additions to Existing Installations. [PI-3319]

(A) Dwelling Units.
Loads added to an existing dwelling unit(s) shall comply with the following as applicable:

(1) ~~Loads F~~for structural additions to an existing dwelling unit or for a previously unwired portion of an existing dwelling unit, either of which exceeds 46.5 m^2 (500 ft^2), the minimum lighting load shall be calculated in accordance with ~~220.12 and~~ 220.14(J).

(2) For structural additions or previously unwired portions of an existing dwelling unit that are less than 46.5 m^2 (500 ft^2), the minimum lighting load shall be permitted to be excluded from the calculations.

(3) Additional loads other than those covered in 220.14(J) shall be ~~Loads for new circuits or extended circuits in previously wired dwelling units shall be~~ calculated in accordance with ~~either 220.12 or~~ 220.14, as applicable.

(B) Other Than Dwelling Units.
Loads for new circuits or extended circuits in other than dwelling units shall be calculated in accordance with either 220.12 or 220.14, as applicable.

220.18 Maximum Loads.
The total load shall not exceed the rating of the branch circuit, and it shall not exceed the maximum loads specified in 220.18(A) through (C) under the conditions specified therein.

(A) Motor-Operated and Combination Loads.
Where a circuit supplies only motor-operated loads, Article 430 shall apply. Where a circuit supplies only air-conditioning equipment, refrigerating equipment, or both, Article 440 shall apply. For circuits supplying loads consisting of motor-operated utilization equipment that is fastened in place and has a motor larger than **1/8** hp in combination with other loads, the total calculated load shall be based on 125 percent of the largest motor load plus the sum of the other loads.

(B) Inductive and LED Lighting Loads.
For circuits supplying lighting units that have ballasts, transformers, autotransformers, or LED drivers, the calculated load shall be based on the total ampere ratings of such units and not on the total watts of the lamps.

(C) Range Loads.
It shall be permissible to apply demand factors for range loads in accordance with Table 220.55, including Note 4.

Part III. Feeder and Service Load Calculations

220.40 General.

The calculated load of a feeder or service shall not be less than the sum of the loads on the branch circuits supplied, as determined by Part II of this article, after any applicable demand factors permitted by Part III or IV or required by Part V have been applied.
Informational Note: See Examples D1(a) through D10 in Informative Annex D. See 220.18(B) for the maximum load in amperes permitted for lighting units operating at less than 100 percent power factor.

220.42 General Lighting.

The demand factors specified in Table 220.42 shall apply to that portion of the total branch-circuit load calculated for general illumination. They shall not be applied in determining the number of branch circuits for general illumination.

Table 220.42 Lighting Load Demand Factors [PI- 3153]

Type of Occupancy	Portion of Lighting Load to Which Demand Factor Applies (Volt-Amperes)	Demand Factor (%)
Dwelling units	First 3000 at	100
	From 3001 to 120,000 at	35
	Remainder over 120,000 at	25
~~Hospitals*~~	~~First 50,000 or less at~~	~~40~~
~~-~~	~~Remainder over 50,000 at~~	~~20~~
Hotels and motels, including apartment houses without provision for cooking by tenants*	First 20,000 or less at	50
	From 20,001 to 100,000 at	40
	Remainder over 100,000 at	30
Warehouses (storage)	First 12,500 or less at	100
	Remainder over 12,500 at	50
All others	Total volt-amperes	100

*The demand factors of this table shall not apply to the calculated load of feeders or services supplying areas in hospitals, hotels, and motels where the entire lighting is likely to be used at one time, as in operating rooms, ballrooms, or dining rooms.

220.43 Show-Window and Track Lighting.

(A) Show Windows.

For show-window lighting, a load of not less than 660 volt-amperes/linear meter or 200 volt-amperes/linear foot shall be included for a show window, measured horizontally along its base.
Informational Note: See 220.14(G) for branch circuits supplying show windows.

(B) Track Lighting.

For track lighting in other than dwelling units or guest rooms or guest suites of hotels or motels, an additional load of 150 volt-amperes shall be included for every 600 mm (2 ft) of lighting track or fraction thereof. Where multicircuit track is installed, the load shall be considered to be divided equally between the track circuits.

Exception: If the track lighting is supplied through a device that limits the current to the track, the load shall be permitted to be calculated based on the rating of the device used to limit the current.

220.44 Receptacle Loads — Other Than Dwelling Units.

Receptacle loads calculated in accordance with 220.14(H) and (I) shall be permitted to be made subject to the demand factors given in Table 220.42 or Table 220.44.

Table 220.44 Demand Factors for Non-Dwelling Receptacle Loads

Portion of Receptacle Load to Which Demand Factor Applies (Volt-Amperes)	Demand Factor (%)
First 10 kVA or less at	100
Remainder over 10 kVA at	50

220.50 Motors.

Motor loads shall be calculated in accordance with 430.24, 430.25, and 430.26 and with 440.6 for hermetic refrigerant motor-compressors.

220.51 Fixed Electric Space Heating.

Fixed electric space-heating loads shall be calculated at 100 percent of the total connected load. However, in no case shall a feeder or service load current rating be less than the rating of the largest branch circuit supplied.

Exception: Where reduced loading of the conductors results from units operating on duty-cycle, intermittently, or from all units not operating at the same time, the authority having jurisdiction may grant permission for feeder and service conductors to have an ampacity less than 100 percent, provided the conductors have an ampacity for the load so determined.

220.52 Small-Appliance and Laundry Loads — Dwelling Unit.

(A) Small-Appliance Circuit Load.

In each dwelling unit, the load shall be calculated at 1500 volt-amperes for each 2-wire small-appliance branch circuit as covered by 210.11(C)(1). Where the load is subdivided through two or more feeders, the calculated load for each shall include not less than 1500 volt-amperes for each 2-wire small-appliance branch circuit. These loads shall be permitted to be included with the general lighting load and subjected to the demand factors provided in Table 220.42.

Exception: The individual branch circuit permitted by 210.52(B)(1), Exception No. 2, shall be permitted to be excluded from the calculation required by 220.52.

(B) Laundry Circuit Load.

A load of not less than 1500 volt-amperes shall be included for each 2-wire laundry branch circuit installed as covered by 210.11(C)(2). This load shall be permitted to be included with the general lighting load and shall be subjected to the demand factors provided in Table 220.42.

220.53 Appliance Load — Dwelling Unit(s).

It shall be permissible to apply a demand factor of 75 percent to the nameplate rating load of four or more appliances fastened in place, other than electric ranges, clothes dryers, space-heating equipment, or air-conditioning equipment, that are served by the same feeder or service in a one-family, two-family, or multifamily dwelling.

220.54 Electric Clothes Dryers — Dwelling Unit(s).

The load for household electric clothes dryers in a dwelling unit(s) shall be either 5000 watts (volt-amperes) or the nameplate rating, whichever is larger, for each dryer served. The use of the demand factors in Table 220.54 shall be permitted. Where two or more single-phase dryers are supplied by a 3-phase, 4-wire feeder or service, the total load shall be calculated on the basis of twice the maximum number connected between any two phases. Kilovolt-amperes (kVA) shall be considered equivalent to kilowatts (kW) for loads calculated in this section.

Table 220.54 Demand Factors for Household Electric Clothes Dryers

Number of Dryers	Demand Factor (%)
1–4	100
5	85
6	75
7	65
8	60
9	55
10	50

Number of Dryers	Demand Factor (%)
11	47
12–23	47% minus 1% for each dryer exceeding 11
24–42	35% minus 0.5% for each dryer exceeding 23
43 and over	25%

220.55 Electric Cooking Appliances in Dwelling Units and Household Cooking Appliances Used in Instructional Programs.

The load for household electric ranges, wall-mounted ovens, counter-mounted cooking units, and other household cooking appliances individually rated in excess of 1**3/4** kW shall be permitted to be calculated in accordance with Table 220.55. Kilovolt-amperes (kVA) shall be considered equivalent to kilowatts (kW) for loads calculated under this section.

Where two or more single-phase ranges are supplied by a 3-phase, 4-wire feeder or service, the total load shall be calculated on the basis of twice the maximum number connected between any two phases.

Table 220.55 Demand Factors and Loads for Household Electric Ranges, Wall-Mounted Ovens, Counter-Mounted Cooking Units, and Other Household Cooking Appliances over 13/4 kW Rating (Column C to be used in all cases except as otherwise permitted in Note 3.)

Number of Appliances	Demand Factor (%) (See Notes)		Column C Maximum Demand (kW) (See Notes) (Not over 12 kW Rating)
	Column A (Less than 3½ kW Rating)	Column B (3½ kW through 8¾ kW Rating)	
1	80	80	8
2	75	65	11
3	70	55	14
4	66	50	17
5	62	45	20
6	59	43	21
7	56	40	22
8	53	36	23
9	51	35	24
10	49	34	25
11	47	32	26
12	45	32	27
13	43	32	28
14	41	32	29
15	40	32	30
16	39	28	31
17	38	28	32
18	37	28	33
19	36	28	34
20	35	28	35

Number of Appliances	Demand Factor (%) (See Notes)		Column C Maximum Demand (kW) (See Notes) (Not over 12 kW Rating)
	Column A (Less than $3\frac{1}{2}$ kW Rating)	Column B ($3\frac{1}{2}$ kW through $8\frac{3}{4}$ kW Rating)	
21	34	26	36
22	33	26	37
23	32	26	38
24	31	26	39
25	30	26	40
26–30	30	24	15 kW + 1 kW for each range
31–40	30	22	
41–50	30	20	25 kW + $\frac{3}{4}$ kW for each range
51–60	30	18	
61 and over	30	16	

Notes:
1. Over 12 kW through 27 kW ranges all of same rating. For ranges individually rated more than 12 kW but not more than 27 kW, the maximum demand in Column C shall be increased 5 percent for each additional kilowatt of rating or major fraction thereof by which the rating of individual ranges exceeds 12 kW.
2. Over $8\frac{3}{4}$ kW through 27 kW ranges of unequal ratings. For ranges individually rated more than $8\frac{3}{4}$ kW and of different ratings, but none exceeding 27 kW, an average value of rating shall be calculated by adding together the ratings of all ranges to obtain the total connected load (using 12 kW for any range rated less than 12 kW) and dividing by the total number of ranges. Then the maximum demand in Column C shall be increased 5 percent for each kilowatt or major fraction thereof by which this average value exceeds 12 kW.
3. Over $1\frac{3}{4}$ kW through $8\frac{3}{4}$ kW. In lieu of the method provided in Column C, it shall be permissible to add the nameplate ratings of all household cooking appliances rated more than $1\frac{3}{4}$ kW but not more than $8\frac{3}{4}$ kW and multiply the sum by the demand factors specified in Column A or Column B for the given number of appliances. Where the rating of cooking appliances falls under both Column A and Column B, the demand factors for each column shall be applied to the appliances for that column, and the results added together.
4. Branch-Circuit Load. It shall be permissible to calculate the branch-circuit load for one range in accordance with Table 220.55. The branch-circuit load for one wall-mounted oven or one counter-mounted cooking unit shall be the nameplate rating of the appliance. The branch-circuit load for a counter-mounted cooking unit and not more than two wall-mounted ovens, all supplied from a single branch circuit and located in the same room, shall be calculated by adding the nameplate rating of the individual appliances and treating this total as equivalent to one range.
5. This table shall also apply to household cooking appliances rated over $1\frac{3}{4}$ kW and used in instructional programs.

Informational Note No. 1: See the examples in Informative Annex D.
Informational Note No. 2: See Table 220.56 for commercial cooking equipment.

220.56 Kitchen Equipment — Other Than Dwelling Unit(s).

It shall be permissible to calculate the load for commercial electric cooking equipment, dishwasher booster heaters, water heaters, and other kitchen equipment in accordance with Table 220.56. These demand factors shall be applied to all equipment that has either thermostatic control or intermittent use as kitchen equipment. These demand factors shall not apply to space-heating, ventilating, or air-conditioning equipment.

However, in no case shall the feeder or service calculated load be less than the sum of the largest two kitchen equipment loads.

Table 220.56 Demand Factors for Kitchen Equipment — Other Than Dwelling Unit(s)

Number of Units of Equipment	Demand Factor (%)
1	100
2	100
3	90
4	80
5	70
6 and over	65

220.60 Noncoincident Loads.
Where it is unlikely that two or more noncoincident loads will be in use simultaneously, it shall be permissible to use only the largest load(s) that will be used at one time for calculating the total load of a feeder or service.
220.61 Feeder or Service Neutral Load.
(A) Basic Calculation.
The feeder or service neutral load shall be the maximum unbalance of the load determined by this article. The maximum unbalanced load shall be the maximum net calculated load between the neutral conductor and any one ungrounded conductor.
Exception: For 3-wire, 2-phase or 5-wire, 2-phase systems, the maximum unbalanced load shall be the maximum net calculated load between the neutral conductor and any one ungrounded conductor multiplied by 140 percent.
(B) Permitted Reductions.
A service or feeder supplying the following loads shall be permitted to have an additional demand factor of 70 percent applied to the amount in 220.61(B)(1) or portion of the amount in 220.61(B)(2) determined by the following basic calculations:

(1) A feeder or service supplying household electric ranges, wall-mounted ovens, counter-mounted cooking units, and electric dryers, where the maximum unbalanced load has been determined in accordance with Table 220.55 for ranges and Table 220.54 for dryers

(2) That portion of the unbalanced load in excess of 200 amperes where the feeder or service is supplied from a 3-wire dc or single-phase ac system; or a 4-wire, 3-phase system; or a 3-wire, 2-phase system; or a 5-wire, 2-phase system

Informational Note: See Examples D1(a), D1(b), D2(b), D4(a), and D5(a) in Informative Annex D.
(C) Prohibited Reductions.
There shall be no reduction of the neutral or grounded conductor capacity applied to the amount in 220.61(C)(1), or portion of the amount in (C)(2), from that determined by the basic calculation:

(1) Any portion of a 3-wire circuit consisting of 2 ungrounded conductors and the neutral conductor of a 4-wire, 3-phase, wye-connected system

(2) That portion consisting of nonlinear loads supplied from a 4-wire, wye-connected, 3-phase system

Informational Note: A 3-phase, 4-wire, wye-connected power system used to supply power to nonlinear loads may necessitate that the power system design allow for the possibility of high harmonic neutral conductor currents.
Part IV. Optional Feeder and Service Load Calculations
220.80 General.
Optional feeder and service load calculations shall be permitted in accordance with Part IV.
220.82 Dwelling Unit.
(A) Feeder and Service Load.
This section applies to a dwelling unit having the total connected load served by a single 120/240-volt or 208Y/120-volt set of 3-wire service or feeder conductors with an ampacity of 100 or greater. It shall be permissible to calculate the feeder and service loads in accordance with this section instead of

the method specified in Part III of this article. The calculated load shall be the result of adding the loads from 220.82(B) and (C). Feeder and service-entrance conductors whose calculated load is determined by this optional calculation shall be permitted to have the neutral load determined by 220.61.

(B) General Loads.

The general calculated load shall be not less than 100 percent of the first 10 kVA plus 40 percent of the remainder of the following loads:

(1) 33 volt-amperes/m^2 or 3 volt-amperes/ft^2 for general lighting and general-use receptacles. The floor area for each floor shall be calculated from the outside dimensions of the dwelling unit. The calculated floor area shall not include open porches, garages, or unused or unfinished spaces not adaptable for future use.

(2) 1500 volt-amperes for each 2-wire, 20-ampere small-appliance branch circuit and each laundry branch circuit covered in 210.11(C)(1) and (C)(2).

(3) The nameplate rating of the following:

   a. All appliances that are fastened in place, permanently connected, or located to be on a specific circuit

   b. Ranges, wall-mounted ovens, counter-mounted cooking units

   c. Clothes dryers that are not connected to the laundry branch circuit specified in item (2)

   d. Water heaters

(4) The nameplate ampere or kVA rating of all permanently connected motors not included in item (3).

(C) Heating and Air-Conditioning Load.

The largest of the following six selections (load in kVA) shall be included:

(1) 100 percent of the nameplate rating(s) of the air conditioning and cooling.

(2) 100 percent of the nameplate rating(s) of the heat pump when the heat pump is used without any supplemental electric heating.

(3) 100 percent of the nameplate rating(s) of the heat pump compressor and 65 percent of the supplemental electric heating for central electric space-heating systems. If the heat pump compressor is prevented from operating at the same time as the supplementary heat, it does not need to be added to the supplementary heat for the total central space heating load.

(4) 65 percent of the nameplate rating(s) of electric space heating if less than four separately controlled units.

(5) 40 percent of the nameplate rating(s) of electric space heating if four or more separately controlled units.

(6) 100 percent of the nameplate ratings of electric thermal storage and other heating systems where the usual load is expected to be continuous at the full nameplate value. Systems qualifying under this selection shall not be calculated under any other selection in 220.82(C).

220.83 Existing Dwelling Unit.

This section shall be permitted to be used to determine if the existing service or feeder is of sufficient capacity to serve additional loads. Where the dwelling unit is served by a 120/240-volt or 208Y/120-volt, 3-wire service, it shall be permissible to calculate the total load in accordance with 220.83(A) or (B).

(A) Where Additional Air-Conditioning Equipment or Electric Space-Heating Equipment Is Not to Be Installed.

The following percentages shall be used for existing and additional new loads.

Load (kVA)	Percent of Load
First 8 kVA of load at	100

Load (kVA)	Percent of Load
Remainder of load at	40

Load calculations shall include the following:

(1) General lighting and general-use receptacles at 33 volt-amperes/m^2 or 3 volt-amperes/ft^2 as determined by ~~220.12~~ 220.14(J) **[PI-XXX]**

(2) 1500 volt-amperes for each 2-wire, 20-ampere small-appliance branch circuit and each laundry branch circuit covered in 210.11(C)(1) and (C)(2)

(3) The nameplate rating of the following:

a. All appliances that are fastened in place, permanently connected, or located to be on a specific circuit

b. Ranges, wall-mounted ovens, counter-mounted cooking units

c. Clothes dryers that are not connected to the laundry branch circuit specified in item (2)

d. Water heaters

(B) Where Additional Air-Conditioning Equipment or Electric Space-Heating Equipment Is to Be Installed.

The following percentages shall be used for existing and additional new loads. The larger connected load of air conditioning or space heating, but not both, shall be used.

Load	Percent of Load
Air-conditioning equipment	100
Central electric space heating	100
Less than four separately . controlled space-heating units	100
First 8 kVA of all other loads	100
Remainder of all other loads	40

Other loads shall include the following:

(1) General lighting and general-use receptacles at 33 volt-amperes/m^2 or 3 volt-amperes/ft^2 as determined by ~~220.12~~ 220.14(J) **[PI-XXX]**

(2) 1500 volt-amperes for each 2-wire, 20-ampere small-appliance branch circuit and each laundry branch circuit covered in 210.11(C)(1) and (C)(2)

(3) The nameplate rating of the following:

a. All appliances that are fastened in place, permanently connected, or located to be on a specific circuit

b. Ranges, wall-mounted ovens, counter-mounted cooking units

c. Clothes dryers that are not connected to the laundry branch circuit specified in item (2)

d. Water heaters

220.84 Multifamily Dwelling.

(A) Feeder or Service Load.

It shall be permissible to calculate the load of a feeder or service that supplies three or more dwelling units of a multifamily dwelling in accordance with Table 220.84 instead of Part III of this article if all the following conditions are met:

(1) No dwelling unit is supplied by more than one feeder.

(2) Each dwelling unit is equipped with electric cooking equipment.

Exception: When the calculated load for multifamily dwellings without electric cooking in Part III of this article exceeds that calculated under Part IV for the identical load plus electric cooking (based on 8 kW per unit), the lesser of the two loads shall be permitted to be used.

(3) Each dwelling unit is equipped with either electric space heating or air conditioning, or both. Feeders and service conductors whose calculated load is determined by this optional calculation shall be permitted to have the neutral load determined by 220.61.

(B) House Loads.
House loads shall be calculated in accordance with Part III of this article and shall be in addition to the dwelling unit loads calculated in accordance with Table 220.84.

Table 220.84 Optional Calculations — Demand Factors for Three or More Multifamily Dwelling Units

Number of Dwelling Units	Demand Factor (%)
3–5	45
6–7	44
8–10	43
11	42
12–13	41
14–15	40
16–17	39
18–20	38
21	37
22–23	36
24–25	35
26–27	34
28–30	33
31	32
32–33	31
34–36	30
37–38	29
39–42	28
43–45	27
46–50	26
51–55	25
56–61	24
62 and over	23

(C) Calculated Loads.
The calculated load to which the demand factors of Table 220.84 apply shall include the following:

(1) 33 volt-amperes/m^2 or 3 volt-amperes/ft^2 for general lighting and general-use receptacles

(2) 1500 volt-amperes for each 2-wire, 20-ampere small-appliance branch circuit and each laundry branch circuit covered in 210.11(C)(1) and (C)(2)

(3) The nameplate rating of the following:

   a. All appliances that are fastened in place, permanently connected, or located to be on a specific circuit

   b. Ranges, wall-mounted ovens, counter-mounted cooking units

   c. Clothes dryers that are not connected to the laundry branch circuit specified in item (2)

   d. Water heaters

(4) The nameplate ampere or kVA rating of all permanently connected motors not included in item (3)

(5) The larger of the air-conditioning load or the fixed electric space-heating load

220.85 Two Dwelling Units.

Where two dwelling units are supplied by a single feeder and the calculated load under Part III of this article exceeds that for three identical units calculated under 220.84, the lesser of the two loads shall be permitted to be used.

220.86 Schools.

The calculation of a feeder or service load for schools shall be permitted in accordance with Table 220.86 in lieu of Part III of this article where equipped with electric space heating, air conditioning, or both. The connected load to which the demand factors of Table 220.86 apply shall include all of the interior and exterior lighting, power, water heating, cooking, other loads, and the larger of the air-conditioning load or space-heating load within the building or structure.

Feeders and service conductors whose calculated load is determined by this optional calculation shall be permitted to have the neutral load determined by 220.61. Where the building or structure load is calculated by this optional method, feeders within the building or structure shall have ampacity as permitted in Part III of this article; however, the ampacity of an individual feeder shall not be required to be larger than the ampacity for the entire building.

This section shall not apply to portable classroom buildings.

Table 220.86 Optional Method — Demand Factors for Feeders and Service Conductors for Schools

Connected Load		Demand Factor (Percent)
First 33 VA/m^2 . Plus,	(3 VA/ft^2) at	100
Over 33 through 220 VA/m^2 . Plus,	(3 through 20 VA/ft^2) at	75
Remainder over 220 VA/m^2	(20 VA/ft^2) at	25

220.87 Determining Existing Loads.

The calculation of a feeder or service load for existing installations shall be permitted to use actual maximum demand to determine the existing load under all of the following conditions:

(1) The maximum demand data is available for a 1-year period.

Exception: If the maximum demand data for a 1-year period is not available, the calculated load shall be permitted to be based on the maximum demand (the highest average kilowatts reached and maintained for a 15-minute interval) continuously recorded over a minimum 30-day period using a recording ammeter or power meter connected to the highest loaded phase of the feeder or service, based on the initial loading at the start of the recording. The recording shall reflect the maximum demand of the feeder or service by being taken when the building or space is occupied and shall include by measurement or calculation the larger of the *heating or cooling equipment load, and other loads that may be periodic in nature due to seasonal or similar conditions.*

(2) The maximum demand at 125 percent plus the new load does not exceed the ampacity of the feeder or rating of the service.

(3) The feeder has overcurrent protection in accordance with 240.4, and the service has overload protection in accordance with 230.90.

220.88 New Restaurants.

Calculation of a service or feeder load, where the feeder serves the total load, for a new restaurant shall be permitted in accordance with Table 220.88 in lieu of Part III of this article.

The overload protection of the service conductors shall be in accordance with 230.90 and 240.4.

Feeder conductors shall not be required to be of greater ampacity than the service conductors.

Service or feeder conductors whose calculated load is determined by this optional calculation shall be permitted to have the neutral load determined by 220.61.

Table 220.88 Optional Method — Permitted Load Calculations for Service and Feeder Conductors for New Restaurants

Total Connected Load (kVA)	All Electric Restaurant Calculated Loads (kVA)	Not All Electric Restaurant Calculated Loads (kVA)
0–200	80%	100%
201–325	10% (amount over 200) + 160.0	50% (amount over 200) + 200.0
326–800	50% (amount over 325) + 172.5	45% (amount over 325) + 262.5
Over 800	50% (amount over 800) + 410.0	20% (amount over 800) + 476.3

Note: Add all electrical loads, including both heating and cooling loads, to calculate the total connected load. Select the one demand factor that applies from the table, then multiply the total connected load by this single demand factor.

Part V. Farm Load Calculations

220.100 General.

Farm loads shall be calculated in accordance with Part V.

220.102 Farm Loads — Buildings and Other Loads.

(A) Dwelling Unit.

The feeder or service load of a farm dwelling unit shall be calculated in accordance with the provisions for dwellings in Part III or IV of this article. Where the dwelling has electric heat and the farm has electric grain-drying systems, Part IV of this article shall not be used to calculate the dwelling load where the dwelling and farm loads are supplied by a common service.

(B) Other Than Dwelling Unit.

Where a feeder or service supplies a farm building or other load having two or more separate branch circuits, the load for feeders, service conductors, and service equipment shall be calculated in accordance with demand factors not less than indicated in Table 220.102.

Table 220.102 Method for Calculating Farm Loads for Other Than Dwelling Unit

Ampere Load at 240 Volts Maximum	Demand Factor (%)
The greater of the following:	
All loads that are expected to operate simultaneously, or	100
125 percent of the full load current of the largest motor, or	
First 60 amperes of the load	
Next 60 amperes of all other loads	50
Remainder of other loads	25

220.103 Farm Loads — Total.

Where supplied by a common service, the total load of the farm for service conductors and service equipment shall be calculated in accordance with the farm dwelling unit load and demand factors specified in Table 220.103. Where there is equipment in two or more farm equipment buildings or for loads having the same function, such loads shall be calculated in accordance with Table 220.102 and shall be permitted to be combined as a single load in Table 220.103 for calculating the total load.

Table 220.103 Method for Calculating Total Farm Load

Individual Loads Calculated in Accordance with Table 220.102	Demand Factor (%)
Largest load	100
Second largest load	75
Third largest load	65
Remaining loads	50

Note: To this total load, add the load of the farm dwelling unit calculated in accordance with Part III or IV of this article. Where the dwelling has electric heat and the farm has electric grain-drying systems, Part IV of this article shall not be used to calculate the dwelling load.

Public Input No. 3445-NFPA 70-2017 [New Section after 220.103]

VI. Optional Calculation Methods for HVAC Equipment

220.104 Electric Chillers. Where reduced loads results from chiller units operating on duty-cycle, or intermittently, or from all chillers not operating at the same time, feeder demand may be calculated from historical maximum demand watt information recorded over at least a 24-month period for the same occupancy class identified in the energy code enforced by the Authority Having Jurisdiction

Additional Proposed Changes

File Name	Description	Approved
CSA-Groups-CEC-Section-8-Circuit-loading-and-demand-factors.1498472174465.pdf	Canadian Electrical Code Section 8 Circuit loading and demand factors	

Statement of Problem and Substantiation for Public Input

It is noteworthy that the occupancy classes that dominate the subject of electric load calculations of Chapter 2 are residential in nature. Not all, but most. Even Annex D, which contains 13 calculation examples, is pre-occupied with load calculations that apply to residential facility classes.

But a large part of the building industry that uses the NEC is obviously non-residential and needs guidance on what electrical designers need to do when mechanical engineers submit a load list that involves one or more electric chiller units supplied from the same service equipment. Without this, 100% demand diversity adds significant capacity that, in most installations, will never be used, will increase waste heat losses and increase flash hazard.

The attachment shows how the technical committees of the Canadian Electrical Code have attempted to resolve this problem. I have made a modification to the CEC approach; recognizing that ASHRAE energy standards prevail in most US jurisdictions.

Submitter Information Verification

Submitter Full Name: Michael Anthony
Organization: Standards Michigan
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 06 08:37:08 EDT 2017

Copyright Assignment

I, Michael Anthony, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Michael Anthony, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 858-NFPA 70-2017 [New Section after 220.40]

220.41 Feeder and Service Loads

(A) Feeder and service calculation loads shall not be less than that specified in table 220.41a

Table 220.41a

Building Type No.	Building Type	VA/ft2 Lighting	General Receptacles	Equipment	HVAC	M
1	Large Office (>30K ft2)	3.00	1.00	1.20	4.70	1
2	Small Office (<30K ft2)	3.00	1.00	1.20	4.30	1
3	Restaurant - Fast Food (<4K ft2)	2.50	1.00	19.50	8.00	1
4	Restaurant - sit Down (>4K ft2)	2.50	1.00	13.70	6.80	1
5	Large Retail (>30K ft2)	2.50	1.00	1.00	5.50	1
6	Small Retail (<30K ft2)	2.50	1.00	1.80	5.00	1
7	Large Food Stores (>30K ft2)	2.50	1.00	1.00	5.50	1
8	Small Food Stores (<30K ft2)	2.50	1.00	1.80	5.00	1
9	Refrigerated Warehouses	0.25	1.00	9.55	5.00	1
10	Non Refrigerated with AC Warehouses	0.25	1.00	0.00	5.00	1
11	Non Refrigerated without AC Warehouses	0.25	1.00	0.00	0.00	1
12	Elementary And Secondary Schools	3.00	1.00	7.20	5.30	1
13	Colleges and Universities	3.00	1.00	12.00	5.30	1
14	Vocational Schools	3.00	1.00	12.00	5.30	1
15	Hospitals	3.00	1.00	3.50	5.00	1
16	Health Clinics	2.50	1.00	2.00	4.30	1
17	Hotels And Motels	2.00	1.00	0.30	5.00	1
18	Auto Repai Shops	2.00	1.00	3.20	4.30	1
19	Miscellaneous Repair	2.00	1.00	6.00	4.30	1
20	Movie Theaters - indoor	2.00	1.00	6.00	6.10	1
21	Bowling Alleys	2.00	1.00	1.90	4.50	1
22	U.S. Post Office	3.00	1.00	1.90	4.50	1
23	Light Manufacturing	3.00	1.00	2.00	4.50	1
24	Heavy Manufacturing	3.00	1.00	19.00	8.00	1

25	Laboratory	3.00	1.00	6	4.50	1
29	Residential	2	2.75	1	3.75	1
30	all others	2	2.75	4.25	5.00	1

(B) The maximum lighting load shall not exceed the value for the building type number shown in Table 220.41a.

(C) The maximum General Receptacles load shall not exceed the value for the building type number shown in Table 220.41a.

(D) The maximum Equipment load shall not exceed the value for the building type number shown in Table 220.41a.

(E) The maximum HVAC load shall not exceed the value for the building type number shown in Table 220.41a.

(F) The maximum miscellaneous load shall not exceed the value for the building type number shown in Table 220.41a.

(G) The maximum Total load shall not exceed the value for the building type number shown in Table 220.41a.

Statement of Problem and Substantiation for Public Input

Ask 10 electrical design professionals what the load (VA/ft2) of a building should be and you will get 10 different answers. The problem is no standardization for load calculations and this is an attempt to provide this.
The table presented is a starting point for conversation. The numbers in the table are from a blend of information from Means, Austin Energy and my own observations.
The last part of the new section is an attempt to limit the size of the electrical service much like ASHRAE has done with power densities for lighting. Too often building owners overestimate the required loads requiring larger services than are actually equired.

Submitter Information Verification

Submitter Full Name: Robert Del Mastro
Organization: [Not Specified]
Street Address:
City:
State:
Zip:
Submittal Date: Mon May 29 15:52:16 EDT 2017

Copyright Assignment

I, Robert Del Mastro, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Robert Del Mastro, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 1075-NFPA 70-2017 [New Section after 220.86]

220.86+ Demonstrated Load

For loads other than those calculated in accordance with Table 220.86, feeder and service load calculations shall be permitted to be based upon demonstrated loads provided that such calculations are performed by a qualified person as determined by the regulatory authority having jurisdiction.

Additional Proposed Changes

File Name	Description	Approved
CSA-Groups-CEC-Section-8-Circuit-loading-and-demand-factors.pdf	Canadian Electrical Code allowance for "Demonstrated Load" concepts to be applied to service and feeder capacity calcuations	

Statement of Problem and Substantiation for Public Input

This proposal places before the committee, and related Task Groups, an example of how our colleagues in Canada have approached a resolution to the problem of oversized building power chains in educational facilities. Note that the "demonstrated load" concept is introduced as a definition at the beginning of this article.

Submitter Information Verification

Submitter Full Name: Michael Anthony
Organization: Standards Michigan
Affilliation: www.standardsmichigan.com
Street Address:
City:
State:
Zip:
Submittal Date: Mon Jun 26 06:09:10 EDT 2017

Public Input No. 4133-NFPA 70-2017 [New Section after 220.86]

TITLE OF NEW CONTENT

Optional Service Size Reduction for All Occupancy Types

Statement of Problem and Substantiation for Public Input

The calculated electrical service ampacity calculated for a new building may be reduced by up to 20% if all of the following conditions are met:

1. Optional demand calculations under Tables 220.86 and 220.88 have not been used to determine demand, and
2. A licensed professional engineer, licensed in electrical engineering in those jurisdictions with branch licensing, shall request the amount of reduction applied for and provide clear and convincing evidence that his or her calculations and data support the request. All letters, reports and calculations prepared by the engineer shall be stamped and signed, and
3. The application is approved by the AHJ performing electrical reviews, and
4. Demand monitoring will be done at least once within 6 months of substantial occupancy and immediately if a main breaker or fuse opens.
5. The physical building area is available at initial occupancy for service equipment to remedy an under-sized service, and
6. The AHJ receives certification or a payment bond, as elected by the AHJ, from the owner or tenant to cover all reasonable costs of necessary improvements in the event the service was undersized, and
7. Any needed improvements are installed and completed within 12 months of substantial occupancy, and
8. Temporary demand management is immediately implemented in the event the service is under-sized.
9. If the service is found to be undersized after construction

Submitter Information Verification

Submitter Full Name: Billie Zidek

Organization: APPA

Affilliation: APPA

Street Address:

City:

State:

Zip:

Submittal Date: Thu Sep 07 15:00:13 EDT 2017

Public Input No. 3214-NFPA 70-2017 [Section No. 220.1]

220.1 Scope.

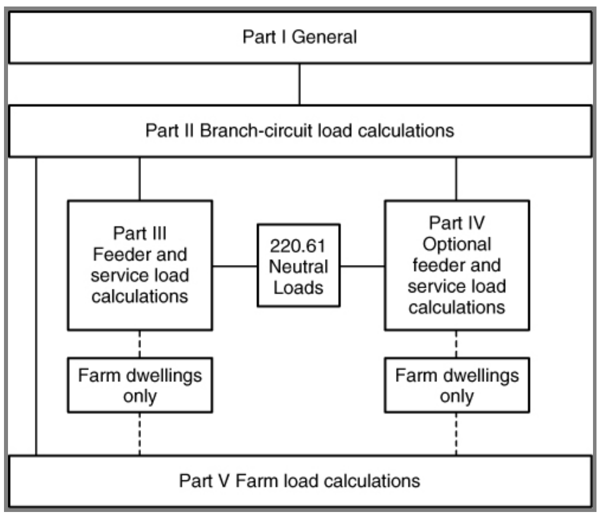
This article provides requirements for calculating branch-circuit, feeder, and service loads. Part I provides general requirements for calculation methods. Part II provides calculation methods for branch-circuit loads. Parts III and IV provide calculation methods for feeder and service loads. Part V provides calculation methods for farm loads.

Informational Note No. 1: See examples in Informative Annex D.

Informational Note No. 2: See Figure 220.1 for information on the organization of Article 220.

Informational Note 3: For information regarding electrical power system design, see 3001.5 IEEE Recommended Practice for the Application of Power Distribution Apparatus in Industrial and Commercial Power Systems

Figure 220.1 Branch-Circuit, Feeder, and Service Load Calculation Methods.



Statement of Problem and Substantiation for Public Input

The stronger the linkage between the NFPA and IEEE on electrical power technology the better.. Consideration for this proposal to be placed elsewhere in the NEC would also be welcomed.

IEEE 3000 Standards Collection™ is the trademarked name of the family of industrial and commercial power systems standards formerly known as IEEE Color Books. The IEEE 3000 Standards Collection overall includes the same content as the Color Books that have been referenced into previous editions of the NEC but is now organized into approximately 70 IEEE “dot” standards that cover specific technical topics. This method of development, of capturing leading practice from transactions among academic and practitioners supports the NFPA International mission of eliminating death, injury, property and economic loss due to fire, electrical and related hazards.

Submitter Information Verification

Submitter Full Name: Michael Anthony
Organization: Standards Michigan

Street Address:
City:
State:
Zip:
Submittal Date: Mon Sep 04 09:05:10 EDT 2017

Copyright Assignment

I, Michael Anthony, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Michael Anthony, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 3138-NFPA 70-2017 [Section No. 220.12]

220.12 Lighting Load for Specified Occupancies.

A unit load of not less than that specified in Table 220.12 for occupancies specified shall constitute the minimum lighting load. Motors rated less than 1/8 HP and connected to a lighting circuit shall shall be considered general lighting load. The floor area for each floor shall be calculated from the outside dimensions of the building, dwelling unit, or other area involved. For dwelling units, the calculated floor area shall not include open porches, garages, or unused or unfinished spaces not adaptable for future use.

Informational Note: The unit values are based on minimum load conditions and 100 percent power factor and may not provide sufficient capacity for the installation contemplated.

Exception No. 1: Where the building is designed and constructed to comply with an energy code adopted by the local authority, the lighting load shall be permitted to be calculated at the values specified in the energy code where the following conditions are met:

(1) A power monitoring system is installed that will provide continuous information regarding the total general lighting load of the building.

(2) The power monitoring system will be set with alarm values to alert the building owner or manager if the lighting load exceeds the values set by the energy code.

(3) The demand factors specified in 220.42 are not applied to the general lighting load.

Exception No. 2: Where a building is designed and constructed to comply with an energy code adopted by the local authority and specifying an overall lighting density of less than 13.5 volt-amperes/13.5 m^2 (1.2 volt-amperes/1.2 ft^2), the unit lighting loads in Table 220.12 for office and bank areas within the building shall be permitted to be reduced by 11 volt-amperes/11 m^2 (1 volt-amperes/1 ft^2).

Table 220.12 General Lighting Loads by Occupancy

Type of Occupancy	Unit Load	
	Volt-amperes/ m^2	Volt-amperes/ ft^2
Armories and auditoriums	11	1
Banks	39[b]	3½[b]
Barber shops and beauty parlors	33	3
Churches	11	1
Clubs	22	2
Courtrooms	22	2
Dwelling units[a]	33	3
Garages — commercial (storage)	6	½
Hospitals	22	2
Hotels and motels, including apartment houses without provision for cooking by tenants[a]	22	2
Industrial commercial (loft) buildings	22	2
Lodge rooms	17	1½
Office buildings	39[b]	3½[b]
Restaurants	22	2

Type of Occupancy	Unit Load Volt-amperes/ m2	Unit Load Volt-amperes/ ft2
Schools	33	3
Stores	33	3
Warehouses (storage)	3	¼
In any of the preceding occupancies except one-family dwellings and individual dwelling units of two-family and multifamily dwellings:	-	-
Assembly halls and auditoriums	11	1
Halls, corridors, closets, stairways	6	½
Storage spaces	3	¼

[a]See 220.14(J).

[b]See 220.14(K).

Statement of Problem and Substantiation for Public Input

Bathroom and kitchen exhaust fans are typically connected to the lighting circuit. It is not clear if this load should be calculated in addition to the general lighting load or is it included in the unit loads specified in Table 220.12. None of the examples in Annex D address this condition. These loads are minimal and can be safely served using the unit loads as demonstrated by the long history of using this method by many installers and inspectors. The method for properly calculating the load should be clear and unambiguous.

Submitter Information Verification

Submitter Full Name: Nathan Philips

Organization: Integrated Electronic Systems

Affilliation: NECA

Street Address:

City:

State:

Zip:

Submittal Date: Fri Sep 01 13:53:19 EDT 2017

Public Input No. 3139-NFPA 70-2017 [Section No. 220.12]

220.12 Lighting Load for Specified Occupancies.

A unit load of not less than that specified in Table 220.12 for occupancies specified shall constitute the minimum lighting load. General lighting loads calculated using the unit load specified in Table 220.12 shall not be subject to the provisions of 210.20(A). The floor area for each floor shall be calculated from the outside dimensions of the building, dwelling unit, or other area involved. For dwelling units, the calculated floor area shall not include open porches, garages, or unused or unfinished spaces not adaptable for future use.

Informational Note: The unit values are based on minimum load conditions and 100 percent power factor and may not provide sufficient capacity for the installation contemplated.

Exception No. 1: Where the building is designed and constructed to comply with an energy code adopted by the local authority, the lighting load shall be permitted to be calculated at the values specified in the energy code where the following conditions are met:

(1) A power monitoring system is installed that will provide continuous information regarding the total general lighting load of the building.

(2) The power monitoring system will be set with alarm values to alert the building owner or manager if the lighting load exceeds the values set by the energy code.

(3) The demand factors specified in 220.42 are not applied to the general lighting load.

Exception No. 2: Where a building is designed and constructed to comply with an energy code adopted by the local authority and specifying an overall lighting density of less than 13.5 volt-amperes/13.5 m^2 (1.2 volt-amperes/1.2 ft^2), the unit lighting loads in Table 220.12 for office and bank areas within the building shall be permitted to be reduced by 11 volt-amperes/11 m^2 (1 volt-amperes/1 ft^2).

Table 220.12 General Lighting Loads by Occupancy

Type of Occupancy	Unit Load	
	Volt-amperes/ m^2	Volt-amperes/ ft^2
Armories and auditoriums	11	1
Banks	39[b]	3½[b]
Barber shops and beauty parlors	33	3
Churches	11	1
Clubs	22	2
Courtrooms	22	2
Dwelling units[a]	33	3
Garages — commercial (storage)	6	½
Hospitals	22	2
Hotels and motels, including apartment houses without provision for cooking by tenants[a]	22	2
Industrial commercial (loft) buildings	22	2
Lodge rooms	17	1½
Office buildings	39[b]	3½[b]
Restaurants	22	2

Type of Occupancy	Unit Load Volt-amperes/ m2	Unit Load Volt-amperes/ ft2
Schools	33	3
Stores	33	3
Warehouses (storage)	3	¼
In any of the preceding occupancies except one-family dwellings and individual dwelling units of two-family and multifamily dwellings:	-	-
Assembly halls and auditoriums	11	1
Halls, corridors, closets, stairways	6	½
Storage spaces	3	¼

[a]See 220.14(J).

[b]See 220.14(K).

Statement of Problem and Substantiation for Public Input

Lighting loads in office buildings, for example, operate continuously. If the loads are calculated using the unit loads in Table 220.12, is derating required in accordance with 210.20(A)? Example D3 in Annex D suggests that it is not yet many inspectors and installers have been taught that it is. This should be clarified so that the calculation method is clear and unambiguous.

Submitter Information Verification

Submitter Full Name: Nathan Philips
Organization: Integrated Electronic Systems
Affilliation: NECA
Street Address:
City:
State:
Zip:
Submittal Date: Fri Sep 01 14:02:46 EDT 2017

Public Input No. 3282-NFPA 70-2017 [Section No. 220.12]

220.12 Lighting Load for Specified Non-dwelling Occupancies.

(A) General. A unit load of not less than that specified in Table 220.12 for ~~occupancies specified shall constitute the minimum lighting load. The floor area for each floor shall be calculated from the outside dimensions of the building, dwelling unit, or other area involved. For dwelling units, the calculated floor area shall not include open porches, garages, or unused or unfinished spaces not adaptable for future use.~~ non-dwelling occupancies and the floor area determined in 220.11 shall be used to calculate the minimum lighting load.

Informational Note: The unit values of Table 220.12 are based on minimum load conditions and ~~100 percent~~ 80 percent power factor and may not provide sufficient capacity for the installation contemplated.

*~~Exception No. 1:~~ **(B) Energy Code.** Where the building is designed and constructed to comply with an energy code adopted by the local authority, the minimum lighting load shall be permitted to be calculated ~~at~~ using the minimum unit values specified in the energy code where the following conditions are met:*

(1) A power monitoring system is installed that will provide continuous information regarding the total general lighting load of the building.

(2) The power monitoring system will be set with alarm values to alert the building owner or manager if the lighting load exceeds the values set by the energy code.

(3) The demand factors specified in 220.42 are not applied to the general lighting load.

~~Exception No. 2: Where a building is designed and constructed to comply with an energy code adopted by the local authority and specifying an overall lighting density of less than 13.5 volt-amperes/13.5 m² (1.2 volt-amperes/1.2 ft²), the unit lighting loads in Table 220.12 for office and bank areas within the building shall be permitted to be reduced by 11 volt-amperes/11 m² (1 volt-amperes/1 ft²).~~

~~Table 220.12 General Lighting Loads by Occupancy~~

~~Type of Occupancy Unit Load Volt-amperes/~~

~~m² Volt-amperes/~~

~~ft² Armories and auditoriums 11 1 Banks 39[b] 3 1/2 [b] Barber shops and beauty parlors 33 3 Churches 11 1 Clubs 22 2 Courtrooms 22 2 Dwelling units[a] 33 3 Garages — commercial (storage) 6 1/2 Hospitals 22 2 Hotels and motels, including apartment houses without provision for cooking by tenants[a] 22 2 Industrial commercial (loft) buildings 22 2 Lodge rooms 17 1 1/2 Office buildings 39[b] 3 1/2 [b] Restaurants 22 2 Schools 33 3 Stores 33 3 Warehouses (storage) 3 1/4 In any of the preceding occupancies except one-family dwellings and individual dwelling units of two-family and multifamily dwellings: - - Assembly halls and auditoriums 11 1 Halls, corridors, closets, stairways 6 1/2 Storage spaces 3 1/4~~

~~[a] See 220.14(J).~~

~~[b] See 220.14(K).~~

Additional Proposed Changes

File Name	Description	Approved

LARRY_AYER_ATTACHMENT_PI_3288_3282.pdf ✓

Statement of Problem and Substantiation for Public Input

The Correlating Committee identified the need to establish an Energy Task Group to review the NEC® and identify areas where industry achievements in the reduction of energy use have not been reflected in the NEC. Identified areas would then be reviewed and public inputs submitted where agreed upon enhancements will provide appropriate alignment while preserving appropriate safety and operational provisions. NEC Article 220 addressing calculations for sizing electrical infrastructure is one area the task group identified. The initial focus for the 2020 NEC public inputs is on alignment of the lighting load calculations more closely with industry technology and practice. The Correlating Committee Energy Task Group, includes: Larry Ayer (Co-Chair), Alan Manche (Co-Chair), Donny Cook, Eric Richman Ashrae 90.1, John McCamish, Ken Boyce, Mike Weaver, Richard Holub, Steve Douglas; Tom Domitrovich, Tim Croushore, and Tim Pope.

NEC Table 220.12 General Lighting Loads by Occupancy has had minimal revisions since the 1970s. Those revisions have consisted of reducing the lighting loads in a few occupancies based on the technology enhancements over time, however a comprehensive set of data has historically not been available to support a revision to this table. The energy codes adopted across the country have also created further discussion around the appropriate values in Table 220.12, however some states adopt and enforce energy codes that were adopted over a decade ago. The development of the lighting power densities in the energy code have been established through case studies of various occupancies which will provide the foundation for this public input to revise the values in NEC Table 220.12.

Several areas are addressed in this public input .

Proposed New Table.....

1. The first significant revision is the list of occupancies. The task group is proposing to expand and align the list of occupancies in the NEC with those found in the ASHRAE 90.1 standard and the International Energy Conservation Code.

2. Assembly halls and auditoriums, Armories and auditoriums, banks, barber shops and beauty parlors, clubs, industrial commercial (loft) buildings, and lodge rooms will be relocated to the notes in Table 220.12. These notes will cross reference these occupancies to the appropriate occupancy to be used in the 2020 Table. It is the intent to eliminate the notes in a future NEC revision cycle.

3. Hall, corridors, closets, stairways, storage spaces will also be eliminated since these areas within a building will be covered by the unit lighting load of the occupancy.

4. Dwelling and multi-family dwelling units will be moved out of the table and and strictly referenced in section 220.14(J) [companion public input], clarifying that the table 220.12 applies only to non-dwelling type occupancies.

5. The values in the table will be established from ASHRAE 90.1 data. ASHRAE has data associated with each occupancy and many with multiple cases to determine the ASHRAE values, however from an NEC perspective, the maximum value must be considered. After reviewing the data trends, the committee is proposing using the Lighting Power Density (LPD) values from the 90.1 - 2000 cycle, which establishes a minimum margin of 25% between the maximum values determined through field studies and the proposed values for Table 220.12. All but four occupancies are reduced to more closely align with actual use based on the field case studies conducted by the ASHRAE Lighting Committee.

6. The four occupancies that increase include: gymnasium, manufacturing facility, religious facility, and warehouses.

Changes within section 220.12 to correlate with new Table.

7. The title for 220.12 is revised to "Lighting Loads for Specified Non-Dwelling Occupancies" to correlate with item 4.

8. Information for floor area calculations has been removed from section 220.12 and has been relocated to a new proposed section 220.11. The new proposed section is part of public input 3288. The relocation is being proposed to address both non-dwelling occupancies in 220.12 and dwelling occupancies in 220.14(J).

9. Exception 1 is being converted to positive text with the title "(B) Energy Code".

10. Exception 2 is deleted as it is no longer needed with the values in the table being revised.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3153-NFPA 70-2017 [Section No. 220.42]	
Public Input No. 3288-NFPA 70-2017 [New Section after 220.10]	
Public Input No. 3147-NFPA 70-2017 [Section No. 220.14(J)]	

Submitter Information Verification

Submitter Full Name: Lawrence Ayer

Organization: Biz Com Electric, Inc.

Affilliation: IEC

Street Address:

City:

State:

Zip:

Submittal Date: Tue Sep 05 09:41:43 EDT 2017

Part II. Branch-Circuit Load Calculations
220.10 General.

Branch-circuit loads shall be calculated as shown in 220.12, 220.14, and 220.16.

220.11 Floor Area (PI-3288)

The floor area for each floor shall be calculated from the outside dimensions of the building, dwelling unit, or other area involved. For dwelling units, the calculated floor area shall not include open porches, garages, or unused or unfinished spaces not adaptable for future use.

220.12 Lighting Load for Specified Occupancies. (PI-3282)

(A) General. A unit load of not less than that specified in Table 220.12 for non-dwelling occupancies specified shall be used to calculate ~~constitute~~ the minimum lighting load. ~~The floor area for each floor shall be calculated from the outside dimensions of the building, dwelling unit, or other area involved. For dwelling units, the calculated floor area shall not include open porches, garages, or unused or unfinished spaces not adaptable for future use.~~ The minimum lighting load shall be determined using the minimum unit load and the floor area as determined in 220.11.

> Informational Note: The unit values of Table 220.12 are based on minimum load conditions and 80~~100~~ percent power factor and may not provide sufficient capacity for the installation contemplated.

(B). Energy Code. ~~Exception No. 1:~~ Where the building is designed and constructed to comply with an energy code adopted by the local authority, the lighting load shall be permitted to be calculated using the unit~~at the~~ values specified in the energy code where the following conditions are met:

- *(1) A power monitoring system is installed that will provide continuous information regarding the total general lighting load of the building.*
- *(2) The power monitoring system will be set with alarm values to alert the building owner or manager if the lighting load exceeds the values set by the energy code.*
- *(3) The demand factors specified in 220.42 are not applied to the general lighting load.*

~~Exception No. 2: Where a building is designed and constructed to comply with an energy code adopted by the local authority and specifying an overall lighting density of less than 13.5 volt-amperes/13.5 m² (1.2 volt-amperes/1.2 ft²), the unit lighting loads in Table 220.12 for office and bank areas within the building shall be permitted to be reduced by 11 volt-amperes/11 m² (1 volt-amperes/1 ft²).~~

Table 220.12 General Lighting Loads by Non-Dwelling Occupancy

~~Type of Occupancy~~	~~Unit Load~~	
	~~Volt-amperes/m²~~	~~Volt-amperes/ft²~~
~~Armories and auditoriums~~	~~11~~	~~1~~
~~Banks~~	~~39[b]~~	~~3½[b]~~

~~Type of Occupancy~~	~~Unit Load~~	
	~~Volt-amperes/m^2~~	~~Volt-amperes/ft^2~~
~~Barber shops and beauty parlors~~	~~33~~	~~3~~
~~Churches~~	~~11~~	~~1~~
~~Clubs~~	~~22~~	~~2~~
~~Courtrooms~~	~~22~~	~~2~~
~~Dwelling units[a]~~	~~33~~	~~3~~
~~Garages — commercial (storage)~~	~~6~~	~~½~~
~~Hospitals~~	~~22~~	~~2~~
~~Hotels and motels, including apartment houses without provision for cooking by tenants[a]~~	~~22~~	~~2~~
~~Industrial commercial (loft) buildings~~	~~22~~	~~2~~
~~Lodge rooms~~	~~17~~	~~1½~~
~~Office buildings~~	~~39[b]~~	~~3½[b]~~
~~Restaurants~~	~~22~~	~~2~~
~~Schools~~	~~33~~	~~3~~
~~Stores~~	~~33~~	~~3~~
~~Warehouses (storage)~~	~~3~~	~~¼~~
~~In any of the preceding occupancies except one-family dwellings and individual dwelling units of two-family and multifamily dwellings:~~	~~-~~	~~-~~
~~Assembly halls and auditoriums~~	~~11~~	~~1~~
~~Halls, corridors, closets, stairways~~	~~6~~	~~½~~
~~Storage spaces~~	~~3~~	~~¼~~

~~[a]See 220.14(J).~~

~~[b]See 220.14(K).~~

Cross references for the 2017 NEC occupancies are provided in the notes to Table 220.12.

Type of Occupancy	Unit Load	
	Volt-amperes/m^2	Volt-amperes/ft^2
Automotive facility	16	1.5
Convention center	15	1.4
Courthouse	15	1.4
Restaurants[4]	16	1.5

Dormitory	16	1.5
Exercise center	15	1.4
Fire station	14	1.3
Gymnasium[3]	18	1.7
Health-care clinic	17	1.6
Hospital	17	1.6
Hotels and motels, including apartment houses without provision for cooking by tenants[6]	18	1.7
Library	16	1.5
Manufacturing facility	24	2.2
Motion picture theater	17	1.6
Museum	17	1.6
Office[1]	14	1.3
Parking garage[8]	3	0.3
Penitentiary	13	1.2
Performing arts theater	16	1.5
Police station	14	1.3
Post office	17	1.6
Religious facility	24	2.2
Retail[5, 7]	20	1.9
School/university	16	1.5
Sports arena	16	1.5
Town hall	15	1.4
Transportation	13	1.2
Warehouse	13	1.2
Workshop	18	1.7

220.14(K).

Notes:

1. **Banks are office type occupancies.**
2. **Industrial Commercial loft buildings are considered manufacturing type occupancies.**
3. **Armories and Auditoriums are considered Gymnasium type occupancies.**
4. **Clubs are considered restaurant occupancies.**
5. **Barber shops and beauty parlors are considered retail occupancies.**
6. **Lodge rooms are similar to hotel and motel**
7. **Stores are considered retail occupancies.**
8. **Garages – Commercial (storage) are considered Parking Garage occupancies.**

220.14 Other Loads — All Occupancies.
In all occupancies, the minimum load for each outlet for general-use receptacles and outlets not used for general illumination shall not be less than that calculated in 220.14(A) through (L), the loads shown being based on nominal branch-circuit voltages.
Exception: The loads of outlets serving switchboards and switching frames in telephone exchanges shall be waived from the calculations.

(A) Specific Appliances or Loads.
An outlet for a specific appliance or other load not covered in 220.14(B) through (L) shall be calculated based on the ampere rating of the appliance or load served.

(B) Electric Dryers and Electric Cooking Appliances in Dwellings and Household Cooking Appliances Used in Instructional Programs.
Load calculations shall be permitted as specified in 220.54 for electric dryers and in 220.55 for electric ranges and other cooking appliances.

(C) Motor Outlets.
Loads for motor outlets shall be calculated in accordance with the requirements in 430.22, 430.24, and 440.6.

(D) Luminaires.
An outlet supplying luminaire(s) shall be calculated based on the maximum volt-ampere rating of the equipment and lamps for which the luminaire(s) is rated.

(E) Heavy-Duty Lampholders.
Outlets for heavy-duty lampholders shall be calculated at a minimum of 600 volt-amperes.

(F) Sign and Outline Lighting.
Sign and outline lighting outlets shall be calculated at a minimum of 1200 volt-amperes for each required branch circuit specified in 600.5(A).

(G) Show Windows.
Show windows shall be calculated in accordance with either of the following:

(1) The unit load per outlet as required in other provisions of this section

(2) At 200 volt-amperes per linear 300 mm (1 ft) of show window

(H) Fixed Multioutlet Assemblies.
Fixed multioutlet assemblies used in other than dwelling units or the guest rooms or guest suites of hotels or motels shall be calculated in accordance with (H)(1) or (H)(2). For the purposes of this section, the calculation shall be permitted to be based on the portion that contains receptacle outlets.

(1) Where appliances are unlikely to be used simultaneously, each 1.5 m (5 ft) or fraction thereof of each separate and continuous length shall be considered as one outlet of not less than 180 volt-amperes.

(2) Where appliances are likely to be used simultaneously, each 300 mm (1 ft) or fraction thereof shall be considered as an outlet of not less than 180 volt-amperes.

(I) Receptacle Outlets.
Except as covered in 220.14(J) and (K), receptacle outlets shall be calculated at not less than 180 volt-amperes for each single or for each multiple receptacle on one yoke. A single piece of equipment consisting of a multiple receptacle comprised of four or more receptacles shall be calculated at not less than 90 volt-amperes per receptacle. This provision shall not be applicable to the receptacle outlets specified in 210.11(C)(1) and (C)(2).

(J) Dwelling Occupancies. (PI-3147)
In one-family, two-family, and multifamily dwellings and in guest rooms or guest suites of hotels and motels, the unit load shall be not less than the 33-VA/m^2 (3 VA/ft2). The lighting and receptacle outlets specified in (J)(1), (J)(2), and (J)(3) ~~-~~are included in the minimum unit load ~~general lighting load calculations of 220.12~~. No additional load calculations shall be required for such outlets. The minimum lighting load shall be determined using the minimum unit load and the floor area as determined in 220.11 for dwelling occupancies.

(1) All general-use receptacle outlets of 20-ampere rating or less, including receptacles connected to the circuits in 210.11(C)(3)

(2) The receptacle outlets specified in 210.52(E) and (G)

(3) The lighting outlets specified in 210.70(A) and (B)

(K) ~~Banks and~~ Office Buildings.
In ~~banks or~~ office buildings, the receptacle loads shall be calculated to be the larger of (1) or (2):

(1) The calculated load from 220.14(I)

(2) 11 volt-amperes/m^2 or 1 volt-ampere/ft^2

(L) Other Outlets.

Other outlets not covered in 220.14(A) through (K) shall be calculated based on 180 volt-amperes per outlet.

220.16 Loads for Additions to Existing Installations. [PI-3319]

(A) Dwelling Units.
Loads added to an existing dwelling unit(s) shall comply with the following as applicable:

(1) ~~Loads F~~for structural additions to an existing dwelling unit or for a previously unwired portion of an existing dwelling unit, either of which exceeds 46.5 m^2 (500 ft^2), the minimum lighting load shall be calculated in accordance with ~~220.12 and~~ 220.14(J).

(2) For structural additions or previously unwired portions of an existing dwelling unit that are less than 46.5 m^2 (500 ft^2), the minimum lighting load shall be permitted to be excluded from the calculations.

(3) Additional loads other than those covered in 220.14(J) shall be ~~Loads for new circuits or extended circuits in previously wired dwelling units shall be~~ calculated in accordance with ~~either 220.12 or~~ 220.14, as applicable.

(B) Other Than Dwelling Units.
Loads for new circuits or extended circuits in other than dwelling units shall be calculated in accordance with either 220.12 or 220.14, as applicable.

220.18 Maximum Loads.
The total load shall not exceed the rating of the branch circuit, and it shall not exceed the maximum loads specified in 220.18(A) through (C) under the conditions specified therein.

(A) Motor-Operated and Combination Loads.
Where a circuit supplies only motor-operated loads, Article 430 shall apply. Where a circuit supplies only air-conditioning equipment, refrigerating equipment, or both, Article 440 shall apply. For circuits supplying loads consisting of motor-operated utilization equipment that is fastened in place and has a motor larger than **1/8** hp in combination with other loads, the total calculated load shall be based on 125 percent of the largest motor load plus the sum of the other loads.

(B) Inductive and LED Lighting Loads.
For circuits supplying lighting units that have ballasts, transformers, autotransformers, or LED drivers, the calculated load shall be based on the total ampere ratings of such units and not on the total watts of the lamps.

(C) Range Loads.
It shall be permissible to apply demand factors for range loads in accordance with Table 220.55, including Note 4.

Part III. Feeder and Service Load Calculations

220.40 General.

The calculated load of a feeder or service shall not be less than the sum of the loads on the branch circuits supplied, as determined by Part II of this article, after any applicable demand factors permitted by Part III or IV or required by Part V have been applied.
Informational Note: See Examples D1(a) through D10 in Informative Annex D. See 220.18(B) for the maximum load in amperes permitted for lighting units operating at less than 100 percent power factor.

220.42 General Lighting.

The demand factors specified in Table 220.42 shall apply to that portion of the total branch-circuit load calculated for general illumination. They shall not be applied in determining the number of branch circuits for general illumination.

Table 220.42 Lighting Load Demand Factors [PI- 3153]

Type of Occupancy	Portion of Lighting Load to Which Demand Factor Applies (Volt-Amperes)	Demand Factor (%)
Dwelling units	First 3000 at	100
	From 3001 to 120,000 at	35
	Remainder over 120,000 at	25
~~Hospitals*~~	~~First 50,000 or less at~~	~~40~~
~~-~~	~~Remainder over 50,000 at~~	~~20~~
Hotels and motels, including apartment houses without provision for cooking by tenants*	First 20,000 or less at	50
	From 20,001 to 100,000 at	40
	Remainder over 100,000 at	30
Warehouses (storage)	First 12,500 or less at	100
	Remainder over 12,500 at	50
All others	Total volt-amperes	100

*The demand factors of this table shall not apply to the calculated load of feeders or services supplying areas in hospitals, hotels, and motels where the entire lighting is likely to be used at one time, as in operating rooms, ballrooms, or dining rooms.

220.43 Show-Window and Track Lighting.

(A) Show Windows.

For show-window lighting, a load of not less than 660 volt-amperes/linear meter or 200 volt-amperes/linear foot shall be included for a show window, measured horizontally along its base.
Informational Note: See 220.14(G) for branch circuits supplying show windows.

(B) Track Lighting.

For track lighting in other than dwelling units or guest rooms or guest suites of hotels or motels, an additional load of 150 volt-amperes shall be included for every 600 mm (2 ft) of lighting track or fraction thereof. Where multicircuit track is installed, the load shall be considered to be divided equally between the track circuits.
Exception: If the track lighting is supplied through a device that limits the current to the track, the load shall be permitted to be calculated based on the rating of the device used to limit the current.

220.44 Receptacle Loads — Other Than Dwelling Units.

Receptacle loads calculated in accordance with 220.14(H) and (I) shall be permitted to be made subject to the demand factors given in Table 220.42 or Table 220.44.

Table 220.44 Demand Factors for Non-Dwelling Receptacle Loads

Portion of Receptacle Load to Which Demand Factor Applies (Volt-Amperes)	Demand Factor (%)
First 10 kVA or less at	100
Remainder over 10 kVA at	50

220.50 Motors.

Motor loads shall be calculated in accordance with 430.24, 430.25, and 430.26 and with 440.6 for hermetic refrigerant motor-compressors.

220.51 Fixed Electric Space Heating.

Fixed electric space-heating loads shall be calculated at 100 percent of the total connected load. However, in no case shall a feeder or service load current rating be less than the rating of the largest branch circuit supplied.

Exception: Where reduced loading of the conductors results from units operating on duty-cycle, intermittently, or from all units not operating at the same time, the authority having jurisdiction may grant permission for feeder and service conductors to have an ampacity less than 100 percent, provided the conductors have an ampacity for the load so determined.

220.52 Small-Appliance and Laundry Loads — Dwelling Unit.

(A) Small-Appliance Circuit Load.

In each dwelling unit, the load shall be calculated at 1500 volt-amperes for each 2-wire small-appliance branch circuit as covered by 210.11(C)(1). Where the load is subdivided through two or more feeders, the calculated load for each shall include not less than 1500 volt-amperes for each 2-wire small-appliance branch circuit. These loads shall be permitted to be included with the general lighting load and subjected to the demand factors provided in Table 220.42.

Exception: The individual branch circuit permitted by 210.52(B)(1), Exception No. 2, shall be permitted to be excluded from the calculation required by 220.52.

(B) Laundry Circuit Load.

A load of not less than 1500 volt-amperes shall be included for each 2-wire laundry branch circuit installed as covered by 210.11(C)(2). This load shall be permitted to be included with the general lighting load and shall be subjected to the demand factors provided in Table 220.42.

220.53 Appliance Load — Dwelling Unit(s).

It shall be permissible to apply a demand factor of 75 percent to the nameplate rating load of four or more appliances fastened in place, other than electric ranges, clothes dryers, space-heating equipment, or air-conditioning equipment, that are served by the same feeder or service in a one-family, two-family, or multifamily dwelling.

220.54 Electric Clothes Dryers — Dwelling Unit(s).

The load for household electric clothes dryers in a dwelling unit(s) shall be either 5000 watts (volt-amperes) or the nameplate rating, whichever is larger, for each dryer served. The use of the demand factors in Table 220.54 shall be permitted. Where two or more single-phase dryers are supplied by a 3-phase, 4-wire feeder or service, the total load shall be calculated on the basis of twice the maximum number connected between any two phases. Kilovolt-amperes (kVA) shall be considered equivalent to kilowatts (kW) for loads calculated in this section.

Table 220.54 Demand Factors for Household Electric Clothes Dryers

Number of Dryers	Demand Factor (%)
1–4	100
5	85
6	75
7	65
8	60
9	55
10	50

Number of Dryers	Demand Factor (%)
11	47
12–23	47% minus 1% for each dryer exceeding 11
24–42	35% minus 0.5% for each dryer exceeding 23
43 and over	25%

220.55 Electric Cooking Appliances in Dwelling Units and Household Cooking Appliances Used in Instructional Programs.

The load for household electric ranges, wall-mounted ovens, counter-mounted cooking units, and other household cooking appliances individually rated in excess of 1**3/4** kW shall be permitted to be calculated in accordance with Table 220.55. Kilovolt-amperes (kVA) shall be considered equivalent to kilowatts (kW) for loads calculated under this section.

Where two or more single-phase ranges are supplied by a 3-phase, 4-wire feeder or service, the total load shall be calculated on the basis of twice the maximum number connected between any two phases.

Table 220.55 Demand Factors and Loads for Household Electric Ranges, Wall-Mounted Ovens, Counter-Mounted Cooking Units, and Other Household Cooking Appliances over 13/4 kW Rating (Column C to be used in all cases except as otherwise permitted in Note 3.)

Number of Appliances	Demand Factor (%) (See Notes)		Column C Maximum Demand (kW) (See Notes) (Not over 12 kW Rating)
	Column A (Less than $3^1/_2$ kW Rating)	Column B ($3^1/_2$ kW through $8^3/_4$ kW Rating)	
1	80	80	8
2	75	65	11
3	70	55	14
4	66	50	17
5	62	45	20
6	59	43	21
7	56	40	22
8	53	36	23
9	51	35	24
10	49	34	25
11	47	32	26
12	45	32	27
13	43	32	28
14	41	32	29
15	40	32	30
16	39	28	31
17	38	28	32
18	37	28	33
19	36	28	34
20	35	28	35

Number of Appliances	Demand Factor (%) (See Notes)		Column C Maximum Demand (kW) (See Notes) (Not over 12 kW Rating)
	Column A (Less than $3\frac{1}{2}$ kW Rating)	Column B ($3\frac{1}{2}$ kW through $8\frac{3}{4}$ kW Rating)	
21	34	26	36
22	33	26	37
23	32	26	38
24	31	26	39
25	30	26	40
26–30	30	24	15 kW + 1 kW for each range
31–40	30	22	
41–50	30	20	25 kW + $\frac{3}{4}$ kW for each range
51–60	30	18	
61 and over	30	16	

Notes:
1. Over 12 kW through 27 kW ranges all of same rating. For ranges individually rated more than 12 kW but not more than 27 kW, the maximum demand in Column C shall be increased 5 percent for each additional kilowatt of rating or major fraction thereof by which the rating of individual ranges exceeds 12 kW.
2. Over $8\frac{3}{4}$ kW through 27 kW ranges of unequal ratings. For ranges individually rated more than $8\frac{3}{4}$ kW and of different ratings, but none exceeding 27 kW, an average value of rating shall be calculated by adding together the ratings of all ranges to obtain the total connected load (using 12 kW for any range rated less than 12 kW) and dividing by the total number of ranges. Then the maximum demand in Column C shall be increased 5 percent for each kilowatt or major fraction thereof by which this average value exceeds 12 kW.
3. Over $1\frac{3}{4}$ kW through $8\frac{3}{4}$ kW. In lieu of the method provided in Column C, it shall be permissible to add the nameplate ratings of all household cooking appliances rated more than $1\frac{3}{4}$ kW but not more than $8\frac{3}{4}$ kW and multiply the sum by the demand factors specified in Column A or Column B for the given number of appliances. Where the rating of cooking appliances falls under both Column A and Column B, the demand factors for each column shall be applied to the appliances for that column, and the results added together.
4. Branch-Circuit Load. It shall be permissible to calculate the branch-circuit load for one range in accordance with Table 220.55. The branch-circuit load for one wall-mounted oven or one counter-mounted cooking unit shall be the nameplate rating of the appliance. The branch-circuit load for a counter-mounted cooking unit and not more than two wall-mounted ovens, all supplied from a single branch circuit and located in the same room, shall be calculated by adding the nameplate rating of the individual appliances and treating this total as equivalent to one range.
5. This table shall also apply to household cooking appliances rated over $1\frac{3}{4}$ kW and used in instructional programs.

Informational Note No. 1: See the examples in Informative Annex D.

Informational Note No. 2: See Table 220.56 for commercial cooking equipment.

220.56 Kitchen Equipment — Other Than Dwelling Unit(s).

It shall be permissible to calculate the load for commercial electric cooking equipment, dishwasher booster heaters, water heaters, and other kitchen equipment in accordance with Table 220.56. These demand factors shall be applied to all equipment that has either thermostatic control or intermittent use as kitchen equipment. These demand factors shall not apply to space-heating, ventilating, or air-conditioning equipment.

However, in no case shall the feeder or service calculated load be less than the sum of the largest two kitchen equipment loads.

Table 220.56 Demand Factors for Kitchen Equipment — Other Than Dwelling Unit(s)

Number of Units of Equipment	Demand Factor (%)
1	100
2	100
3	90
4	80
5	70
6 and over	65

220.60 Noncoincident Loads.
Where it is unlikely that two or more noncoincident loads will be in use simultaneously, it shall be permissible to use only the largest load(s) that will be used at one time for calculating the total load of a feeder or service.
220.61 Feeder or Service Neutral Load.
(A) Basic Calculation.
The feeder or service neutral load shall be the maximum unbalance of the load determined by this article. The maximum unbalanced load shall be the maximum net calculated load between the neutral conductor and any one ungrounded conductor.
Exception: For 3-wire, 2-phase or 5-wire, 2-phase systems, the maximum unbalanced load shall be the maximum net calculated load between the neutral conductor and any one ungrounded conductor multiplied by 140 percent.
(B) Permitted Reductions.
A service or feeder supplying the following loads shall be permitted to have an additional demand factor of 70 percent applied to the amount in 220.61(B)(1) or portion of the amount in 220.61(B)(2) determined by the following basic calculations:

(1) A feeder or service supplying household electric ranges, wall-mounted ovens, counter-mounted cooking units, and electric dryers, where the maximum unbalanced load has been determined in accordance with Table 220.55 for ranges and Table 220.54 for dryers

(2) That portion of the unbalanced load in excess of 200 amperes where the feeder or service is supplied from a 3-wire dc or single-phase ac system; or a 4-wire, 3-phase system; or a 3-wire, 2-phase system; or a 5-wire, 2-phase system

Informational Note: See Examples D1(a), D1(b), D2(b), D4(a), and D5(a) in Informative Annex D.
(C) Prohibited Reductions.
There shall be no reduction of the neutral or grounded conductor capacity applied to the amount in 220.61(C)(1), or portion of the amount in (C)(2), from that determined by the basic calculation:

(1) Any portion of a 3-wire circuit consisting of 2 ungrounded conductors and the neutral conductor of a 4-wire, 3-phase, wye-connected system

(2) That portion consisting of nonlinear loads supplied from a 4-wire, wye-connected, 3-phase system

Informational Note: A 3-phase, 4-wire, wye-connected power system used to supply power to nonlinear loads may necessitate that the power system design allow for the possibility of high harmonic neutral conductor currents.
Part IV. Optional Feeder and Service Load Calculations
220.80 General.
Optional feeder and service load calculations shall be permitted in accordance with Part IV.
220.82 Dwelling Unit.
(A) Feeder and Service Load.
This section applies to a dwelling unit having the total connected load served by a single 120/240-volt or 208Y/120-volt set of 3-wire service or feeder conductors with an ampacity of 100 or greater. It shall be permissible to calculate the feeder and service loads in accordance with this section instead of

the method specified in Part III of this article. The calculated load shall be the result of adding the loads from 220.82(B) and (C). Feeder and service-entrance conductors whose calculated load is determined by this optional calculation shall be permitted to have the neutral load determined by 220.61.

(B) General Loads.

The general calculated load shall be not less than 100 percent of the first 10 kVA plus 40 percent of the remainder of the following loads:

(1) 33 volt-amperes/m^2 or 3 volt-amperes/ft^2 for general lighting and general-use receptacles. The floor area for each floor shall be calculated from the outside dimensions of the dwelling unit. The calculated floor area shall not include open porches, garages, or unused or unfinished spaces not adaptable for future use.

(2) 1500 volt-amperes for each 2-wire, 20-ampere small-appliance branch circuit and each laundry branch circuit covered in 210.11(C)(1) and (C)(2).

(3) The nameplate rating of the following:

  a. All appliances that are fastened in place, permanently connected, or located to be on a specific circuit

  b. Ranges, wall-mounted ovens, counter-mounted cooking units

  c. Clothes dryers that are not connected to the laundry branch circuit specified in item (2)

  d. Water heaters

(4) The nameplate ampere or kVA rating of all permanently connected motors not included in item (3).

(C) Heating and Air-Conditioning Load.

The largest of the following six selections (load in kVA) shall be included:

(1) 100 percent of the nameplate rating(s) of the air conditioning and cooling.

(2) 100 percent of the nameplate rating(s) of the heat pump when the heat pump is used without any supplemental electric heating.

(3) 100 percent of the nameplate rating(s) of the heat pump compressor and 65 percent of the supplemental electric heating for central electric space-heating systems. If the heat pump compressor is prevented from operating at the same time as the supplementary heat, it does not need to be added to the supplementary heat for the total central space heating load.

(4) 65 percent of the nameplate rating(s) of electric space heating if less than four separately controlled units.

(5) 40 percent of the nameplate rating(s) of electric space heating if four or more separately controlled units.

(6) 100 percent of the nameplate ratings of electric thermal storage and other heating systems where the usual load is expected to be continuous at the full nameplate value. Systems qualifying under this selection shall not be calculated under any other selection in 220.82(C).

220.83 Existing Dwelling Unit.

This section shall be permitted to be used to determine if the existing service or feeder is of sufficient capacity to serve additional loads. Where the dwelling unit is served by a 120/240-volt or 208Y/120-volt, 3-wire service, it shall be permissible to calculate the total load in accordance with 220.83(A) or (B).

(A) Where Additional Air-Conditioning Equipment or Electric Space-Heating Equipment Is Not to Be Installed.

The following percentages shall be used for existing and additional new loads.

Load (kVA)	Percent of Load
First 8 kVA of load at	100

Load (kVA)	Percent of Load
Remainder of load at	40

Load calculations shall include the following:

(1) General lighting and general-use receptacles at 33 volt-amperes/m^2 or 3 volt-amperes/ft^2 as determined by ~~220.12~~ 220.14(J) **[PI-XXX]**

(2) 1500 volt-amperes for each 2-wire, 20-ampere small-appliance branch circuit and each laundry branch circuit covered in 210.11(C)(1) and (C)(2)

(3) The nameplate rating of the following:

a. All appliances that are fastened in place, permanently connected, or located to be on a specific circuit

b. Ranges, wall-mounted ovens, counter-mounted cooking units

c. Clothes dryers that are not connected to the laundry branch circuit specified in item (2)

d. Water heaters

(B) Where Additional Air-Conditioning Equipment or Electric Space-Heating Equipment Is to Be Installed.
The following percentages shall be used for existing and additional new loads. The larger connected load of air conditioning or space heating, but not both, shall be used.

Load	Percent of Load
Air-conditioning equipment	100
Central electric space heating	100
Less than four separately . controlled space-heating units	100
First 8 kVA of all other loads	100
Remainder of all other loads	40

Other loads shall include the following:

(1) General lighting and general-use receptacles at 33 volt-amperes/m^2 or 3 volt-amperes/ft^2 as determined by ~~220.12~~ 220.14(J) **[PI-XXX]**

(2) 1500 volt-amperes for each 2-wire, 20-ampere small-appliance branch circuit and each laundry branch circuit covered in 210.11(C)(1) and (C)(2)

(3) The nameplate rating of the following:

a. All appliances that are fastened in place, permanently connected, or located to be on a specific circuit

b. Ranges, wall-mounted ovens, counter-mounted cooking units

c. Clothes dryers that are not connected to the laundry branch circuit specified in item (2)

d. Water heaters

220.84 Multifamily Dwelling.
(A) Feeder or Service Load.
It shall be permissible to calculate the load of a feeder or service that supplies three or more dwelling units of a multifamily dwelling in accordance with Table 220.84 instead of Part III of this article if all the following conditions are met:

(1) No dwelling unit is supplied by more than one feeder.

(2) Each dwelling unit is equipped with electric cooking equipment.

Exception: When the calculated load for multifamily dwellings without electric cooking in Part III of this article exceeds that calculated under Part IV for the identical load plus electric cooking (based on 8 kW per unit), the lesser of the two loads shall be permitted to be used.

(3) Each dwelling unit is equipped with either electric space heating or air conditioning, or both. Feeders and service conductors whose calculated load is determined by this optional calculation shall be permitted to have the neutral load determined by 220.61.

(B) House Loads.
House loads shall be calculated in accordance with Part III of this article and shall be in addition to the dwelling unit loads calculated in accordance with Table 220.84.

Table 220.84 Optional Calculations — Demand Factors for Three or More Multifamily Dwelling Units

Number of Dwelling Units	Demand Factor (%)
3–5	45
6–7	44
8–10	43
11	42
12–13	41
14–15	40
16–17	39
18–20	38
21	37
22–23	36
24–25	35
26–27	34
28–30	33
31	32
32–33	31
34–36	30
37–38	29
39–42	28
43–45	27
46–50	26
51–55	25
56–61	24
62 and over	23

(C) Calculated Loads.
The calculated load to which the demand factors of Table 220.84 apply shall include the following:

(1) 33 volt-amperes/m^2 or 3 volt-amperes/ft^2 for general lighting and general-use receptacles

(2) 1500 volt-amperes for each 2-wire, 20-ampere small-appliance branch circuit and each laundry branch circuit covered in 210.11(C)(1) and (C)(2)

(3) The nameplate rating of the following:

a. All appliances that are fastened in place, permanently connected, or located to be on a specific circuit

b. Ranges, wall-mounted ovens, counter-mounted cooking units

c. Clothes dryers that are not connected to the laundry branch circuit specified in item (2)

d. Water heaters

(4) The nameplate ampere or kVA rating of all permanently connected motors not included in item (3)

(5) The larger of the air-conditioning load or the fixed electric space-heating load

220.85 Two Dwelling Units.

Where two dwelling units are supplied by a single feeder and the calculated load under Part III of this article exceeds that for three identical units calculated under 220.84, the lesser of the two loads shall be permitted to be used.

220.86 Schools.

The calculation of a feeder or service load for schools shall be permitted in accordance with Table 220.86 in lieu of Part III of this article where equipped with electric space heating, air conditioning, or both. The connected load to which the demand factors of Table 220.86 apply shall include all of the interior and exterior lighting, power, water heating, cooking, other loads, and the larger of the air-conditioning load or space-heating load within the building or structure.

Feeders and service conductors whose calculated load is determined by this optional calculation shall be permitted to have the neutral load determined by 220.61. Where the building or structure load is calculated by this optional method, feeders within the building or structure shall have ampacity as permitted in Part III of this article; however, the ampacity of an individual feeder shall not be required to be larger than the ampacity for the entire building.

This section shall not apply to portable classroom buildings.

Table 220.86 Optional Method — Demand Factors for Feeders and Service Conductors for Schools

Connected Load		Demand Factor (Percent)
First 33 VA/m^2 . Plus,	(3 VA/ft^2) at	100
Over 33 through 220 VA/m^2 . Plus,	(3 through 20 VA/ft^2) at	75
Remainder over 220 VA/m^2	(20 VA/ft^2) at	25

220.87 Determining Existing Loads.

The calculation of a feeder or service load for existing installations shall be permitted to use actual maximum demand to determine the existing load under all of the following conditions:

(1) The maximum demand data is available for a 1-year period.

Exception: If the maximum demand data for a 1-year period is not available, the calculated load shall be permitted to be based on the maximum demand (the highest average kilowatts reached and maintained for a 15-minute interval) continuously recorded over a minimum 30-day period using a recording ammeter or power meter connected to the highest loaded phase of the feeder or service, based on the initial loading at the start of the recording. The recording shall reflect the maximum demand of the feeder or service by being taken when the building or space is occupied and shall include by measurement or calculation the larger of the *heating or cooling equipment load, and other loads that may be periodic in nature due to seasonal or similar conditions.*

(2) The maximum demand at 125 percent plus the new load does not exceed the ampacity of the feeder or rating of the service.

(3) The feeder has overcurrent protection in accordance with 240.4, and the service has overload protection in accordance with 230.90.

220.88 New Restaurants.
Calculation of a service or feeder load, where the feeder serves the total load, for a new restaurant shall be permitted in accordance with Table 220.88 in lieu of Part III of this article.
The overload protection of the service conductors shall be in accordance with 230.90 and 240.4.
Feeder conductors shall not be required to be of greater ampacity than the service conductors.
Service or feeder conductors whose calculated load is determined by this optional calculation shall be permitted to have the neutral load determined by 220.61.

Table 220.88 Optional Method — Permitted Load Calculations for Service and Feeder Conductors for New Restaurants

Total Connected Load (kVA)	All Electric Restaurant Calculated Loads (kVA)	Not All Electric Restaurant Calculated Loads (kVA)
0–200	80%	100%
201–325	10% (amount over 200) + 160.0	50% (amount over 200) + 200.0
326–800	50% (amount over 325) + 172.5	45% (amount over 325) + 262.5
Over 800	50% (amount over 800) + 410.0	20% (amount over 800) + 476.3

Note: Add all electrical loads, including both heating and cooling loads, to calculate the total connected load. Select the one demand factor that applies from the table, then multiply the total connected load by this single demand factor.

Part V. Farm Load Calculations

220.100 General.
Farm loads shall be calculated in accordance with Part V.

220.102 Farm Loads — Buildings and Other Loads.

(A) Dwelling Unit.
The feeder or service load of a farm dwelling unit shall be calculated in accordance with the provisions for dwellings in Part III or IV of this article. Where the dwelling has electric heat and the farm has electric grain-drying systems, Part IV of this article shall not be used to calculate the dwelling load where the dwelling and farm loads are supplied by a common service.

(B) Other Than Dwelling Unit.
Where a feeder or service supplies a farm building or other load having two or more separate branch circuits, the load for feeders, service conductors, and service equipment shall be calculated in accordance with demand factors not less than indicated in Table 220.102.

Table 220.102 Method for Calculating Farm Loads for Other Than Dwelling Unit

Ampere Load at 240 Volts Maximum	Demand Factor (%)
The greater of the following:	
All loads that are expected to operate simultaneously, or	100
125 percent of the full load current of the largest motor, or	
First 60 amperes of the load	
Next 60 amperes of all other loads	50
Remainder of other loads	25

220.103 Farm Loads — Total.

Where supplied by a common service, the total load of the farm for service conductors and service equipment shall be calculated in accordance with the farm dwelling unit load and demand factors specified in Table 220.103. Where there is equipment in two or more farm equipment buildings or for loads having the same function, such loads shall be calculated in accordance with Table 220.102 and shall be permitted to be combined as a single load in Table 220.103 for calculating the total load.

Table 220.103 Method for Calculating Total Farm Load

Individual Loads Calculated in Accordance with Table 220.102	Demand Factor (%)
Largest load	100
Second largest load	75
Third largest load	65
Remaining loads	50

Note: To this total load, add the load of the farm dwelling unit calculated in accordance with Part III or IV of this article. Where the dwelling has electric heat and the farm has electric grain-drying systems, Part IV of this article shall not be used to calculate the dwelling load.

Public Input No. 3357-NFPA 70-2017 [Section No. 220.12]

220.12 Lighting Load for Specified Occupancies.

A unit load of not less than that specified in Table 220.12 for occupancies specified shall constitute the minimum lighting load. The floor area for each floor shall be calculated from the outside dimensions of the building, dwelling unit, or other area involved. For dwelling units, the calculated floor area shall not include open porches, garages, or unused or unfinished spaces not adaptable for future use.

Informational Note: The unit values are based on minimum load conditions and 100 percent power factor and may not provide sufficient capacity for the installation contemplated.

Exception No. 1: Where the building is designed and constructed to comply with an energy code adopted by the local authority, the lighting load shall be permitted to be calculated at the values specified in the energy code where the following conditions are met:

(1) A power monitoring system is installed that will provide continuous information regarding the total general lighting load of the building.

(2) The power monitoring system will be set with alarm values to alert the building owner or manager if the lighting load exceeds the values set by the energy code.

(3) The demand factors specified in 220.42 are not applied to the general lighting load.

Exception No. 2: Where a building is designed and constructed to comply with an energy code adopted by the local authority and specifying an overall lighting density of less than 13.5 volt-amperes/~~13.5 m~~ m ^{2} (1.2 volt-amperes/~~1.2 ft~~ ft ^{2}), the unit lighting loads in Table 220.12 for office and bank areas within the building shall be permitted to be reduced by 11 volt-amperes/~~11 m~~ m ^{2} (1 volt-amperes/~~1 ft~~ ft ^{2}).

Table 220.12 General Lighting Loads by Occupancy

Type of Occupancy	Unit Load	
	Volt-amperes/ m^2	Volt-amperes/ ft^2
Armories and auditoriums	11	1
Banks	39[b]	3½[b]
Barber shops and beauty parlors	33	3
Churches	11	1
Clubs	22	2
Courtrooms	22	2
Dwelling units[a]	33	3
Garages — commercial (storage)	6	½
Hospitals	22	2
Hotels and motels, including apartment houses without provision for cooking by tenants[a]	22	2
Industrial commercial (loft) buildings	22	2
Lodge rooms	17	1½
Office buildings	39[b]	3½[b]
Restaurants	22	2
Schools	33	3

Type of Occupancy	Unit Load Volt-amperes/ m2	Unit Load Volt-amperes/ ft2
Stores	33	3
Warehouses (storage)	3	¼
In any of the preceding occupancies except one-family dwellings and individual dwelling units of two-family and multifamily dwellings:	-	-
Assembly halls and auditoriums	11	1
Halls, corridors, closets, stairways	6	½
Storage spaces	3	¼

[a]See 220.14(J).

[b]See 220.14(K).

Additional Proposed Changes

File Name	Description	Approved
70-17-5_1262.pdf	70_17-5_1262	✓

Statement of Problem and Substantiation for Public Input

NOTE: This public input originates from Tentative Interim Amendment No. 17-5 (Log 1262) issued by the Standards Council on July 18, 2017 and per the NFPA Regs., needs to be reconsidered by the Technical Committee for the next edition of the Document.

Substantiation: Exception No. 2 to 220.12 was a new requirement in the 2017 NEC. The allowance to reduce the unit lighting load of Table 220.12 by 1 volt-ampere/ft2 for banks and office areas was a positive step toward recognizing how the requirements in adopted energy codes can affect compliance with the National Electrical Code. During the Second Draft it appears the numeric values “13.5 m2, (1.2 ft2), 11 m2 and (1 ft2)” were repeated in the formula. Because this was overlooked during the regular revision process, CMP 2 voted on the exception with the repeated numeric values and as currently written there will be confusion in the industry, a TIA is necessary to remove additional numeric values.

Emergency Nature: The standard contains an error or an omission that was overlooked during the regular revision process. Having repeated numeric values in the formula will result in considerable confusion in the industry and misapplications of the exception.

Submitter Information Verification

Submitter Full Name: CMP ON NEC-P02
Organization: Code-Making Panel 2
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 05 16:51:49 EDT 2017

Copyright Assignment

I, CMP ON NEC-P02, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am CMP ON NEC-P02, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Tentative Interim Amendment

NFPA® 70®

National Electrical Code®

2017 Edition

Reference: 220.12, Exception No. 2
TIA 17-5
(TIA Log #1262)

Pursuant to Section 5 of the NFPA *Regulations Governing the Development of NFPA Standards*, the National Fire Protection Association has issued the following Tentative Interim Amendment to NFPA 70®, *National Electrical Code®*, 2017 edition. The TIA was processed by the National Electrical Code Panel 2 and the NEC Correlating Committee, and was issued by the Standards Council on July 18, 2017, with an effective date of August 7, 2017.

A Tentative Interim Amendment is tentative because it has not been processed through the entire standards-making procedures. It is interim because it is effective only between editions of the standard. A TIA automatically becomes a public input of the proponent for the next edition of the standard; as such, it then is subject to all of the procedures of the standards-making process.

1. *Revise 220.12, Exception No. 2 to read as follows:*

Exception No. 2: Where a building is designed and constructed to comply with an energy code adopted by the local authority and specifying an overall lighting density of less than 13.5 volt-amperes/~~13.5~~ m^2 (1.2 volt-amperes/~~1.2~~ ft^2), the unit lighting loads in Table 220.12 for office and bank areas within the building shall be permitted to be reduced by 11 volt-amperes/~~11~~ m^2 (1 volt-amperes/~~1~~ ft^2).

Issue Date: July 18, 2017

Effective Date: August 7, 2017

(Note: For further information on NFPA Codes and Standards, please see www.nfpa.org/docinfo)

Public Input No. 3588-NFPA 70-2017 [Section No. 220.12]

220.12 Lighting Load for Specified Occupancies.

A unit load of not less than that specified in Table 220.12 for occupancies specified shall constitute the minimum lighting load. The floor area for each floor shall be calculated from the outside dimensions of the building, dwelling unit, or other area involved. For dwelling units, the calculated floor area shall not include open porches, garages, or unused or unfinished spaces not adaptable for future use.

Informational Note: The unit values are based on minimum load conditions and 100 percent power factor and may not provide sufficient capacity for the installation contemplated.

Exception No. 1: Where the building is designed and constructed to comply with an energy code adopted by the local authority, the lighting load shall be permitted to be calculated at the values specified in the energy code where the following conditions are met:

(1) A power monitoring system is installed that will provide continuous information regarding the total general lighting load of the building.

(2) The power monitoring system will be set with alarm values to alert the building owner or manager if the lighting load exceeds the values set by the energy code.

(3) The demand factors specified in 220.42 are not applied to the general lighting load.

Exception No. 2: Where a building is designed and constructed to comply with an energy code adopted by the local authority and specifying an overall lighting density of less than 13.5 volt-amperes/13.5 m^2 (1.2 volt-amperes/1.2 ft^2), the unit lighting loads in Table 220.12 for office and bank areas within the building shall be permitted to be reduced by 11 volt-amperes/11 m^2 (1 volt-amperes/1 ft^2).

Table 220.12 General Lighting Loads by Occupancy

Type of Occupancy	Unit Load	
	Volt-amperes/ m^2	Volt-amperes/ ft^2
Armories and auditoriums	11	1
Banks	39[b]	3½[b]
Barber shops and beauty parlors	33	3
Churches	11	1
Clubs	22	2
Courtrooms	22	2
Dwelling units[a]	33	3
Garages — commercial (storage)	6	½
~~Hospitals~~	~~22~~	~~2~~
Hotels and motels, including apartment houses without provision for cooking by tenants[a]	22	2
Industrial commercial (loft) buildings	22	2
Lodge rooms	17	1½
Office buildings	39[b]	3½[b]
Restaurants	22	2

Type of Occupancy	Unit Load Volt-amperes/ m2	Volt-amperes/ ft2
Schools	33	3
Stores	33	3
Warehouses (storage)	3	¼
In any of the preceding occupancies except one-family dwellings and individual dwelling units of two-family and multifamily dwellings:	-	-
Assembly halls and auditoriums	11	1
Halls, corridors, closets, stairways	6	½
Storage spaces	3	¼

[a]See 220.14(J).

[b]See 220.14(K).

Additional Proposed Changes

File Name	Description	Approved
NFPA_70_Article_220..14_I_for_New_Section_517.23_Bourgault_Submission.pdf	This change is needed to avoid conflict with new section 517.23, attached for reference.	✓
NFPA_70_New_Section_517.23_A_Bourgault_Submission.pdf	New section 517.23 (A) for reference. Article was submitted to 517.	✓
NFPA_70_New_Section_517.23_B_Bourgault_Submission.pdf	New section 517.23 (B) for reference. Article was submitted to 517.	✓

Statement of Problem and Substantiation for Public Input

Substantiation provided in uploaded documents. Related studies sent to NFPA in Quincy.

Submitter Information Verification

Submitter Full Name: Ron Bourgault
Organization: Mazzetti
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 06 14:22:08 EDT 2017

Copyright Assignment

Section 220.14 (I)

Change to 220.14 (I) Add new section 517.23 to paragraph. And Table 220.12: Delete Hospitals from table.

Substantiation

This change breaks the tie of 180 VA for health care facilities allowing 517.23 to dictate the load calculation

Due to the requirements of NFPA 99 and FGI Guidelines (which are enforced through the Federal Centers of Medicare & Medicaid Services) the outlet quantity in health care facilities are mandated to be far higher than normally encountered in other occupancies. This high density of outlets is intended to allow clinicians the flexibility to provide care in multiple case scenarios within the same space. In addition, many of these spaces are required to have a set of completely redundant electrical outlets to accommodate medical equipment in the event of an isolated electrical failure. In nearly all of these spaces, the outlets are not intended for simultaneous use.

Currently the calculated sizing of the distribution systems serving these outlets fall under the 180VA requirement outlined in NFPA 70 Article 220.14(L). Adherence to this requirement necessitates the calculation of exceedingly high load densities for typical clinical spaces. For example:

Article 517.19(C) (1) requires that a minimum of 36 receptacles be provided in each operating room. Per Article 220.14(L) a 400-square foot operating room will have a plug load density of 8.1VA / square foot (if duplex receptacles are used) or as high as 16.2VA / square foot if simplex receptacles are used. These load densities are significantly higher than the actual loads that are encountered in these spaces.

Several recent comprehensive studies including; *Plug and Process Loads in Medical Office Buildings* , *Quantifying Hospital Cord Connected Plug Loads in Inpatient Areas* , and *Healthcare Energy End-Use Monitoring* ' have concluded that the receptacle load densities in even the most acute healthcare spaces are far less than the presently mandated load densities. These studies have been provided as reference in this proposal.

The requirements of 220.14(L) lead to mandatory oversizing of the distribution components including, feeders, transformers and overcurrent protective devices. This larger equipment introduces several operational issues including higher arc-flash hazards in the clinical care environment.

This proposal is intended to seek relieve healthcare facilities from the mandatory requirements of Article 220.14(L) and place the minimum calculated load densities under the purview of Article 517. This Public Input proposal is intended to be accepted with a companion proposal to Article 517 which will introduce a new section 517.23 which will provide plug load densities for healthcare facilities.

New Section

517.23 (A) **Health Care Facilities,** Rating of feeders, busses, transformers, generators, and services shall be calculated in accordance with Table 517.23(A), with respect to receptacles and cord-connected equipment.

Table 517.23(A) Receptacle Outlet Loads and Cord Connected Equipment for Health Care Facilities

A unit load of not less that the specified in Table 517.23 for health care facility occupancies shall constitute the minimum receptacle load. The floor area for each floor shall be calculated from the outside dimensions of the building, or other area involved, the calculated floor area shall not include atriums, or unfinished spaces not adaptable for future use.

Table 517.23 Health Care Facility Receptacle Outlet and Cord Connected Loads by Occupancy

Type of Occupancy	Unit Load	
	Volt-amperes/m^2	Volt-amperes/ft^2
Category 1 (Critical Care)	32.30	3.00
Category 2 (General Care)	21.50	2.00
Category 3 (Basic Care)	16.10	1.50
Category 4 (Support Space)	13.50	1.25

Substantiation

Due to the requirements of NFPA 99 and FGI Guidelines (which are enforced through the Federal Centers of Medicare & Medicaid Services) the outlet quantity in health care facilities are mandated to be far higher than normally encountered in other occupancies. This high density of outlets is intended to allow clinicians the flexibility to provide care in multiple case scenarios within the same space. In addition, many of these spaces are required to have a set of completely redundant electrical outlets to accommodate medical equipment in the event of an isolated electrical failure. In nearly all of these spaces, the outlets are not intended for simultaneous use.

Currently the calculated sizing of the distribution systems serving these outlets fall under the 180VA requirement outlined in NFPA 70 Article 220.14(L). Adherence to this requirement necessitates the calculation of exceedingly high load densities for typical clinical spaces. For example:

Several recent comprehensive studies including; *Plug and Process Loads in Medical Office Buildings* , *Quantifying Hospital Cord Connected Plug Loads in Inpatient Areas* , and *Healthcare Energy End-Use Monitoring* have concluded that the receptacle load densities in even the most acute healthcare spaces are far less than the presently mandated load densities. These studies have been provided as reference in this proposal.

The requirements of 220.14(L) lead to mandatory oversizing of the distribution components including, feeders, transformers and overcurrent protective devices. This larger equipment introduces several operational issues including higher arc-flash hazards in the clinical care environment.

This proposal is intended to seek relieve healthcare facilities from the mandatory requirements of Article 220.14(L) and place the minimum calculated load densities under the purview of Article 517. This Public Input proposal is intended to be accepted with a companion proposal to Article 517 which will introduce a new section 517.23 which will provide plug load densities for healthcare facilities.

Additional Input:

Change to 220.14 (I) Add 517.23 to paragraph. A separate submission has been made to Article 220 for this change.

Substantiation:

This change breaks the tie of 180 VA for health care facilities allowing 517.23 to dictate the load calculation

New Section

517.23 (B) **Receptacle Outlets.** The maximum number of receptacle outlets connected to a 15 ampere branch circuit shall not exceed 6 outlets. The maximum number of receptacle outlets connected to a 20 ampere branch circuit shall not exceed 8 outlets.

Substantiation

This section is needed to support new section 517.23 (A). It establishes necessary limits for the number of receptacles permitted on a branch circuit.

Due to the requirements of NFPA 99 and FGI Guidelines (which are enforced through the Federal Centers of Medicare & Medicaid Services) the outlet quantity in health care facilities are mandated to be far higher than normally encountered in other occupancies. This high density of outlets is intended to allow clinicians the flexibility to provide care in multiple case scenarios within the same space. In addition, many of these spaces are required to have a set of completely redundant electrical outlets to accommodate medical equipment in the event of an isolated electrical failure. In nearly all of these spaces, the outlets are not intended for simultaneous use.

Currently the calculated sizing of the distribution systems serving these outlets fall under the 180VA requirement outlined in NFPA 70 Article 220.14(L). Adherence to this requirement necessitates the calculation of exceedingly high load densities for typical clinical spaces. For example:

Article 517.19(C) (1) requires that a minimum of 36 receptacles be provided in each operating room. Per Article 220.14(L) a 400-square foot operating room will have a plug load density of 8.1VA / square foot (if duplex receptacles are used) or as high as 16.2VA / square foot if simplex receptacles are used. These load densities are significantly higher than the actual loads that are encountered in these spaces.

Several recent comprehensive studies including; *Plug and Process Loads in Medical Office Buildings*, *Quantifying Hospital Cord Connected Plug Loads in Inpatient Areas*, and *Healthcare Energy End-Use Monitoring*, have concluded that the receptacle load densities in even the most acute healthcare spaces are far less than the presently mandated load densities. These studies have been provided as reference in this proposal.

The requirements of 220.14(L) lead to mandatory oversizing of the distribution components including, feeders, transformers and overcurrent protective devices. This larger equipment introduces several operational issues including higher arc-flash hazards in the clinical care environment.

This proposal is intended to seek relieve healthcare facilities from the mandatory requirements of Article 220.14(L) and place the minimum calculated load densities under the purview of Article 517. This Public Input proposal is intended to be accepted with a companion proposal to Article 517 which will introduce a new section 517.25 which will provide plug load densities for healthcare facilities.

Public Input No. 4122-NFPA 70-2017 [Section No. 220.12]

220.12 Lighting Load for Specified Occupancies.

A unit load of not less than that specified in Table 220.12 for occupancies specified shall constitute the minimum lighting load. The floor area for each floor shall be calculated from the outside dimensions of the building, dwelling unit, or other area involved. For dwelling units, the calculated floor area shall not include open porches, garages, or unused or unfinished spaces not adaptable for future use.

Informational Note: The unit values are based on minimum load conditions and 100 percent power factor and may not provide sufficient capacity for the installation contemplated.

Exception No. 1: Where the building is designed and constructed to comply with an energy code adopted by the local authority, the lighting load shall be permitted to be calculated at the values specified in the energy code where the following conditions are met:

(1) A power monitoring system is installed that will provide continuous information regarding the total general lighting load of the building.

(2) The power monitoring system will be set with alarm values to alert the building owner or manager if the lighting load exceeds the values set by the energy ~~code~~ code and automatically take action to reduce the connected load .

(3) The demand factors specified in 220.42 are not applied to the general lighting load.

Exception No. 2: Where a building is designed and constructed to comply with an energy code adopted by the local authority and specifying an overall lighting density of less than 13.5 volt-amperes/13.5 m^2 (1.2 volt-amperes/1.2 ft^2), the unit lighting loads in Table 220.12 for office and bank areas within the building shall be permitted to be reduced by 11 volt-amperes/11 m^2 (1 volt-amperes/1 ft^2).

Table 220.12 General Lighting Loads by Occupancy

Type of Occupancy	Unit Load Volt-amperes/ m^2	Unit Load Volt-amperes/ ft^2
Armories and auditoriums	11	1
Banks	39[b]	3½[b]
Barber shops and beauty parlors	33	3
Churches	11	1
Clubs	22	2
Courtrooms	22	2
Dwelling units[a]	33	3
Garages — commercial (storage)	6	½
Hospitals	22	2
Hotels and motels, including apartment houses without provision for cooking by tenants[a]	22	2
Industrial commercial (loft) buildings	22	2
Lodge rooms	17	1½
Office buildings	39[b]	3½[b]
Restaurants	22	2

Type of Occupancy	Unit Load Volt-amperes/ m^2	Unit Load Volt-amperes/ ft^2
Schools	33	3
Stores	33	3
Warehouses (storage)	3	¼
In any of the preceding occupancies except one-family dwellings and individual dwelling units of two-family and multifamily dwellings:	-	-
Assembly halls and auditoriums	11	1
Halls, corridors, closets, stairways	6	½
Storage spaces	3	¼

[a]See 220.14(J).

[b]See 220.14(K).

Statement of Problem and Substantiation for Public Input

The default load calculation method presented in this section has a proven safety and performance track record but is clearly too conservative for installations based on a locally adopted energy code. However, from a safety perspective the inclusion of metering or power monitoring alone which does not have the ability to take action when the system is overloaded creates a significant hazard that should be addressed. This revision would require automatic action to reduce the connected load during an overload.

Submitter Information Verification

Submitter Full Name: Chad Kennedy
Organization: Schneider Electric
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 07 14:44:18 EDT 2017

Public Input No. 577-NFPA 70-2017 [Section No. 220.12]

220.12 Lighting Load for Specified Occupancies.

A unit load of not less than that specified in Table 220.12 for occupancies specified shall constitute the minimum lighting load. The floor area for each floor shall be calculated from the outside dimensions of the building, dwelling unit, or other area involved. For dwelling units, the calculated floor area shall not include open porches, garages, or unused or unfinished spaces not adaptable for future use.

Informational Note: The unit values are based on minimum load conditions and 100 percent power factor and may not provide sufficient capacity for the installation contemplated.

Exception No. 1: Where the building is designed and constructed to comply with an energy code adopted by the local authority, the lighting load shall be permitted to be calculated at the values specified in the energy code where the following conditions are met:

(1) A power monitoring system is installed that will provide continuous information regarding the total general lighting load of the building.

(2) The power monitoring system will be set with alarm values to alert the building owner or manager if the lighting load exceeds the values set by the energy code.

(3) The demand factors specified in 220.42 are not applied to the general lighting load.

Exception No. 2: Where a building is designed and constructed to comply with an energy code adopted by the local authority and specifying an overall lighting density of less than 13.5 volt-amperes/13.5 m^2 (1.2 volt-amperes/1.2 ft^2), the unit lighting loads in Table 220.12 for office and bank areas within the building shall be permitted to be reduced by 11 volt-amperes/11 m^2 (1 volt-amperes/1 ft^2).

Table 220.12 General Lighting Loads by Occupancy

Type of Occupancy	Unit Load: Volt-amperes/ m^2	Unit Load: Volt-amperes/ ft^2
Armories and auditoriums	11	1
Banks	39[b]	3½[b]
Barber shops and beauty parlors	33	3
Churches	11	1
Clubs	22	2
Courtrooms	22	2
Dwelling units[a]	33	3
Garages — commercial (storage)	6	½
Hospitals	22	2
Hotels and motels, including apartment houses without provision for cooking by tenants[a]	22	2
Industrial commercial (loft) buildings	22	2
Lodge rooms	17	1½
Office buildings	39[b]	3½[b]
Restaurants	22	2
Schools	33	3

Type of Occupancy	Unit Load Volt-amperes/ m2	Volt-amperes/ ft2
Stores	33	3
Warehouses (storage)	3	¼
In any of the preceding occupancies except one-family dwellings and individual dwelling units of two-family and multifamily dwellings:	-	-
Assembly halls and auditoriums	11	1
Halls, corridors, closets, stairways	6	½
Storage spaces	3	¼

[a]See 220.14(J).

[b]See 220.14(K).

Note to Table 220.12. The unit loads are considered non-continuous loads for calculation purposes.

Statement of Problem and Substantiation for Public Input

It is unclear whether the unit lighting loads in Table 220.12 are considered continuous or non-continuous loads when calculating the overall building service. The code making panel should clarify this. This proposal removes the continuous mark-up requirement for calculation purposes given the large gap that exists between the actual lighting load and the unit lighting load.

An office building service installed today is sized at 3.5 watts per square foot with actual lighting loads more in the range of .7 watts per square foot. There is no reason to add the additional 25% mark up for continuous operation, given these very conservative values.

Submitter Information Verification

Submitter Full Name: David Hittinger

Organization: Independent Electrical Contractors

Affilliation: Independent Electrical Contractors Codes and Standard

Street Address:

City:

State:

Zip:

Submittal Date: Sat Apr 22 22:08:48 EDT 2017

Copyright Assignment

I, David Hittinger, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am David Hittinger, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 3831-NFPA 70-2017 [Section No. 220.14]

220.14 Other Loads — All Occupancies.

In all occupancies, the minimum load for each outlet for general-use receptacles and outlets not used for general illumination shall not be less than that calculated in 220.14(A) through (L), the loads shown being based on nominal branch-circuit voltages.

Exception: The loads of outlets serving switchboards and switching frames in telephone exchanges shall be waived from the calculations.

(A) Specific Appliances or Loads.

An outlet for a specific appliance or other load not covered in 220.14(B) through (L) shall be calculated based on the ampere rating of the appliance or load served.

(B) Electric Dryers and Electric Cooking Appliances in Dwellings and Household Cooking Appliances Used in Instructional Programs.

Load calculations shall be permitted as specified in 220.54 for electric dryers and in 220.55 for electric ranges and other cooking appliances.

(C) Motor Outlets.

Loads for motor outlets shall be calculated in accordance with the requirements in 430.22, 430.24, and 440.6.

(D) Luminaires.

An outlet supplying luminaire(s) shall be calculated based on the maximum volt-ampere rating of the equipment and lamps for which the luminaire(s) is rated.

(E) Heavy-Duty Lampholders.

Outlets for heavy-duty lampholders shall be calculated at a minimum of 600 volt-amperes.

(F) Sign and Outline Lighting.

Sign and outline lighting outlets shall be calculated at a minimum of 1200 volt-amperes for each required branch circuit specified in 600.5(A).

(G) Show Windows.

Show windows shall be calculated in accordance with either of the following:

(1) The unit load per outlet as required in other provisions of this section

(2) At 200 volt-amperes per linear 300 mm (1 ft) of show window

(H) Fixed Multioutlet Assemblies.

Fixed multioutlet assemblies used in other than dwelling units or the guest rooms or guest suites of hotels or motels shall be calculated in accordance with (H)(1) or (H)(2). For the purposes of this section, the calculation shall be permitted to be based on the portion that contains receptacle outlets.

(1) Where appliances are unlikely to be used simultaneously, each 1.5 m (5 ft) or fraction thereof of each separate and continuous length shall be considered as one outlet of not less than 180 volt-amperes.

(2) Where appliances are likely to be used simultaneously, each 300 mm (1 ft) or fraction thereof shall be considered as an outlet of not less than 180 volt-amperes.

(I) Receptacle Outlets.

Except as covered in 220.14(J) and (K), receptacle outlets shall be calculated at not less than 180 volt-amperes for each single or for each multiple receptacle on one yoke. A single piece of equipment consisting of a multiple receptacle comprised of four or more receptacles shall be calculated at not less than 90 volt-amperes per receptacle. This provision shall not be applicable to the receptacle outlets specified in 210.11(C)(1) and (C)(2).

(J) Dwelling Occupancies.

In one-family, two-family, and multifamily dwellings and in guest rooms or guest suites of hotels and motels, the outlets specified in (J)(1), (J)(2), and (J)(3) are included in the general lighting load calculations of 220.12. No additional load calculations shall be required for such outlets.

(1) All general-use receptacle outlets of 20-ampere rating or less, including receptacles connected to the circuits in 210.11(C)(3)

(2) The receptacle outlets specified in 210.52(E) and (G)

(3) The lighting outlets specified in 210.70(A) and (B)

(K) Banks and Office Buildings.

In banks or office buildings, the receptacle loads shall be calculated to be the larger of (1) or (2):

(1) The calculated load from 220.14(I)

(2) 11 volt-amperes/m^2 or 1 volt-ampere/ft^2

(L) – In health care facilities the receptacle loads shall be calculated in accordance with the requirements of 517.22.

(M) Other Outlets.

Other outlets not covered in 220.14(A) through (~~K~~ L) shall be calculated based on 180 volt-amperes per outlet.

Statement of Problem and Substantiation for Public Input

Due to the requirements of NFPA 99 and FGI Guidelines (which are enforced through the Federal Centers of Medicare & Medicaid Services) the outlet quantity in health care facilities are mandated to be far higher than normally encountered in other occupancies. This high density of outlets is intended to allow clinicians the flexibility to provide care in multiple case scenarios within the same space. In addition, many of these spaces are required to have a set of completely redundant electrical outlets to accommodate medical equipment in the event of an isolated electrical failure. In nearly all of these spaces, the outlets are not intended for simultaneous use.

Currently the calculated sizing of the distribution systems serving these outlets fall under the 180VA requirement outlined in NFPA 70 Article 220.12(L). Adherence to this requirement necessitates the calculation of exceedingly high load densities for typical clinical spaces. For example:

Article 517.19(C) (1) requires that a minimum of 36 receptacles be provided in each operating room. Per Article 220.12(L) a 400-square foot operating room will have a plug load density of 8.1VA / square foot (if duplex receptacles are used) or as high as 16.2VA / square foot if simplex receptacles are used. These load densities are significantly higher than the actual loads that are encountered in these spaces which have been found to be less than 3VA / square foot.

Several recent comprehensive studies including; Plug and Process Loads in Medical Office Buildings, Quantifying Hospital Cord Connected Plug Loads in Inpatient Areas, and Healthcare Energy End-Use Monitoring, have concluded that the receptacle load densities in even the most acute healthcare spaces are far less than the presently mandated load densities. These studies have been provided as reference in this proposal.

The requirements of 220.12(L) lead to mandatory oversizing of the distribution components including, feeders, transformers and overcurrent protective devices. This larger equipment introduces several operational issues including higher arc-flash hazards in the clinical care environment.

This proposal is intended to relieve healthcare facilities from the mandatory requirements of Article 220.12(L) and place the minimum calculated load densities under the purview of Article 517. This Public Input proposal is intended to be accepted with a companion proposal to Article 517 which will introduce a new section 517.22 which will provide plug load densities for healthcare facilities.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3833-NFPA 70-2017 [New Part after II.]	New swction referenced in 517

Submitter Information Verification

Submitter Full Name:	Jason DAntona
Organization:	Thompson Consultants Inc
Affilliation:	TC Chair of NFPA 99 HEA-ELS
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Thu Sep 07 00:00:20 EDT 2017

Public Input No. 2389-NFPA 70-2017 [Section No. 220.14(C)]

(C) Motor Outlets.

Loads for motor outlets shall be calculated in accordance with the requirements in 430.~~22~~ 6 , 430.~~24~~ 26 , and 440.~~6~~ 4 .

Statement of Problem and Substantiation for Public Input

See my related revisions to change 220.50 and 430.6 as a means to determine motor load.

The reference to 430.24 and 440.6 appears to be incorrect, as it addresses conductor sizing and not motor loads.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3696-NFPA 70-2017 [Section No. 430.6]	Revises 430.6 to remove conductor ampacity

Submitter Information Verification

Submitter Full Name: James Degnan

Organization: Stantec

Affilliation: ASHE

Street Address:

City:

State:

Zip:

Submittal Date: Thu Aug 17 17:30:56 EDT 2017

Public Input No. 330-NFPA 70-2017 [Section No. 220.14(I)]

(I) Receptacle Outlets.

Except as covered in 220.14(J) and (K), receptacle outlets shall be calculated at not less than 180 volt-amperes for each single or for each multiple receptacle on one yoke. A single piece of equipment consisting of a multiple receptacle comprised of four or more receptacles shall be calculated at not less than 90 volt-amperes per receptacle. This provision shall not be applicable to the receptacle outlets specified in 210.11(C)(1) and (C)(2).

Additional Proposed Changes

File Name	Description	Approved
2017March17_TGammon_Public_Input_for_NEC_220.pdf		✓

Statement of Problem and Substantiation for Public Input

I am not suggesting a change. I am urging caution before changing the requirements on calculating receptacle outlets as 180VA per single yoke.

Submitter Information Verification

Submitter Full Name: Tammy Gammon

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Fri Mar 17 09:22:59 EDT 2017

Public Input for NEC 220.14 submitted by Tammy Gammon, Ph.D., P.E.

I was contracted by the Fire Protection Research Foundation to review the available literature and develop a data collection plan to evaluate electrical feeder and branch circuit loading. My report included studies on receptacle loading which showed average and demand receptacle power densities to be fairly low in several office building studies.

There has been a move to reduce receptacle outlet calculations from 180VA per single yolk to 120VA. I am asking that the NEC CMP only consider such a change after an extensive study on receptacle loading. If the NEC CMP does determine that a change in receptacle loading requirements is warranted, please consider making a change in the demand factor for non-dwelling receptacle load (220.44), not at the branch circuit level.

Unlike lighting and mechanical loads, receptacle loads are not fixed. We do not know what plug loads will be connected today or 35 years from now. The Energy Information Administration (part of DOE) projects the energy intensity of MELs (miscellaneous electric loads, often largely receptacle load) to increase by 11.5% from 2015 to 2040 [1]. One study of bank branches in the Pacific Northwest found that MELs accounted for 32% of the branches' energy consumption [2].

A branch circuit exclusively supplying receptacle load might supply eight duplex receptacles (180x8=1440VA), which provide 16 electrical outlets. Modern desktop office equipment may have low power requirements, but corded equipment in an office space such as large copiers, heaters, water coolers, coffee machines, toaster ovens, microwaves, refrigerators, lab equipment, and intermittent loads like power tools and vacuum cleaners can easily cause breaker tripping. Branch circuits serving some spaces like kitchens/break rooms and laboratories may have high demand loads. In one office study, peak daytime demand load for a kitchen area measured 9 W/ft^2 [3].

Even without the plague of nuisance tripping, over time heavily loading branch circuits and receptacles might facilitate overheating leading to low-level faults and arcing capable of initiating fires.

[1] *Annual Energy Outlook 2016 with Projections to 2040*, U.S. Energy Information Administration, August 2014.

[2] E. Rauch, M. Baechler, and G. Sullivan, "Assessing and Reducing Miscellaneous Electric Loads (MELS) in Banks," PNNL-20973, September 26, 2011.

[3] L. Justin, A. Marston, R. Sunnam, and O. Baumann, "Simulating Empirically-Determined Plug Loads to Improve the Knowledge of Design Loads and Assess Building Performance Improvement Opportunities," ASHRAE and IBPSA-USA SimBuild 2016 Building Performance Modeling Conference, Salt Lake City, Utah, August 8-12, 2016.

Public Input No. 3585-NFPA 70-2017 [Section No. 220.14(I)]

(I) Receptacle Outlets.

Except as covered in 220.14(J) ~~and~~ , (K) and Section 517.23 , receptacle outlets shall be calculated at not less than 180 volt-amperes for each single or for each multiple receptacle on one yoke. A single piece of equipment consisting of a multiple receptacle comprised of four or more receptacles shall be calculated at not less than 90 volt-amperes per receptacle. This provision shall not be applicable to the receptacle outlets specified in 210.11(C)(1) and (C)(2).

Additional Proposed Changes

File Name	Description	Approved
NFPA_70_Article_220..14_I_for_New_Section_517.23_Bourgault_Submission.pdf	This change is needed to avoid conflict with new section 517.23, attached for reference.	✓
NFPA_70_New_Section_517.23_A_Bourgault_Submission.pdf	New section 517.23(A) for reference. Article was submitted to 517.	✓
NFPA_70_New_Section_517.23_B_Bourgault_Submission.pdf	New section 517.23 (B) for reference. Article was submitted to 517.	✓

Statement of Problem and Substantiation for Public Input

Substantiation provided in uploaded documents. Related studies sent to NFPA in Quincy.

Submitter Information Verification

Submitter Full Name: Ron Bourgault
Organization: Mazzetti
Street Address:
City:
State:
Zip:

Submittal Date: Wed Sep 06 14:18:07 EDT 2017

Copyright Assignment

Section 220.14 (I)

Change to 220.14 (I) Add new section 517.23 to paragraph. And Table 220.12: Delete Hospitals from table.

Substantiation

This change breaks the tie of 180 VA for health care facilities allowing 517.23 to dictate the load calculation

Due to the requirements of NFPA 99 and FGI Guidelines (which are enforced through the Federal Centers of Medicare & Medicaid Services) the outlet quantity in health care facilities are mandated to be far higher than normally encountered in other occupancies. This high density of outlets is intended to allow clinicians the flexibility to provide care in multiple case scenarios within the same space. In addition, many of these spaces are required to have a set of completely redundant electrical outlets to accommodate medical equipment in the event of an isolated electrical failure. In nearly all of these spaces, the outlets are not intended for simultaneous use.

Currently the calculated sizing of the distribution systems serving these outlets fall under the 180VA requirement outlined in NFPA 70 Article 220.14(L). Adherence to this requirement necessitates the calculation of exceedingly high load densities for typical clinical spaces. For example:

Article 517.19(C) (1) requires that a minimum of 36 receptacles be provided in each operating room. Per Article 220.14(L) a 400-square foot operating room will have a plug load density of 8.1VA / square foot (if duplex receptacles are used) or as high as 16.2VA / square foot if simplex receptacles are used. These load densities are significantly higher than the actual loads that are encountered in these spaces.

Several recent comprehensive studies including; *Plug and Process Loads in Medical Office Buildings* , *Quantifying Hospital Cord Connected Plug Loads in Inpatient Areas* , and *Healthcare Energy End-Use Monitoring*' have concluded that the receptacle load densities in even the most acute healthcare spaces are far less than the presently mandated load densities. These studies have been provided as reference in this proposal.

The requirements of 220.14(L) lead to mandatory oversizing of the distribution components including, feeders, transformers and overcurrent protective devices. This larger equipment introduces several operational issues including higher arc-flash hazards in the clinical care environment.

This proposal is intended to seek relieve healthcare facilities from the mandatory requirements of Article 220.14(L) and place the minimum calculated load densities under the purview of Article 517. This Public Input proposal is intended to be accepted with a companion proposal to Article 517 which will introduce a new section 517.23 which will provide plug load densities for healthcare facilities.

New Section

517.23 (A) **Health Care Facilities,** Rating of feeders, busses, transformers, generators, and services shall be calculated in accordance with Table 517.23(A), with respect to receptacles and cord-connected equipment.

Table 517.23(A) Receptacle Outlet Loads and Cord Connected Equipment for Health Care Facilities

A unit load of not less that the specified in Table 517.23 for health care facility occupancies shall constitute the minimum receptacle load. The floor area for each floor shall be calculated from the outside dimensions of the building, or other area involved, the calculated floor area shall not include atriums, or unfinished spaces not adaptable for future use.

Table 517.23 Health Care Facility Receptacle Outlet and Cord Connected Loads by Occupancy

Type of Occupancy	Unit Load	
	Volt-amperes/m²	Volt-amperes/ft²
Category 1 (Critical Care)	32.30	3.00
Category 2 (General Care)	21.50	2.00
Category 3 (Basic Care)	16.10	1.50
Category 4 (Support Space)	13.50	1.25

Substantiation

Due to the requirements of NFPA 99 and FGI Guidelines (which are enforced through the Federal Centers of Medicare & Medicaid Services) the outlet quantity in health care facilities are mandated to be far higher than normally encountered in other occupancies. This high density of outlets is intended to allow clinicians the flexibility to provide care in multiple case scenarios within the same space. In addition, many of these spaces are required to have a set of completely redundant electrical outlets to accommodate medical equipment in the event of an isolated electrical failure. In nearly all of these spaces, the outlets are not intended for simultaneous use.

Currently the calculated sizing of the distribution systems serving these outlets fall under the 180VA requirement outlined in NFPA 70 Article 220.14(L). Adherence to this requirement necessitates the calculation of exceedingly high load densities for typical clinical spaces. For example:

Several recent comprehensive studies including; *Plug and Process Loads in Medical Office Buildings* , *Quantifying Hospital Cord Connected Plug Loads in Inpatient Areas* , and *Healthcare Energy End-Use Monitoring* , have concluded that the receptacle load densities in even the most acute healthcare spaces are far less than the presently mandated load densities. These studies have been provided as reference in this proposal.

The requirements of 220.14(L) lead to mandatory oversizing of the distribution components including, feeders, transformers and overcurrent protective devices. This larger equipment introduces several operational issues including higher arc-flash hazards in the clinical care environment.

This proposal is intended to seek relieve healthcare facilities from the mandatory requirements of Article 220.14(L) and place the minimum calculated load densities under the purview of Article 517. This Public Input proposal is intended to be accepted with a companion proposal to Article 517 which will introduce a new section 517.23 which will provide plug load densities for healthcare facilities.

Additional Input:

Change to 220.14 (I) Add 517.23 to paragraph. A separate submission has been made to Article 220 for this change.

Substantiation:

This change breaks the tie of 180 VA for health care facilities allowing 517.23 to dictate the load calculation

New Section

517.23 (B) **Receptacle Outlets.** The maximum number of receptacle outlets connected to a 15 ampere branch circuit shall not exceed 6 outlets. The maximum number of receptacle outlets connected to a 20 ampere branch circuit shall not exceed 8 outlets.

Substantiation

This section is needed to support new section 517.23 (A). It establishes necessary limits for the number of receptacles permitted on a branch circuit.

Due to the requirements of NFPA 99 and FGI Guidelines (which are enforced through the Federal Centers of Medicare & Medicaid Services) the outlet quantity in health care facilities are mandated to be far higher than normally encountered in other occupancies. This high density of outlets is intended to allow clinicians the flexibility to provide care in multiple case scenarios within the same space. In addition, many of these spaces are required to have a set of completely redundant electrical outlets to accommodate medical equipment in the event of an isolated electrical failure. In nearly all of these spaces, the outlets are not intended for simultaneous use.

Currently the calculated sizing of the distribution systems serving these outlets fall under the 180VA requirement outlined in NFPA 70 Article 220.14(L). Adherence to this requirement necessitates the calculation of exceedingly high load densities for typical clinical spaces. For example:

Article 517.19(C) (1) requires that a minimum of 36 receptacles be provided in each operating room. Per Article 220.14(L) a 400-square foot operating room will have a plug load density of 8.1VA / square foot (if duplex receptacles are used) or as high as 16.2VA / square foot if simplex receptacles are used. These load densities are significantly higher than the actual loads that are encountered in these spaces.

Several recent comprehensive studies including; *Plug and Process Loads in Medical Office Buildings*, *Quantifying Hospital Cord Connected Plug Loads in Inpatient Areas*, and *Healthcare Energy End-Use Monitoring*, have concluded that the receptacle load densities in even the most acute healthcare spaces are far less than the presently mandated load densities. These studies have been provided as reference in this proposal.

The requirements of 220.14(L) lead to mandatory oversizing of the distribution components including, feeders, transformers and overcurrent protective devices. This larger equipment introduces several operational issues including higher arc-flash hazards in the clinical care environment.

This proposal is intended to seek relieve healthcare facilities from the mandatory requirements of Article 220.14(L) and place the minimum calculated load densities under the purview of Article 517. This Public Input proposal is intended to be accepted with a companion proposal to Article 517 which will introduce a new section 517.25 which will provide plug load densities for healthcare facilities.

Public Input No. 1499-NFPA 70-2017 [Section No. 220.14(J)]

(J) Dwelling Occupancies.

In one-family, two-family, and multifamily dwellings and in guest rooms or guest suites of hotels and motels, the outlets specified in (J)(1), (J)(2), and (J)(3) are included in the general lighting load calculations of 220.12. No additional load calculations shall be required for such outlets.

(1) All general-use receptacle outlets of 20-ampere rating or less, including receptacles connected to the circuits in 210.11(C)(3) and 210.11(C)(4)

(2) The receptacle outlets specified in 210.52(E) and (G)

(3) The lighting outlets specified in 210.70(A) and (B)

Statement of Problem and Substantiation for Public Input

Add reference to Garage circuit (C)(4)

Submitter Information Verification

Submitter Full Name: Mike Holt

Organization: Mike Holt Enterprises Inc

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 01 11:17:27 EDT 2017

Public Input No. 3147-NFPA 70-2017 [Section No. 220.14(J)]

(J) Dwelling Occupancies.

In one-family, two-family, and multifamily dwellings and in guest rooms or guest suites of hotels and motels, the minimum unit load shall be not less than 33-VA/m^2 (3 VA/ft^2). The lighting and receptacle outlets specified in (J)(1), (J)(2), and (J)(3) are included in the ~~general lighting load calculations of~~ ~~220.12~~ ~~.~~ minimum unit load. No additional load calculations shall be required for such outlets. The minimum lighting load shall be detemined using the minimum unit load and the floor area as dtermined in 220.11 for dwelling occupancies.

(1) All general-use receptacle outlets of 20-ampere rating or less, including receptacles connected to the circuits in 210.11(C)(3)

(2) The receptacle outlets specified in 210.52(E) and (G)

(3) The lighting outlets specified in 210.70(A) and (B)

Statement of Problem and Substantiation for Public Input

The Correlating Committee identified the need to establish an Energy Task Group to begin reviewing the NEC® to identify areas where industry revisions of energy use have not been reflected in the NEC. Identified areas would then be reviewed and public inputs submitted where agreed upon enhancements will provide appropriate alignment while preserving appropriate safety and operational provisions. NEC Article 220 addressing calculations for sizing electrical infrastructure is one area the task group identified. The initial focus for the 2020 NEC public inputs is on alignment of the lighting load calculations more closely with industry technology and practice. The Correlating Committee Energy Task Group, includes: Larry Ayer (Co-Chair), Alan Manche (Co-Chair), Donny Cook, Eric Richman, John McCamish, Ken Boyce, Mike Weaver, Richard Holub, Steve Douglas; Tom Domitrovich, Tim Croushore, and Tim Pope.

To correlate the change of Table 220.12 to an ASHRAE 90.1 based equivalent a few changes are necessary. The ASHRAE 90.1 table incorporates dwelling unit lighting loads of approximately 1.0 watts per square foot. The long-standing NEC calculation of 3.0 watts/s.f. for dwelling type applications which includes the general purpose receptacle load has been used successfully for many years and lowering this value could have unintended consequences. As a result the Task Group has removed all references to dwelling unit type occupancies in the proposed new 220.12 table, concentrating on non-dwelling unit occupancies. Editorial changes are being to certain sections of Article 220 to reflect this change.

This specific public input makes editorial changes to the dwelling unit load calculation section 220.14(J) and removes the reference to Table 220.12.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3153-NFPA 70-2017 [Section No. 220.42]	
Public Input No. 3282-NFPA 70-2017 [Section No. 220.12]	
Public Input No. 3288-NFPA 70-2017 [New Section after 220.10]	
Public Input No. 3319-NFPA 70-2017 [Section No. 220.16]	

Submitter Information Verification

Submitter Full Name: Lawrence Ayer
Organization: Biz Com Electric Inc
Affilliation: IEC
Street Address:
City:
State:
Zip:
Submittal Date: Fri Sep 01 15:10:46 EDT 2017

Copyright Assignment

Public Input No. 1095-NFPA 70-2017 [Section No. 220.14(K)]

(K) Banks and Office Buildings.

In banks or office buildings, the receptacle loads shall be calculated to be the larger of (1) or (2):

(1) The calculated load from 220.14(I) after all demand factors have been applied

(2) 11 volt-amperes/m^2 or 1 volt-ampere/ft^2

Statement of Problem and Substantiation for Public Input

It is unclear to the user of the code whether the calculated receptacle loads for Banks and Office Buildings in list item (1) of section 220.14(K) is before or after the application of any demand factors. This proposed change will clarify that the calculated load in list item 1 is after all demand factors have been applied. Then, the larger of the two list items should be compared.

Submitter Information Verification

Submitter Full Name: David Hittinger

Organization: Independent Electrical Contractors

Affilliation: Independent Electrical Contractors Codes and Standard

Street Address:

City:

State:

Zip:

Submittal Date: Fri Jun 30 14:46:32 EDT 2017

Public Input No. 1309-NFPA 70-2017 [Section No. 220.14(K)]

(K) Banks and Office Buildings.

In banks or office buildings, the receptacle loads shall be calculated to be the larger of (1) or (2):

(1) The calculated load from 220.14(I)

(2) 11 volt-amperes/m^2 or 1 volt-ampere/ft^2

<u>Note: Where the calculated load is based on 220.14(I), it shall be permissible to apply the demand factors for receptacle loads in accordance with Table 220.44.</u>

Statement of Problem and Substantiation for Public Input

There is no point-to-point substantiation for the use of Table 220.44 for determining receptacle loads as part of the Feeder and Service Load Calculation in Banks and Office Buildings.

Per Section 220.14(K), receptacle loads are calculated by using the largest of either - 1) the calculated load from 220.14(I) or 2) 11 volt-amperes/m² or 1 volt-ampere/ft².

Using option 1- we calculate our receptacle load at 180VA for "each single or for each multiple receptacle on one yoke" per 220.14(I).

If option 1 is used, then our receptacle load is considerably greater than option 2 where sq footage is used. This disparity in load size is considerable.

Example:

Office Building @ 50k sq ft. with 500 duplex receptacles.

Using option 1 of 220.14(K) = 500 receptacles X 180VA = 90kVA -----------per 220.14(I)

Using option 2 of 220.14(K) = 50,0000 X 1VA per sq ft = 50kVA

There is a 40kVA difference comparing the two options.

This impact is particularly noteworthy as Banks and Office Buildings are already impacted per Unit Load requirements found in Table 220.12 for General Lighting Loads under Branch Circuit Load Calculations (calculated at 3½ VA per sq ft) and 100% Demand Factor requirements found in Table 220.42 under Feeder and Service Load Calculations.

When Table 220.44 is utilized in conjunction with option 1 of 220.14(K), there exists a equitable impact.

Example:

Office Building @ 50k sq ft. with 500 planned duplex receptacles.

Using option 1 of 220.14(K) = 500 receptacles X 180VA = 90kVA (per 220.14(I))

Applying the demand factors as prescribed in Table 220.44- 90kVA - 10kVA = 80kVA

80kVA X 50% = 40kVA

10kVA + 40kVA = 50kVA

Using option 2 of 220.14(K) = 50,0000 X 50kVA

We ask that this existing Code section be revised to demonstrate a point-to-point substantiation of the use of Table 220.44 when determining the impact of receptacle loads on Bank and Office Building Feeder and Service Load Calculations.

Submitter Information Verification

Submitter Full Name: Andrew Rogers

Organization: Santa Clara Electrical JATC

Street Address:

City:

State:

Zip:

Submittal Date: Tue Jul 25 15:52:41 EDT 2017

Public Input No. 3639-NFPA 70-2017 [Section No. 220.16]

220.16 Loads for Additions to Existing Installations.

(A) Dwelling Units.

Loads added to an existing dwelling unit(s) shall comply with the following as applicable:

(1) ~~Loads for~~ For structural additions to an existing dwelling unit or for a previously unwired portion of an existing dwelling unit, either of which exceeds 46.5 m^2 (500 ft^2), the minimum lighting load shall be calculated in accordance with 220.~~12~~ ~~and~~ ~~220.14~~ .

~~Loads for new circuits or extended circuits in previously wired dwelling units~~

(2) 14(J) .

(3) For structural additions to an existing dwelling unit or for a previously unwired portion of an existing dwelling unit, either of which is less than or equal to 460.5 m^2 (500 ft^2), the minimum lighting load shall be permitted to be excluded from the calculations.

(4) Additional loads other than those covered in 220.14(J) shall be calculated in accordance with ~~either~~ 220.~~12~~ ~~or~~ ~~220.~~ 14, as applicable.

(B) Other Than Dwelling Units.

Loads for new circuits or extended circuits in other than dwelling units shall be calculated in accordance with either 220.12 or 220.14, as applicable.

Additional Proposed Changes

File Name	Description	Approved
220.16_Attachment.docx		✓

Statement of Problem and Substantiation for Public Input

The Correlating Committee identified the need to establish an Energy Task Group to review the NEC® and identify areas where industry achievements in the reduction of energy use have not been reflected in the NEC. Identified areas would then be reviewed and public inputs submitted where agreed upon enhancements will provide appropriate alignment while preserving appropriate safety and operational provisions. NEC Article 220 addressing calculations for sizing electrical infrastructure is one area the task group identified. The initial focus for the 2020 NEC public inputs is on alignment of the lighting load calculations more closely with industry technology and practice. The Correlating Committee Energy Task Group, includes: Larry Ayer (Co-Chair), Alan Manche (Co-Chair), Donny Cook, Eric Richman Ashrae 90.1, John McCamish, Ken Boyce, Mike Weaver, Richard Holub, Steve Douglas; Tom Domitrovich, Tim Croushore, and Tim Pope.

PI-3282 has modified Table 220.12 and has removed any reference to dwelling occupancies. As a result any minimum lighting load calculation for dwelling type occupancies are found only in 220.14(J). This specific public input correlates the changes in Table 220.12 with section 220.16. Other changes are proposed in list items (A)(2) and (A)(3) to provide better clarity and usability to the user of the standard.

An attachment is provided to show the correct structure of 220.16 since Terraview did not provide the proper formatting.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3282-NFPA 70-2017 [Section No. 220.12]	
Public Input No. 3153-NFPA 70-2017 [Section No. 220.42]	
Public Input No. 3147-NFPA 70-2017 [Section No. 220.14(J)]	
Public Input No. 3288-NFPA 70-2017 [New Section after 220.10]	

Submitter Information Verification

Submitter Full Name: Lawrence Ayer
Organization: Biz Com Electric Inc
Affilliation: IEC
Street Address:
City:
State:
Zip:

Submittal Date: Wed Sep 06 15:48:18 EDT 2017

220.16 Loads for Additions to Existing Installations.
(A) Dwelling Units.
Loads added to an existing dwelling unit(s) shall comply with the following as applicable:

(1) ~~Loads for~~ For structural additions to an existing dwelling unit or for a previously unwired portion of an existing dwelling unit, either of which exceeds 46.5 m^2 (500 ft^2), the minimum lighting load shall be calculated in accordance with ~~220.12 and~~ 220.14(J).

~~Loads for new circuits or extended circuits in previously wired dwelling units shall be~~

(2) For structural additions to an existing dwelling unit or for a previously unwired portion of an existing dwelling unit, either of which is less than or equal to 460.5 m^2 (500 ft^2), the minimum lighting load shall be permitted to be excluded from the calculations.

(3) Additional loads other than the minimum lighting load in 220.14(J) shall be calculated in accordance with either 220.~~12 or 220.~~14, as applicable.

(B) Other Than Dwelling Units.
Loads for new circuits or extended circuits in other than dwelling units shall be calculated in accordance with either 220.12 or 220.14, as applicable.

Public Input No. 2820-NFPA 70-2017 [Sections 210.19(A)(1), 210.19(A)(2), 210.19(A)(3), 210.19(A...]

Sections 210.19(A)(1), 210.19(A)(2), 210.19(A)(3), 210.19(A)(4)

(1) General.

Branch-circuit conductors shall have an ampacity not less than the maximum load to be served. Conductors shall be sized to carry not less than the larger of 210.19(A)(1)(a) or (b).

(a) Where a branch circuit supplies continuous loads or any combination of continuous and noncontinuous loads, the minimum branch-circuit conductor size shall have an allowable ampacity not less than the noncontinuous load plus 125 percent of the continuous load.

(b) The minimum branch-circuit conductor size shall have an allowable ampacity not less than the maximum load to be served after the application of any adjustment or correction factors.

Exception: If the assembly, including the overcurrent devices protecting the branch circuit(s), is listed for operation at 100 percent of its rating, the allowable ampacity of the branch-circuit conductors shall be permitted to be not less than the sum of the continuous load plus the noncontinuous load.

(2) Grounded Conductor.

The size of the branch circuit grounded conductor, for circuits rated 30 amps or more, shall not be smaller than that required by 250.122, and shall comply with 210.19(A)(1)

(3) Branch Circuits with More than One Receptacle.

Conductors of branch circuits supplying more than one receptacle for cord-and-plug-connected portable loads shall have an ampacity of not less than the rating of the branch circuit.

(~~3~~ 4) Household Ranges and Cooking Appliances.

Branch-circuit conductors supplying household ranges, wall-mounted ovens, counter-mounted cooking units, and other household cooking appliances shall have an ampacity not less than the rating of the branch circuit and not less than the maximum load to be served. For ranges of 8¾ kW or more rating, the minimum branch-circuit rating shall be 40 amperes.

Exception No. 1: Conductors tapped from a 50-ampere branch circuit supplying electric ranges, wall-mounted electric ovens, and counter-mounted electric cooking units shall have an ampacity of not less than 20 amperes and shall be sufficient for the load to be served. These tap conductors include any conductors that are a part of the leads supplied with the appliance that are smaller than the branch-circuit conductors. The taps shall not be longer than necessary for servicing the appliance.

Exception No. 2: The neutral conductor of a 3-wire branch circuit supplying a household electric range, a wall-mounted oven, or a counter-mounted cooking unit shall be permitted to be smaller than the ungrounded conductors where the maximum demand of a range of 8¾-kW or more rating has been calculated according to Column C of Table 220.55, but such conductor shall have an ampacity of not less than 70 percent of the branch-circuit rating and shall not be smaller than 10 AWG.

(4 5) – Other Loads.

Branch-circuit conductors that supply loads other than those specified in 210.3and other than cooking appliances as covered in 210.19(A)(3) shall have an ampacity sufficient for the loads served and shall not be smaller than 14 AWG.

Exception No. 1: Tap conductors shall have an ampacity sufficient for the load served. In addition, they shall have an ampacity of not less than 15 for circuits rated less than 40 amperes and not less than 20 for circuits rated at 40 or 50 amperes and only where these tap conductors supply any of the following loads:

(a) Individual lampholders or luminaires with taps extending not longer than 450 mm (18 in.) beyond any portion of the lampholder or luminaire

(b) A luminaire having tap conductors as provided in 410.117

(c) Individual outlets, other than receptacle outlets, with taps not over 450 mm (18 in.) long

(d) Infrared lamp industrial heating appliances

(e) Nonheating leads of deicing and snow-melting cables and mats

Exception No. 2: Fixture wires and flexible cords shall be permitted to be smaller than 14 AWG as permitted by 240.5.

Statement of Problem and Substantiation for Public Input

The grounded conductor for a feeder can be smaller as long as it isn't smaller than the equipment grounding conductor. There are pieces of equipment that do not need a full sized neutral so it seems appropriate to have a section in here that is similar to the feeder grounded conductors but for branch circuits

Submitter Information Verification

Submitter Full Name: Dennis Alwon
Organization: Alwon Electric
Street Address:
City:
State:
Zip:
Submittal Date: Sun Aug 27 16:27:22 EDT 2017

Public Input No. 45-NFPA 70-2017 [Section No. 220.40]

220.40 General.

The calculated load of a feeder or service shall not be less than the sum of the continuous and noncontinuous loads on the branch circuits supplied, as determined by Part II of this article, after any applicable demand factors permitted by Part III or IV or required by Part V have been applied.

Exception: If the assembly, including the overcurrent devices protecting the feeder or service conductors, is listed for operation at 100%25 of its rating, the allowable ampacity of the feeder or service conductors shall be permitted to be not less than the sum of the continuous load plus the noncontinuous load.

Informational Note No 1 : See Examples D1(a) through D10 in Informative Annex D. See 220.18(B) for the maximum load in amperes permitted for lighting units operating at less than 100 percent power factor.

Informational Note No 2: See 215.2 for sizing the combination of the continuous and noncontinuous load.

Statement of Problem and Substantiation for Public Input

Many of the circuit breaker devices in service rated equipment are rated at an 80% continuous load rating. By not sizing the continuous load at 125% for a service calculation, the overcurrent device could be overload by the total of the continuous load. Article 215.2 requires the continuous load to be sized at 125% for a feeder and the same applies to the electrical service conductors tin 230.42 However the language belongs in Article 220 as this article has purview over the load calculations for feeders and service conductors. As an example, a 400 A service rated transfer switch has a breaker rated at 80% continuous load or 320 Amps. The actual sum of all the continuous load is 268 Amps. When multiplied by 125%, the continuous load is now calculated at 335 A which exceeds the rating of the circuit breaker. The proposed exception would allow the calculated sum of the continuous and non continuous load to not exceed 100% where the overcurrent device for the service is listed for use at a 100% continuous load rating.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 44-NFPA 70-2017 [Definition: Calculated Load]	Public Input 45 seeks to add that a sizing calculation of a service or feeder takes into account the continuous load at 125%

Submitter Information Verification

Submitter Full Name: Brian Baughman

Organization: Generac Power Systems Inc

Street Address:

City:

State:

Zip:

Submittal Date: Tue Jan 24 16:26:53 EST 2017

Copyright Assignment

I, Brian Baughman, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Brian Baughman, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 1500-NFPA 70-2017 [Section No. 220.42]

220.42 General Lighting.

The demand factors specified in Table 220.42 shall apply to that portion of the total branch-circuit load calculated for general illumination. They shall not be applied in determining the number of branch circuits for general illumination.

Table 220.42 Lighting Load Demand Factors

Type of Occupancy	Portion of Lighting Load to Which Demand Factor Applies (Volt-Amperes)	Demand Factor (%)	
Dwelling units*	First 3000 at	100	
	-	From 3001 to 120,000 at	35
	-	Remainder over 120,000 at	25
Hospitals**	First 50,000 or less at	40	
	-	Remainder over 50,000 at	20
Hotels and motels, including apartment houses without provision for cooking by tenants*	First 20,000 or less at	50	
	From 20,001 to 100,000 at	40	
	Remainder over 100,000 at	30	
Warehouses (storage)	First 12,500 or less at	100	
	Remainder over 12,500 at	50	
All others	Total volt-amperes	100	

*The demand factors of this table shall apply to the small appliance circuits and laundry circuit in accordance with 220.52.

**The demand factors of this table shall not apply to the calculated load of feeders or services supplying areas in hospitals, hotels, and motels where the entire lighting is likely to be used at one time, as in operating rooms, ballrooms, or dining rooms.

Statement of Problem and Substantiation for Public Input

The new note should help the Code user to know that when applying dwelling unit lighting demand factors, they need to include the small appliance circuits and the laundry circuit.

Submitter Information Verification

Submitter Full Name: Mike Holt

Organization: Mike Holt Enterprises Inc

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 01 11:19:43 EDT 2017

Copyright Assignment

I, Mike Holt, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Mike Holt, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 3153-NFPA 70-2017 [Section No. 220.42]

220.42 General Lighting.

The demand factors specified in Table 220.42 shall apply to that portion of the total branch-circuit load calculated for general illumination. They shall not be applied in determining the number of branch circuits for general illumination.

Table 220.42 Lighting Load Demand Factors

Type of Occupancy	**Portion of Lighting Load to Which Demand Factor Applies (Volt-Amperes)**	**Demand Factor (%)**	
Dwelling units	First 3000 at	100	
	-	From 3001 to 120,000 at	35
	-	Remainder over 120,000 at	25
~~Hospitals*~~	~~First 50,000 or less at~~	~~40~~	
-	~~Remainder over 50,000 at~~	~~20~~	
Hotels and motels, including apartment houses without provision for cooking by tenants*	First 20,000 or less at	50	
	From 20,001 to 100,000 at	40	
	Remainder over 100,000 at	30	
Warehouses (storage)	First 12,500 or less at	100	
	Remainder over 12,500 at	50	
All others	Total volt-amperes	100	

*The demand factors of this table shall not apply to the calculated load of feeders or services supplying areas in ~~hospitals,~~ hotels ~~,~~ and motels where the entire lighting is likely to be used at one time, as in ~~operating rooms,~~ ballrooms ~~,~~ or dining rooms.

Additional Proposed Changes

File Name	Description	Approved
Hospital_Derating_Examples.docx		✓

Statement of Problem and Substantiation for Public Input

The Correlating Committee identified the need to establish an Energy Task Group to review the NEC® and identify areas where industry achievements in the reduction of energy use have not been reflected in the NEC. Identified areas would then be reviewed and public inputs submitted where agreed upon enhancements will provide appropriate alignment while preserving appropriate safety and operational provisions. NEC Article 220 addressing calculations for sizing electrical infrastructure is one area the task group identified. The initial focus for the 2020 NEC public inputs is on alignment of the lighting load calculations more closely with industry technology and practice. The Correlating Committee Energy Task Group, includes: Larry Ayer (Co-Chair), Alan Manche (Co-Chair), Donny Cook, Eric Richman Ashrae 90.1, John McCamish, Ken Boyce, Mike Weaver, Richard Holub, Steve Douglas; Tom Domitrovich, Tim Croushore, and Tim Pope.

Public Input 3282 has been submitted to modify NEC Table 220.12 General Lighting Loads by Occupancy to reflect the significant advancement in energy reduction in lighting. The Task Group has reviewed the derating factors in Table 220.42 as they pertain to the proposed revisions to Table 220.12 in public input 3282. After the review the Task Group proposes to delete all derating factors for Hospitals.

1. As an example a 500,000 square foot hospital in the 2017 NEC would require an electrical distribution system sized to handle 1,000 kVA of lighting (500,000 sq.ft x 2 va/sf)

2. Taking the demand factors for hospitals and applying Table 220.42 (ignoring the first 50,000 VA and simply using the 20% demand) to the 1,000 kVA value one would end up with 200 kVA of lighting.

3. Utilizing Ashrae 90.1 - 2016 actual data, the average hospital lighting load today is .94 watts per square foot which means that the example 500,000 s.f hospital would have 470 kVA of lighting, assuming all lights were on.

4. Comparing the demand load of 200 kVA after applying the derating factors to the 2016 - 100% connected lighting load tells us that the derating table assumes that 42% of lights are on in the hospital.

5. Changing the Hospital unit load to 1.6 VA/sf for the 2020 NEC cycle and using the same derating factors will then assume that 32% of lights are on in the same hospital.

5. The task group does not have data from ASHRAE or other organizations to validate this information and therefore proposes to delete the derating values for hospital lighting.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3282-NFPA 70-2017 [Section No. 220.12]	Proposed changes to Table 220.12
Public Input No. 3147-NFPA 70-2017 [Section No. 220.14(J)]	
Public Input No. 3639-NFPA 70-2017 [Section No. 220.16]	
Public Input No. 3288-NFPA 70-2017 [New Section after 220.10]	

Submitter Information Verification

Submitter Full Name:	Lawrence Ayer
Organization:	Biz Com Electric Inc
Affilliation:	IEC
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Fri Sep 01 16:14:28 EDT 2017

Copyright Assignment

I, Lawrence Ayer, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Lawrence Ayer, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

	2017	2020	
		(2000 Ashrae)	(2004 Ashrae)
Hospital sq. footage	500000	500000	500000
Multiplier	2	1.6	1.2
Connected Lighting	1000000	800000	600000
Demand Figure	**0.20**	**0.20**	**0.20**
Demand Lighting figure	200000	160000	120000
Actual ASHRAE Lighting calcs	0.94	0.94	0.94
Actual 100% conn load	470000	470000	470000
% of Lighting considered on	43%	34%	26%
Proposed new Demand factor	**0.20**	**0.25**	**0.35**
Use of new Demand Factor	**200000**	**200000**	**210000**

Table 220.42 Lighting Load Demand Factors

Type of Occupancy	Portion of Lighting Load to Which Demand Factor Applies (Volt-Amperes)	Demand Factor (%)
Dwelling units	First 3000 at	100
	From 3001 to 120,000 at	35
	Remainder over 120,000 at	25
Hospitals*	First 50,000 or less at	40
	Remainder over 50,000 at	20
Hotels and motels, including apartment houses without provision for cooking by tenants*	First 20,000 or less at	50
	From 20,001 to 100,000 at	40
	Remainder over 100,000 at	30
Warehouses (storage)	First 12,500 or less at	100
	Remainder over 12,500 at	50
All others	Total volt-amperes	100

*The demand factors of this table shall not apply to the calculated load of feeders or services supplying areas in hospitals, hotels, and motels where the entire lighting is likely to be used at one time, as in operating rooms, ballrooms, or dining rooms.

Public Input No. 3368-NFPA 70-2017 [Section No. 220.42]

220.42 General Lighting.

The demand factors specified in Table 220.42 shall apply to that portion of the total branch-circuit load calculated for general illumination. They shall not be applied in determining the number of branch circuits for general illumination.

Table 220.42 Lighting Load Demand Factors

Type of Occupancy	Portion of Lighting Load to Which Demand Factor Applies (Volt-Amperes)	Demand Factor (%)
Dwelling units	First 3000 at	100
	From 3001 to 120,000 at	35
	Remainder over 120,000 at	25
~~Hospitals~~		
Health Care Facilities *	First 50,000 or less at	40
	Remainder over 50,000 at	20
Hotels and motels, including apartment houses without provision for cooking by tenants*	First 20,000 or less at	50
	From 20,001 to 100,000 at	40
	Remainder over 100,000 at	30
Warehouses (storage)	First 12,500 or less at	100
	Remainder over 12,500 at	50
All others	Total volt-amperes	100

*The demand factors of this table shall not apply to the calculated load of feeders or services supplying areas in ~~hospitals~~ health care facilities , hotels, and motels where the entire lighting is likely to be used at one time, as in operating rooms, ballrooms, or dining rooms.

Statement of Problem and Substantiation for Public Input

The demand factors in Table 220.42, which may be used for receptacle loads per 220.44, generate demand loads that are approximately 40% of what is calculated using Table 220.44. This is proven to be a beneficial demand factor for Hospital design, because other NEC calculation methods generally lead to distribution equipment and feeders that are oversized. Our work as consulting engineers at Mazzetti, which includes significant studies and load monitoring at a variety of outpatient healthcare facilities, shows that other types of healthcare facilities, not just hospitals, have this same problem with oversized distribution equipment and feeders and would therefore benefit from being able to use the more aggressive demand factors allowed under Table 220.42. We are therefore recommending that the allowed use of this table be expanded to include all health care facilities rather than just hospitals.

A Mazzetti study on plug loads at outpatient facilities, as well as an ASHE Monograph on plug loads in Inpatient facilities, have been submitted as part of Public Input No. 3565-NFPA 70-2017.

Submitter Information Verification

Submitter Full Name: Jay Jack

Organization: Mazzetti

Street Address:

City:

State:

Zip:

Submittal Date: Tue Sep 05 17:10:02 EDT 2017

Public Input No. 3409-NFPA 70-2017 [Section No. 220.42]

220.42 General Lighting.

The demand factors specified in Table 220.42 shall apply to that portion of the total branch-circuit load calculated for general illumination. They shall not be applied in determining the number of branch circuits for general illumination.

Table 220.42 Lighting Load Demand Factors

Type of Occupancy	**Portion of Lighting Load to Which Demand Factor Applies (Volt-Amperes)**	**Demand Factor (%)**	
Dwelling units	First 3000 at	100	
	–	~~From 3001 to 120~~ Next 117 ,000 at	35
	–	Remainder over 120,000 at	25
Hospitals*	First 50,000 or less at	40	
	–	Remainder over 50,000 at	20
Hotels and motels, including apartment houses without provision for cooking by tenants*	First 20,000 or less at	50	
	From 20,001 to 100,000 at	40	
	Remainder over 100,000 at	30	
Warehouses (storage)	First 12,500 or less at	100	
	Remainder over 12,500 at	50	
All others	Total volt-amperes	100	

*The demand factors of this table shall not apply to the calculated load of feeders or services supplying areas in hospitals, hotels, and motels where the entire lighting is likely to be used at one time, as in operating rooms, ballrooms, or dining rooms.

Statement of Problem and Substantiation for Public Input

I work with many students helping them to learn NEC codes. This table always causes confusion but when I tell them to cross out what I deleted and just add next 117,000 it totally made sense. Just thought this would be a useful and more understanding change.

Submitter Information Verification

Submitter Full Name: Dennis Alwon

Organization: Alwon Electric

Street Address:

City:

State:

Zip:

Submittal Date: Tue Sep 05 20:12:21 EDT 2017

Copyright Assignment

I, Dennis Alwon, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Dennis Alwon, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

Public Input No. 3583-NFPA 70-2017 [Section No. 220.44]

220.44 Receptacle Loads — Other Than Dwelling Units and Health Care Facilities .

Receptacle loads calculated in accordance with 220.14(H) and (I) shall be permitted to be made subject to the demand factors given in Table 220.42 or Table 220.44.

Table 220.44 Demand Factors for Non-Dwelling Receptacle Loads

Portion of Receptacle Load to Which Demand Factor Applies (Volt-Amperes)	Demand Factor (%)
First 10 kVA or less at	100
Remainder over 10 kVA at	50

Additional Proposed Changes

File Name	Description	Approved
NFPA_70_New_Section_517.22_Bourgault_Submission.pdf	New section 517.22 for reference. Articles was submitted to 517.	✓
NFPA_70_New_Section_517.24_A_Bourgault_Submission.pdf	New section 517.24(A) for reference. Article was submitted to 517.	✓
NFPA_70_New_Section_517.24_B_Bourgault_Submission.pdf	New section 517.24 (B) for reference. Articles was submitted to 517.	✓
NFPA_70_Article_220.44_for_New_Section_517.22_and_517.24_Bourgault_Submission.pdf	This change is needed to avoid conflict with new section 517.22 and 517.24 (A), attached for reference.	✓

Statement of Problem and Substantiation for Public Input

Substantiation provided in uploaded documents. Related studies sent to NFPA in Quincy.

Submitter Information Verification

Submitter Full Name: Ron Bourgault
Organization: Mazzetti
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 06 14:14:21 EDT 2017

Copyright Assignment

I, Ron Bourgault, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Ron Bourgault, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

New Section

517.22 **Health Care Facilities.** Rating of feeders, busses, transformers, generators, and services shall be calculated in accordance with Table 517.22, with respect to receptacles and cord-connected equipment.

Table 517.22 Receptacle Outlet and Cord Connected Equipment Demand Factors for Health Care Facilities

Portion of Receptacle Load to Which Demand Factor Applies (Volt-Amperes)	Demand Factor (%)
First 5.0 kVA or less at	100
Second 5.0 kVA to 10 kVA at	50
Remainder over 10 kVA at	25

Substantiation

Due to the requirements of NFPA 99 and FGI Guidelines (which are enforced through the Federal Centers of Medicare & Medicaid Services) the outlet quantity in health care facilities are mandated to be far higher than normally encountered in other occupancies. This high density of outlets is intended to allow clinicians the flexibility to provide care in multiple case scenarios within the same space. In addition, many of these spaces are required to have a set of completely redundant electrical outlets to accommodate medical equipment in the event of an isolated electrical failure. In nearly all of these spaces, the outlets are not intended for simultaneous use.

Currently the calculated sizing of the distribution systems serving these outlets fall under the 180VA requirement outlined in NFPA 70 Article 220.14(L). Adherence to this requirement necessitates the calculation of exceedingly high load densities for typical clinical spaces. For example:

Article 517.19(C) (1) requires that a minimum of 36 receptacles be provided in each operating room. Per Article 220.14(L) a 400-square foot operating room will have a plug load density of 8.1VA / square foot (if duplex receptacles are used) or as high as 16.2VA / square foot if simplex receptacles are used. These load densities are significantly higher than the actual loads that are encountered in these spaces.

Several recent comprehensive studies including; *Plug and Process Loads in Medical Office Buildings* , *Quantifying Hospital Cord Connected Plug Loads in Inpatient Areas* , and *Healthcare Energy End-Use Monitoring*' have concluded that the receptacle load densities in even the most acute healthcare spaces are far less than the presently mandated load densities. These studies have been provided as reference in this proposal.

The requirements of 220.14(L) lead to mandatory oversizing of the distribution components including, feeders, transformers and overcurrent protective devices. This larger equipment introduces several operational issues including higher arc-flash hazards in the clinical care environment.

This proposal is intended to seek relieve healthcare facilities from the mandatory requirements of Article 220.14(L) and place the minimum calculated load densities under the purview of Article 517. This Public Input proposal is intended to be accepted with a companion proposal to Article 517 which will introduce a new section 517.22 which will provide plug load densities for healthcare facilities.

Additional Input:

Change to 220.44: Receptacle Loads -- Other Than Dwelling Units and **Health Care Facilities.** A separate submission has been made to Article 220 for this change.

Substantiation:

By adding Health Care Facilities to the title of this section, this table no longer applies to health care facilities and it allows for different demand factors as identified in new section 517.22.

New Section

517.24 (A) **Health Care Facilities.** Rating of feeders, busses, transformers, generators, and services shall be calculated in accordance with Table 517.24 (A), with respect cord-connected equipment.

Table 517.24(A) Cord Connected Equipment Demand Factors for Health Care Facilities

Number of Cord Connected Equipment	Percent of Full Load
1 to 5	100
5 to 10	50
More Than 10	25

Substantiation

Due to the requirements of NFPA 99 and FGI Guidelines (which are enforced through the Federal Centers of Medicare & Medicaid Services) the outlet quantity in health care facilities are mandated to be far higher than normally encountered in other occupancies. This high density of outlets is intended to allow clinicians the flexibility to provide care in multiple case scenarios within the same space. In addition, many of these spaces are required to have a set of completely redundant electrical outlets to accommodate medical equipment in the event of an isolated electrical failure. In nearly all of these spaces, the outlets are not intended for simultaneous use.

Currently the calculated sizing of the distribution systems serving these outlets fall under the 180VA requirement outlined in NFPA 70 Article 220.14(L). Adherence to this requirement necessitates the calculation of exceedingly high load densities for typical clinical spaces. For example:

Article 517.19(C) (1) requires that a minimum of 36 receptacles be provided in each operating room. Per Article 220.14(L) a 400-square foot operating room will have a plug load density of 8.1VA / square foot (if duplex receptacles are used) or as high as 16.2VA / square foot if simplex receptacles are used. These load densities are significantly higher than the actual loads that are encountered in these spaces.

Several recent comprehensive studies including; *Plug and Process Loads in Medical Office Buildings* , *Quantifying Hospital Cord Connected Plug Loads in Inpatient Areas* , and *Healthcare Energy End-Use Monitoring* , have concluded that the receptacle load densities in even the most acute healthcare spaces are far less than the presently mandated load densities. These studies have been provided as reference in this proposal.

The requirements of 220.14(L) lead to mandatory oversizing of the distribution components including, feeders, transformers and overcurrent protective devices. This larger equipment introduces several operational issues including higher arc-flash hazards in the clinical care environment.

This proposal is intended to seek relieve healthcare facilities from the mandatory requirements of Article 220.14(L) and place the minimum calculated load densities under the purview of Article 517. This Public Input proposal is intended to be accepted with a companion proposal to Article 517 which will introduce a new section 517.24 which will provide plug load densities for healthcare facilities.

By adding Health Care Facilities to the title , the table no longer applies to health care facilites and it allows for different demand factors as identified in 517.24.

Additional Input:
Change to 220.44: Receptacle Loads -- Other Than Dwelling Units and **Health Care Facilities.** A separate submission has been made to Article 220 for this change.

Substantiation:
By adding Health Care Facilities to the title , the table no longer applies to health care facilites and it allows for different demand factors as identified in 517.24.

New Section

517.24 (B) **Receptacle Outlets.** The maximum number of receptacle outlets connected to a 15 ampere branch circuit shall not exceed 6 outlets. The maximum number of receptacle outlets connected to a 20 ampere branch circuit shall not exceed 8 outlets.

Substantiation

This section is needed to support new section 517.24 (A). It establishes necessary limits for the number of receptacles permitted on a branch circuit.

Due to the requirements of NFPA 99 and FGI Guidelines (which are enforced through the Federal Centers of Medicare & Medicaid Services) the outlet quantity in health care facilities are mandated to be far higher than normally encountered in other occupancies. This high density of outlets is intended to allow clinicians the flexibility to provide care in multiple case scenarios within the same space. In addition, many of these spaces are required to have a set of completely redundant electrical outlets to accommodate medical equipment in the event of an isolated electrical failure. In nearly all of these spaces, the outlets are not intended for simultaneous use.

Currently the calculated sizing of the distribution systems serving these outlets fall under the 180VA requirement outlined in NFPA 70 Article 220.14(L). Adherence to this requirement necessitates the calculation of exceedingly high load densities for typical clinical spaces. For example:

Article 517.19(C) (1) requires that a minimum of 36 receptacles be provided in each operating room. Per Article 220.14(L) a 400-square foot operating room will have a plug load density of 8.1VA / square foot (if duplex receptacles are used) or as high as 16.2VA / square foot if simplex receptacles are used. These load densities are significantly higher than the actual loads that are encountered in these spaces.

Several recent comprehensive studies including; *Plug and Process Loads in Medical Office Buildings* , *Quantifying Hospital Cord Connected Plug Loads in Inpatient Areas* , and *Healthcare Energy End-Use Monitoring* , have concluded that the receptacle load densities in even the most acute healthcare spaces are far less than the presently mandated load densities. These studies have been provided as reference in this proposal.

The requirements of 220.14(L) lead to mandatory oversizing of the distribution components including, feeders, transformers and overcurrent protective devices. This larger equipment introduces several operational issues including higher arc-flash hazards in the clinical care environment.

This proposal is intended to seek relieve healthcare facilities from the mandatory requirements of Article 220.14(L) and place the minimum calculated load densities under the purview of Article 517. This Public Input proposal is intended to be accepted with a companion proposal to Article 517 which will introduce a new section 517.25 which will provide plug load densities for healthcare facilities.

Section 220.44

Change title of 220.44: Receptacle Loads -- Other Than Dwelling Units and **Health Care Facilities.**

Substantiation

By adding Health Care Facilities to the title, this table no longer applies to health care facilities and it allows for different demand factors as identified in new sections 517.22 and 517.24

Due to the requirements of NFPA 99 and FGI Guidelines (which are enforced through the Federal Centers of Medicare & Medicaid Services) the outlet quantity in health care facilities are mandated to be far higher than normally encountered in other occupancies. This high density of outlets is intended to allow clinicians the flexibility to provide care in multiple case scenarios within the same space. In addition, many of these spaces are required to have a set of completely redundant electrical outlets to accommodate medical equipment in the event of an isolated electrical failure. In nearly all of these spaces, the outlets are not intended for simultaneous use.

Currently the calculated sizing of the distribution systems serving these outlets fall under the 180VA requirement outlined in NFPA 70 Article 220.14(L). Adherence to this requirement necessitates the calculation of exceedingly high load densities for typical clinical spaces. For example:

Article 517.19(C) (1) requires that a minimum of 36 receptacles be provided in each operating room. Per Article 220.14(L) a 400-square foot operating room will have a plug load density of 8.1VA / square foot (if duplex receptacles are used) or as high as 16.2VA / square foot if simplex receptacles are used. These load densities are significantly higher than the actual loads that are encountered in these spaces.

Several recent comprehensive studies including; *Plug and Process Loads in Medical Office Buildings* , *Quantifying Hospital Cord Connected Plug Loads in Inpatient Areas* , and *Healthcare Energy End-Use Monitoring*' have concluded that the receptacle load densities in even the most acute healthcare spaces are far less than the presently mandated load densities. These studies have been provided as reference in this proposal.

The requirements of 220.14(L) lead to mandatory oversizing of the distribution components including, feeders, transformers and overcurrent protective devices. This larger equipment introduces several operational issues including higher arc-flash hazards in the clinical care environment.

This proposal is intended to seek relieve healthcare facilities from the mandatory requirements of Article 220.14(L) and place the minimum calculated load densities under the purview of Article 517. This Public Input proposal is intended to be accepted with a companion proposal to Article 517 which will introduce a new section 517.22 which will provide plug load densities for healthcare facilities.

Public Input No. 2394-NFPA 70-2017 [Section No. 220.50]

220.50 Motors.

Motor loads shall be calculated in accordance with 430.~~24~~ 6 , 430.~~25~~ ~~, and~~ ~~430.~~ 26 and with 440.~~6~~ 4 for hermetic refrigerant motor-compressors.

Statement of Problem and Substantiation for Public Input

See related PI for modification to 430.6.

The title of 220.50 is "Motor Loads" 430.24, 430.25 and 440.6 all refer to conductor sizing criteria and not motor loads. The closest "load" reference in 430 is 430.6 which has text linking to the motor full load current tables. Similarly 440.4 references motor full load currents and is more appropriate for load determination than 440.6.

References to 430. 24, 430.25, and 440.6 should appear in Articles 210 and 215.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2389-NFPA 70-2017 [Section No. 220.14(C)]	similar for outlets
Public Input No. 3696-NFPA 70-2017 [Section No. 430.6]	removes conductor ampacity from 430.6

Submitter Information Verification

Submitter Full Name: James Degnan
Organization: Stantec
Affilliation: ASHE
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 17 18:14:06 EDT 2017

Copyright Assignment

Public Input No. 2552-NFPA 70-2017 [Section No. 220.52(B)]

(B) Laundry Circuit Load.

A load of not less than 1500 volt-amperes shall be included for each 2-wire laundry branch circuit installed as covered by 210.11(C)(2). This load shall be permitted to be included with the general lighting load and shall be subjected to the demand factors provided in Table 220.42.

(C) Bathroom Circuit Load.

A load of no less than 1500-volt-amperes shall be included for each 2-wire bathroom branch circuit installed as covered by 210.11(C)(3). This load shall be permitted to be included with the general lighting load and shall be subjected to the demand factors provided in Table 220.42.

Statement of Problem and Substantiation for Public Input

Load in modern day dwelling unit has continued to increase in today's world. Blow dryers, curling irons, make-up mirrors, etc., are used in abundance, and many home have multiple bathrooms. The load would also be submitted to demand factors, similar to a laundry branch circuit, which may serve a clothes washing machine, electric iron, or other laundry load, which is also there, but can be intermittent.

Requiring a simple 1500 VA be added to the dwelling unit load makes sense, and is often questioned in the electrical industry why this is not a requirement. Ask any father with a wife and many daughters, in the house, and they'll say thank you!

Submitter Information Verification

Submitter Full Name: Michael Weitzel

Organization:

Street Address:

City:

State:

Zip:

Submittal Date: Sun Aug 20 21:33:12 EDT 2017

Public Input No. 1501-NFPA 70-2017 [Section No. 220.53]

220.53 Appliance Load — Dwelling Unit(s).

It shall be permissible to apply a demand factor of 75 percent to the nameplate rating load of four or more appliances fastened in place, other than ~~electric~~ ranges, ovens and cooktop cooking appliances, clothes dryers, space-heating equipment, or air-conditioning equipment, that are served by the same feeder or service in a one-family, two-family, or multifamily dwelling.

Statement of Problem and Substantiation for Public Input

Edit to clarify that the 75% demand factor does not apply to ranges, ovens and countertops cooking equipment.

Submitter Information Verification

Submitter Full Name: Mike Holt

Organization: Mike Holt Enterprises Inc

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 01 11:25:38 EDT 2017

Public Input No. 32-NFPA 70-2017 [Section No. 220.53]

220.53 Appliance Load — Dwelling Unit(s).

It shall be permissible to apply a demand factor of 75 percent to the nameplate rating load of four or more appliances fastened in place, permanently connected, or located to be on a specific circuit, other than electric ranges, clothes dryers, space-heating equipment, or air-conditioning equipment, that are served by the same feeder or service in a one-family, two-family, or multifamily dwelling.

Statement of Problem and Substantiation for Public Input

In residential construction it is a common practice to install dedicated branch circuits to appliances that are not fastened in place, examples of such are refrigerators, wine chillers, chest freezers, large commercial grade coffee machines, and microwave ovens that are placed on a on shelf within the kitchen cabinetry. 220.82(B) has language that captures these types of appliances in a sizing calculation, unfortunately Part III of Article 220 does not, as these appliances are not connected to the small appliance circuits and not fastened in place. 220.14(I) and 220.14(J) do not properly capture the VA rating of these appliances in a load calculation. Including these types of appliances to the requirements in 220.53 will allow all appliances that are supplied by a dedicated branch circuit to be accounted for in a Part III sizing calculation.

Submitter Information Verification

Submitter Full Name: Brian Baughman

Organization: Generac Power Systems Inc

Street Address:

City:

State:

Zip:

Submittal Date: Mon Jan 23 14:39:35 EST 2017

Public Input No. 4338-NFPA 70-2017 [Section No. 220.53]

220.53 Appliance Load — Dwelling Unit(s).

It shall be permissible to apply a demand factor of 75 percent to the nameplate rating load of four or more appliances rated 1/4 hp or greater (or the equivalent ampere rating) that are fastened in place, other than electric ranges, clothes dryers, space-heating equipment, or air-conditioning equipment, that are served by the same feeder or service in a one-family, two-family, or multifamily dwelling.

Statement of Problem and Substantiation for Public Input

When applying the demand factor in 220.53, some Code users are including items such as bathroom exhaust fans in order to reduce the load calculation. By limiting the size of motor loads to 1/4 hp or greater, or the equivalent non-motor ampere rating, this reduction in load will be limited to larger appliances.

Submitter Information Verification

Submitter Full Name: Christel Hunter
Organization: Cerro Wire
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 07 22:04:28 EDT 2017

Public Input No. 4256-NFPA 70-2017 [Section No. 220.60]

220.60 Noncoincident Loads.

Where it is unlikely that two or more noncoincident loads will be in use simultaneously, it shall be permissible to use only the largest load(s) that will be used at one time for calculating the total load of a feeder or service. When one or more of the noncoincident loads is a motor load, 125% of the motor load(s) is used to determine if the motor is the largest load.

Statement of Problem and Substantiation for Public Input

This change clarifies that the value found in 220.18 (A), that is, 125% of the largest motor load, is used when determining if a motor load is included in the load calculations when the motor is one of the noncoincident loads.

Submitter Information Verification

Submitter Full Name: Nathan Philips

Organization: Integrated Electronic Systems

Affilliation: NECA

Street Address:

City:

State:

Zip:

Submittal Date: Thu Sep 07 17:33:17 EDT 2017

Public Input No. 563-NFPA 70-2017 [Section No. 220.60]

220.60 Noncoincident Loads.

Where it is unlikely that two or more noncoincident loads will be in use simultaneously, it shall be permissible to use only the largest load(s) that will be used at one time for calculating the total load of a feeder or service. Where the non coincidents loads result in the omittion of air condition equipment, it shall be permitted to be used as the largest motor if appicable per article 220.50.

Statement of Problem and Substantiation for Public Input

it would ease the confustion when calculating a dwelling unit, do to the A/C motor load is normallat the largest motor load in the dwelling unit and Some test and study guides will give hints that say if it is omitted per 220.60 then you sould chose a different motor. In the case that it is omitted, should the A/C be seen as not to exist on the circuit?. A(n) added code rule would help clear or make the interpretation more definitive.

Submitter Information Verification

Submitter Full Name: markco yates

Organization: Electrician

Street Address:

City:

State:

Zip:

Submittal Date: Fri Apr 21 09:16:54 EDT 2017

Public Input No. 1504-NFPA 70-2017 [Section No. 220.80]

220.80 General.

Optional feeder and service load calculations shall be permitted in accordance with Part IV, instead of the method specified in Part III of this article .

Statement of Problem and Substantiation for Public Input

Text added to clarify that the optional method (Part IV) is permitted instead of the standard method permitted in Part III.

Submitter Information Verification

Submitter Full Name: Mike Holt

Organization: Mike Holt Enterprises Inc

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 01 11:36:54 EDT 2017

Public Input No. 1502-NFPA 70-2017 [Section No. 220.82(A)]

(A) Feeder and Service Load.

This section applies to a dwelling unit having the total connected load served by a single 120/240-volt or 208Y/120-volt set of 3-wire service or feeder conductors with an ampacity of 100 or greater. It shall be permissible to calculate the feeder and service loads in accordance with this section instead of the method specified in Part III of this article, where the conductors supply the entire load associated with an individual dwelling unit . The calculated load shall be the result of adding the loads from 220.82(B) and (C). Feeder and service-entrance conductors whose calculated load is determined by this optional calculation shall be permitted to have the neutral load determined by 220.61 .

Statement of Problem and Substantiation for Public Input

My PI only added the text "where conductors supply the entire load associated with an individual dwelling unit" for clarity.

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 01 11:29:40 EDT 2017

Public Input No. 1503-NFPA 70-2017 [Section No. 220.83 [Excluding any Sub-Sections]]

This section shall be permitted to be used to determine if the existing service or feeder is of sufficient capacity to serve additional loads. Where the dwelling unit is served by a 120/240-volt or 208Y/120-volt, 3-wire service, and the conductors supply the entire load associated with an individual dwelling unit , it shall be permissible to calculate the total load in accordance with 220.83(A) or (B).

Statement of Problem and Substantiation for Public Input

Added text "and the conductors supply the entire load associated with an individual dwelling unit," for clarity.

Submitter Information Verification

Submitter Full Name: Mike Holt

Organization: Mike Holt Enterprises Inc

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 01 11:33:17 EDT 2017

Public Input No. 3667-NFPA 70-2017 [Section No. 220.86]

220.86 ~~Schools.~~ 86 Educational Occupanies

The calculation of a feeder or service load for ~~schools~~ educational occupancies shall be permitted in accordance with Table 220.86 in lieu of Part III of this article where equipped with electric space heating, air conditioning, or both. The connected load to which the demand factors of Table 220.86 apply shall include all of the interior and exterior lighting, power, water heating, cooking, other loads, and the larger of the air-conditioning load or space-heating load within the building or structure.

Feeders and service conductors whose calculated load is determined by this optional calculation shall be permitted to have the neutral load determined by 220.61. Where the building or structure load is calculated by this optional method, feeders within the building or structure shall have ampacity as permitted in Part III of this article; however, the ampacity of an individual feeder shall not be required to be larger than the ampacity for the entire building.

This section shall not apply to portable classroom buildings.

Table 220.86 Optional Method — Demand Factors for Feeders and Service Conductors for ~~Schools~~ Educational Occupancies

Connected Load		Demand Factor (Percent)
First 33 VA/m^2 Plus,	(3 VA/ft^2) at	100
Over 33 through 220 VA/m^2 Plus,	(3 through 20 VA/ft^2) at	75
Remainder over 220 VA/m^2	(20 VA/ft^2) at	25

Statement of Problem and Substantiation for Public Input

The Committee resolved a similar proposal last cycle with the claim that this section permits use of Table 220.86 for schools up to the 12th grade. This proposal is intended to clarify that a section developed for "schools" may not be appropriate for colleges and universities with significantly different use patterns and should be harmonized with the dominant building code in the US.

K-12 schools have a higher occupancy rate (and a higher power density requirement) 9 months of the year than colleges and universities which operate year-round but with a much lower power density across a broad span of occupancy classes. Anecdotal evidence suggests that college and university square footage, on average, is 80 percent unoccupied because much less of the square footage is devoted to instruction.

Admittedly, another section could be written for Group B educational buildings which would involve commercial design practice (and perhaps a campus-style complex of buildings) but for the moment, this title change will improve useability of the 2020 NEC for the education facilities industry..

For the convenience of the committee without easy access to the IBC: All Group E occupancies have three features in common:

- they are limited to the education, supervision or personal care of persons at an educational level no greater than 12th grade
- the occupants are only in the facility for a limited time each day
- there are at least six persons being educated, supervised, or cared for at the same time.

Submitter Information Verification

Submitter Full Name: Michael Anthony

Organization: Standards Michigan

Street Address:

City:

State:

Zip:

Submittal Date: Wed Sep 06 16:30:14 EDT 2017

Public Input No. 3674-NFPA 70-2017 [Section No. 220.86]

220.86 Schools.

The calculation of a feeder or service load for schools shall be permitted in accordance with Table 220.86 in lieu of Part III of this article where equipped with electric space heating, air conditioning, or both. The connected load to which the demand factors of Table 220.86 apply shall include all of the interior and exterior lighting, power, water heating, cooking, other loads, and the larger of the air-conditioning load or space-heating load within the building or structure.

Feeders and service conductors whose calculated load is determined by this optional calculation shall be permitted to have the neutral load determined by 220.61. Where the building or structure load is calculated by this optional method, feeders within the building or structure shall have ampacity as permitted in Part III of this article; however, the ampacity of an individual feeder shall not be required to be larger than the ampacity for the entire building.

This section shall not apply to portable classroom buildings.

Table 220.86 Optional Method — Demand Factors for Feeders and Service Conductors for Schools

	Connected Load	Demand Factor (Percent)
First 33 VA/m^2	(~~3 VA~~ 2 VA /ft^2) at	100
Plus,		
Over 33 through 220 VA/m^2	(~~3 through 20 VA~~ 2 through 15 VA /ft^2) at	75
Plus,		
Remainder over 220 VA/m^2	(~~20 VA~~ 15 VA /ft^2) at	25

Additional Proposed Changes

File Name	Description	Approved
NFPA_FPRF_REPORT-Branch-Circuit-Loading-Phase1-FINAL.pdf	Evaluation of Electrical Feeder and Branch Circuit Loading: Phase I Final Report by Tammy Gammon, Ph,D, P.E.	✓
NFPA_FPRF_REPORT-Branch-Circuit-Loading-Phase1-FINAL.pdf		✓

Statement of Problem and Substantiation for Public Input

The loading data gathered by the original University of Michigan workgroup that informed the exception in Table 220.12 in the 2014 NEC revealed that school power system capacity is being significantly overdesigned at least by 25-33%.   This outcome catalyzed more investigation into the appropriate design guidelines for branch circuits and feeders.

A milestone in that advocacy priority resulted in a Fire Protection Research Foundation project that is linked on this landing page for Standards Michigan advocacy priorities, created to establish platform for more investigation into this concept and others during the 2020 NEC revision cycle:

http://standardsmichigan.com/nfpa-2020-concepts/

We hope that the results of this study -- also attached herewith -- enlightens the discussion of the technical committee. Safety and economic benefits accrue for most occupancy classes governed by the NEC.

Submitter Information Verification

Submitter Full Name: Michael Anthony

Organization: Standards Michigan

Street Address:

City:

State:

Zip:

Submittal Date: Wed Sep 06 16:49:33 EDT 2017

RESEARCH FOUNDATION

RESEARCH FOR THE NFPA MISSION

Evaluation of Electrical Feeder and Branch Circuit Loading: Phase I

FINAL REPORT BY:

Tammy Gammon, Ph.D., P.E.

Georgia USA

January 2017

1 Batterymarch Park, Quincy, MA 02169-7417, USA
Email: foundation@nfpa.org   Web: nfpa.org/foundation

This page intentionally blank

FOREWORD

Interest has been growing in recent years to investigate and clarify the degree to which the feeder and branch circuit load design requirements in NFPA 70, *National Electrical Code®* (NEC®) need to be adjusted based on the increasing pace of technological innovation along the entire span of the electrical power chain.

There are multiple factors driving this issue and supporting the need to address this topic. For example, today's Energy Codes are driving down the electrical load presented by end use equipment and thus load growth assumptions that justify "spare capacity" should be re-examined. In addition, larger than necessary transformers that supply power to feeder and branch circuits expose unnecessary flash hazard to electricians working on live equipment.

This report summarizes a Phase I effort to develop a data collection plan to provide statistically significant load data for a variety of occupancy and loading types to provide a technical basis for considering revisions to the feeder and branch circuit design requirements in the National Electrical Code®. This initial effort has an emphasis on general commercial (office) occupancies, and the deliverables provide a review of the literature, and clarify the key elements of a data collection plan in support of a potential second phase (not included in the scope of this effort).

This page intentionally blank

ACKNOWLEDGEMENTS

The Fire Protection Research Foundation expresses gratitude to the report author Tammy Gammon, Ph.D., P.E. located in Georgia USA.

The Research Foundation appreciates the guidance provided by the Project Technical Panelists, the funding provided by the project sponsors, and all others that contributed to this research effort. Special thanks are expressed to the following Panel members: Robert Arno, Harris Corp. & IEEE Fellow; Mark Earley, NFPA; Mark Hilbert, IAEI & CMP-2 Chair; Brian Liebel, Illuminating Engineering Society of North America; and Mark Lien, Illuminating Engineering Society of N.A. (Alt to B Liebel). Thanks are also extended to the following Sponsors: Michael Berthelsen, University of Minnesota; Brett Garrett, The Ohio State University (alternate for Bob Wajnryb); Lou Galante, University of Iowa; Jeff Gambrall, University of Iowa (Alternate to Lou Galante); Dean Hansen, University of Texas Austin; Kane Howard, Michigan State University; Michael Hughes, Michigan Association of Physical Plant Administrators; Jim Jackson, University of Nebraska (alternate for Brian Meyers); Paul Kempf, University of Notre Dame; Brian Meyers, University of Nebraska; Bob Wajnryb, The Ohio State University; and Bob Yanniello, Eaton Corporation. Gratitude is likewise expressed to three liaisons that supported this effort: Mike Anthony, University of Michigan; Jim Harvey, University of Michigan; and Richard Robben, Ann Arbor, MI.

About the Fire Protection Research Foundation

The Fire Protection Research Foundation plans, manages, and communicates research on a broad range of fire safety issues in collaboration with scientists and laboratories around the world. The Foundation is an affiliate of NFPA.

About the National Fire Protection Association (NFPA)

Founded in 1896, NFPA is a global, nonprofit organization devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards. The association delivers information and knowledge through more than 300 consensus codes and standards, research, training, education, outreach and advocacy; and by partnering with others who share an interest in furthering the NFPA mission.

All NFPA codes and standards can be viewed online for free.

NFPA's membership totals more than 60,000 individuals around the world.

Keywords: electrical feeder, branch circuit, loading, transformer, NEC, National Electrical Code, NFPA 70

Report number: FRPF-2016-32

PROJECT TECHNICAL PANEL

Robert Arno, Harris Corp. & IEEE Fellow (NY)

Mark Earley, NFPA (MA)

Mark Hilbert, IAEI & CMP-2 Chair (NH)

Brian Liebel, Illuminating Engineering Society of North America (NY)

Mark Lien, Illuminating Engineering Society of N.A. (NY) (Alt to B Liebel)

PROJECT SPONSORS

Eaton Corporation, Bob Yanniello

Michigan Association of Physical Plant Administrators, Michael Hughes

Michigan State University, Kane Howard

The Ohio State University, Bob Wajnryb and Brett Garrett (alternate)

University of Iowa, Lou Galante and Jeff Gambrall (alternate)

University of Minnesota, Michael Berthelsen

University of Nebraska, Brian Meyers and Jim Jackson (alternate)

University of Notre Dame, Paul Kempf

University of Texas Austin, Dean Hansen

PROJECT LIAISONS

Mike Anthony, University of Michigan (MI)

Jim Harvey, University of Michigan (MI)

Richard Robben, Ann Arbor, MI

This page intentionally blank

Fire Protection Research Foundation Project

Review of Literature and Data Collection Plan

Evaluation of Electrical Feeder and Branch Circuit Loading: Phase 1

Submitted by

Tammy Gammon, Ph.D., P.E.

January 2017

Project Technical Panel

Mark Hilbert, IAEI and NEC Code-Making Panel 2 Chair
Robert Arno, Harris Corporation
Mark Earley, NFPA
Brian Liebel, IES

Project Sponsors

University of Minnesota
The Ohio State University
University of Iowa
University of Texas – Austin
Michigan State University
Michigan Association of Physical Plant Administrators
University of Nebraska
University of Notre Dame
Eaton Corporation

EXECUTIVE SUMMARY

The purpose of this Phase I project is to conduct a literature review and to develop a data collection plan for an ambitious Phase II study on the evaluation of electrical feeder and branch circuit loading. The intent of this research is to evaluate electrical feeder and branch circuit loading given present National Electrical Code requirements, electrical safety, energy conservation, and reduction of capital investment.

This research project focuses on commercial buildings. Report Sections 1 through 7 cover a review of related work and published data. Specifically, electricity usage and commercial building demographics are reviewed in Sections 1 and 2 to provide insight into the number of feeders and branch circuits installed in the United States and the amount of electricity supplied by them. Furthermore, Section 2 on commercial buildings and Section 3 on end-use loads have been included because the characteristics of the commercial buildings determine the electrical loads and the design of the electrical feeders and branch circuits supplying those loads. Section 4 addresses some of the factors which shape end-use equipment decisions and includes energy consumption projections for commercial buildings to the year 2040.

Commercial building energy conservation codes are covered in Section 5 with a focus on lighting and power requirements in ASHRAE 90.1. In Section 6, the following engineering practices are discussed: one utility, traditional building electrical system design, and design in federal buildings. The NEC's minimum lighting power requirements are also compared with ASRHAE 90.1 and other guidelines in Section 6.

Section 7 addresses transformer efficiency and electrical safety issues as a function of transformer loading. Section 7 contains the author's analysis regarding concern that lightly loaded transformers (supplying lightly loaded feeders) are associated with additional energy losses and increased arc flash hazards.

The data collection plan is presented in Section 8. Although included as the final section of this report, Section 8 has been written to serve as a document which can stand alone, independent of the other report sections.

TABLE OF CONTENTS

1 Electricity Usage in the United States 1

1.1 Electric Utility Customers and Consumption........ 1

1.2 Seasonal Influences and Climate........ 2

2 Commercial Buildings 5

2.1 General Demographics for All Commercial Buildings [5] 5

2.2 Commercial Building Types and Specific Demographics [5]........ 8

2.3 Commercial Building Energy Usage by Geography [5]........11

2.4 Commercial Building Energy Usage by Building Type [5]........15

2.5 Electric Utility Commercial Building Loading 18

3 Building End-Use Loads and Electricity Consumption 19

3.1 End-Use Load Types and CBECS Models [5] 19

3.2 CBECS End-Use Load Consumption [5] 20

3.3 Miscellaneous Electric Loads in CDM and Elsewhere 25

3.4 Receptacle and Plug and Process Load Studies........29

3.4.1 Lawrence Berkeley National Laboratory Office Receptacle Study........29

3.4.2 University of Idaho & California PIER Studies on Receptacle Load Power........31

3.4.3 NREL Study on Plug and Process Load Power Density and Other Work 32

3.4.4 Studies on Device Power Consumption 34

3.4.5 Receptacle Load Power Densities in Real Estate and Building Design 36

4 EIA Model and Predictions for Commercial Buildings........37

4.1 NEMS Commercial Demand Module........37

4.2 EIA 2015-2040 Projections for Commercial Buildings 38

5 Commercial Building Energy Conservation Codes 38

5.1 U.S. Department of Energy (DOE) Commercial Buildings Models........38

5.2 Historical Perspective, Energy Savings, and Coverage 41

5.3 ASHRAE 90.1 – General, Power, and Lighting Requirements 42

5.4 Development of ASHRAE 90.1 Lighting Power Allowances 45

6 Engineering Practices 47

6.1 Electric Utility Demand Load and Transformer Sizing for Commercial Buildings 47

6.2 Traditional Design Practices for Electrical Systems in Buildings 49

6.2.1 Building Demand Load, Panel, and Feeder Sizing 49

6.2.2 Branch Circuit Sizing and Protection 50

6.2.3 In-House Transformers and Connecting Equipment Selection 51

6.3 NEC Lighting Requirements and Other Lighting Guidelines 51

6.3.1 NEC and NEC Comparison with ASHRAE Requirements 51

6.3.2 IEEE, IES, and Federal Lighting Recommendations 53

6.4 Federal Recommendations in Building Electrical System Design 54

6.4.1 GSA's PBS-P100, Facilities Standards for the Public Buildings Service 54

6.4.2 PBS-P100 Advanced Building Metering and Control 55

6.4.3 PBS-P100 Demand Load Calculations 55

6.4.4 PBS-P100 Treatment of Harmonics 56

7 Oversizing and "Rightsizing" Transformers 57

7.1 1999 Cadmus Transformer Loading Study [32] 57

7.2 Transformer Loading and Efficiency 58

7.3 Transformer Sizing and Arc Flash Hazards in Building Systems 64

8 Data Collection and Analysis Plan for Evaluation of Electrical Feeder and Branch Circuit Loading Project Phase II 68

8.1 Motivation for Project 68

8.2 Relevance of Project Focus 71

8.3 Selection of Study Type and Participating Study Buildings 72

8.3.1 Objective 72

8.3.2 Types of Commercial Buildings 73

8.3.3 Geographic Distribution of Study Buildings 74

8.3.4 Criteria for Building Selection 76

8.3.5 Required Building Documents and Information 80

8.4 Site Monitoring 82

8.4.1 System Monitoring Options 82

8.4.2 Monitoring Equipment 84

8.4.3 Method of Data Collection on Site and to Project Personnel 86

8.5 Data Analysis 86

8.5.1 Evaluation of Lighting Load 86

8.5.2 Evaluation of Receptacle Load 87

8.5.3 Evaluation of Other Loads 87

8.5.4 Evaluation of In-House Feeder Sizing and Transformer Loading 87

8.5.5 Evaluation of Main Feeder Size and Service Transformer Loading 88

8.5.6 General Evaluation of Power Quality 88

8.6 Deliverables 88

8.7 Budget 88

9 References 89

10 Appendices 91

Appendix A. U.S. Census Bureau Population Density Map 91

Appendix B. Manufacturer Monitoring Equipment Information 93

Appendix B.1 GE EPM 4600 Multi-feed Power and Energy Metering System 94

Appendix B.2 Honeywell E-Mon Class 3400 Smart Meter 107

Appendix B.3 Onset Data Loggers for Real Power or Phase RMS Currents 110

Appendix B.4 GE ASPMETER Metering Panelboard 128

LIST OF FIGURES

Figure 1. Numbers of U.S. Electric Utility Customers in June 2016 2

Figure 2. Annual Retail U.S. Electricity Sales from 2001 to 2015 2

Figure 3. Monthly Electricity Sales in U.S. from 2001 to 2015 4

Figure 4. IECC Climate Regions in the U.S. 4

Figure 5. Commercial Buildings – Numbers and Total Floorspace Categorized by Size............ 6

Figure 6. Commercial Buildings – Numbers and Mean Square Feet Categorized by Year 7

Figure 7. Commercial Buildings – Numbers and Mean Square Feet Categorized by Region 7

Figure 8. Commercial Building Types – Numbers, Floorspace, & Electricity Consumption 10

Figure 9. Commercial Building Types – Mean Size and Operating Hours 10

Figure 10. Percentage Employees by Commercial Building Type 11

Figure 11. Electricity Consumption in Commercial Buildings Categorized by Climate 12

Figure 12. Number of Commercial Buildings (Percentage) Categorized by Climate 12

Figure 13. Mean Annual Electric Energy and Power Intensities Categorized by Climate...........14

Figure 14. Percentage Energy Source Consumption Categorized by Geographic Region 14

Figure 15. Mean Annual Electric Energy and Power Intensities Categorized by Region............15

Figure 16. Percentage of Energy Source Consumption Categorized by Building Type.............16

Figure 17. Electric Energy Intensity Categorized by Commercial Building Type 16

Figure 18. Electric Power Intensity Categorized by Commercial Building Type 17

Figure 19. Austin Energy - Commercial Building Average Electric Power Intensity 18

Figure 20. Percentage End-Use Electricity Consumption for All Commercial Buildings 21

Figure 21. AC and Ventilation and Refrigeration Electricity Consumption by Building Type 22

Figure 22. Office Equipment/Computing, Lighting, and Cooking Consumption by Type 22

Figure 23. Refrigeration, AC and Ventilation Electric Energy Intensity by Building Type 23

Figure 24. Lighting and Office Equipment/Computing Electric Energy Intensity by Type 23

Figure 25. Refrigeration, AC and Ventilation Electric Power Intensity by Type 25
Figure 26. Plug Load Office Building Study at Lawrence Berkeley National Laboratories..........30
Figure 27. Energy & Power Intensities for DOE Reference Office Buildings in Miami................41
Figure 28. Austin Energy – VA and Power Demand Load in Commercial Buildings 48
Figure 29. Efficiency Curves for Three Eaton 45 kVA, 480Δ-208Y-V Transformers 60
Figure 30. Power Losses as Percentage of Power Supplied for Three Eaton Transformers......60
Figure 31. Power Losses: 7.5 to 45 kVA Loads Supplied by 30 to 75 kVA Transformers 61
Figure 32. Power Losses: 75 to 225 kVA Loads Supplied by 75 to 300 kVA Transformers 61
Figure 33. Efficiency as Function of Rise for 45 kVA, 480Δ-208YV, EL-4 Core Transformer.....62
Figure 34. Efficiency as Function of Rise for 45 kVA, 480Δ-208YV, EL-5 Core Transformer.....62
Figure 35. Efficiency as Function of Rise for 45 kVA, 480Δ-208YV, EL-6 Amorphous Core......62
Figure 36. Available Short-Circuit Current at Transformer Secondary in Typical Systems.........66
Figure 37. 1584-2002 Arc Current at Transformer Secondary in Typical Systems 66
Figure 38. 1584-2002 Incident Energy after 100 ms at Secondary in Typical Systems.............67
Figure 39. IECC Climate Regions in the U.S. 75
Figure 40. Monitoring Optimal Site with Load Separation 77
Figure 41. Monitoring "Good" or "Optimal" Site 78
Figure 42. Monitoring Acceptable Site..79
Figure 43. Monitoring a Site Not Meeting "Optimal," "Good," or "Acceptable" Ranking 80

LIST OF TABLES

Table 1. IECC Climate Zones [2],[3],[4] 5

Table 2. IECC Climate, Precipitation, and Temperature Descriptions [3] 5

Table 3. Estimated Mean Power Intensities (W/ft^2) for Commercial Office Buildings* 25

Table 4. Navigant MELs - Total & Unit 2011 Energy Consumption and Active Power Draw 27

Table 5. 2011 MEL Percentage Energy Consumption by Predominant Building Category 28

Table 6. Subcategory MEL Equipment used in Composite Profile (Annual Basis for 2011) 29

Table 7. Summary of Results in University of Idaho's Receptacle Load Study* 31

Table 8. New Buildings Institute Receptacle and Lighting Load Office Study [11] 32

Table 9. Plug and Process Load Power Densities of Four Government Offices 33

Table 10. Plug and Process Load Power Densities of Seven Stanford University Buildings 33

Table 11. Plug and Process Load Power Densities of Ten Office Buildings 33

Table 12. Baumann Study: Plug Load Power Densities in Different Office Space Types* 34

Table 13. Measured Power Consumption of Common Office Devices in Various States* 35

Table 14. Baumann Study - Device Nameplate and Idle and In-use Power Consumption* 36

Table 15. Commercial Demand Module Building Categories, Floorspace, and Occupancy* 38

Table 16. DOE Reference Building Models and Equivalent CBECS Building Type 39

Table 17. ASHRAE 90.1 & IECC Building Area Method Lighting Power Density Allowances 44

Table 18. ASHRAE 90.1 & IECC Lighting Power Allowances for Selected Space Types 45

Table 19. Austin Energy Demand Factors for Connected Commercial Loads 48

Table 20. Austin Energy Three-Phase Pad-mount Transformer Loading Guidelines[a,b,c] 49

Table 21. Traditional Engineering Demand Factors for Building Loads* 50

Table 22. NEC (VA/ft^2) and ASHRAE 90.1 (W/ft^2) Lighting Power Density by Occupancy 53

Table 23. Recommended Illumination Levels and Lighting Densities in PBS-P100 54

Table 24. 2014 PBS-P100 Minimum Receptacle Load Power Density 56

Table 25. 2014 PBS-P100 Additional Spare Capacity 56

Table 26. Measured Transformer Load Factor in 1999 Cadmus Study 57

Table 27. 1999 Cadmus Study – Power Factor, Total Harmonic Distortion, and K-Factor.........58

Table 28. Eaton Percentage of Transformers Manufactured in 2016 by Rise Type 63

Table 29. Eaton Percentage of Transformers Manufactured in 2016 by K-Factor Rating 64

Table 30. Three Typical 480-V Building Systems 65

Table 31. Impedance for 480Δ-208Y/120 V, 150°C Rise, 15 – 300 kVA Transformers.............66

Table 32. NEC (VA/ft^2) and ASHRAE 90.1 (W/ft^2) Lighting Power Density by Occupancy.........69

Table 33. Geographic Selection and Number of Monitoring Sites 75

Table 34. System Monitoring Options for Study Buildings 82

1 ELECTRICITY USAGE IN THE UNITED STATES

1.1 Electric Utility Customers and Consumption

This project addresses National Electrical Code Articles 210 – 230, specifically Article 220, which provides the requirements for branch-circuit, feeder, and service load calculations. The NEC has been adopted in 47 states[1] and applies to the vast majority of building electrical systems in this country. Although some entities generate part of or all their electric power on site, most electric power users in this country are customers of an electric power utility. Figure 1 reveals that electric utilities had close to 150 million customer accounts in June 2016. Over 131 million residential accounts provide power to the U.S. population, estimated at over 322 million. Electric utilities also had 18.3 million commercial and 827,000 industrial accounts in June 2016. Even though the number of commercial customers equals less than 14% of the number of residential customers, Figure 2 shows that the two sectors have purchased roughly the same amount of electricity over the past fifteen years. In 2015, the residential, commercial, and industrial sectors purchased 1.40, 1.36, and 0.96 trillion kW-hours, respectively.

The sheer number of electric utility customers and the amount of electricity sold in the United States attest to the importance of the National Electric Code (first printed in 1897) which applies to all new electrical installations where it is adopted and enforced. Since each electric utility customer must have at least one electrical service feeder, the number of service feeders must approach 150 million and the numbers of distribution feeders and branch circuits must exceed a billion.

[1]As of September 1, 2016, the NEC (2008, 2011, or 2014 edition) had been adopted in all states except Arizona, Missouri, and Mississippi. Source: http://www.electricalcodecoalition.org/state-adoptions.aspx, accessed September 9, 2016. The 2017 edition of NFPA 70, *The National Electrical Code* or *NEC*, was issued by the National Fire Protection Association (NFPA) in August 2016.

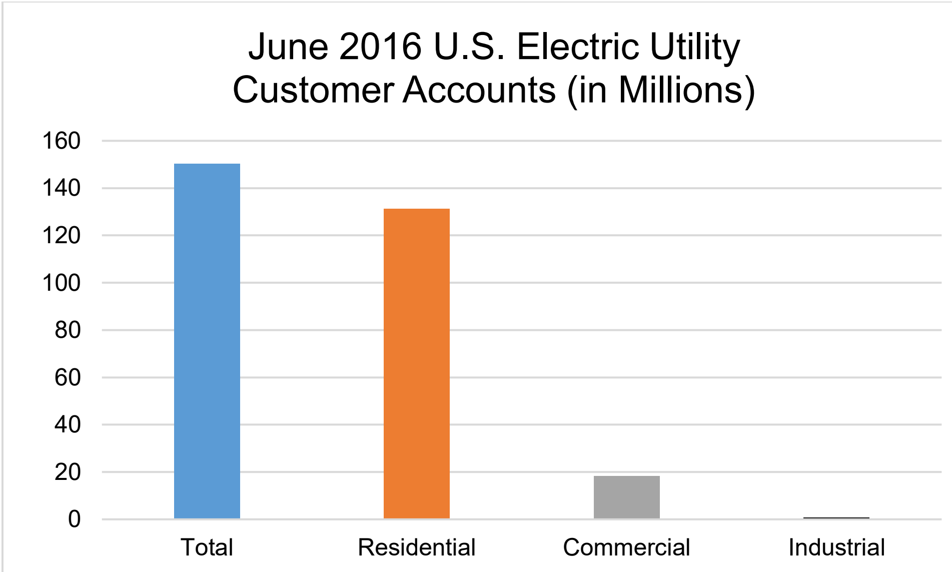


Figure 1. Numbers of U.S. Electric Utility Customers in June 2016
(Data Source: [1])

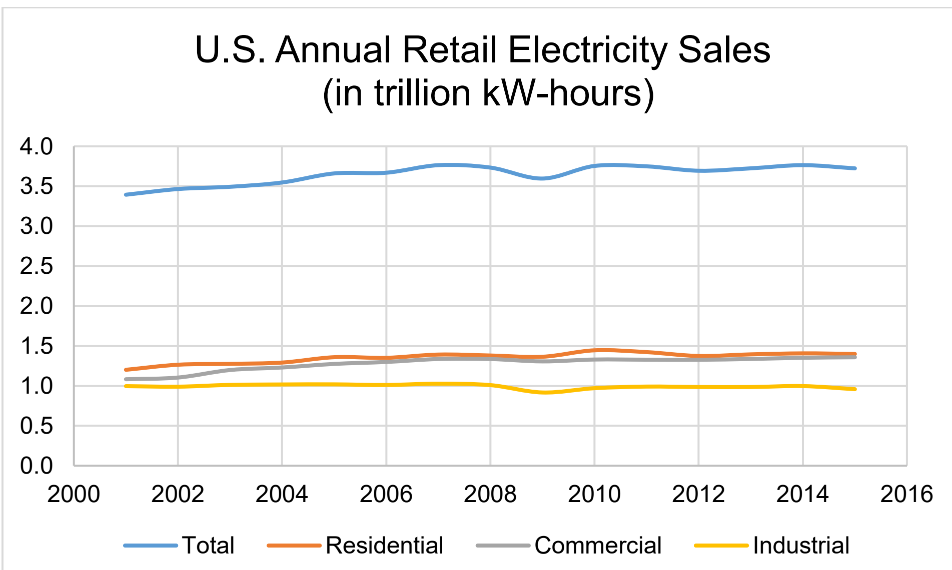


Figure 2. Annual Retail U.S. Electricity Sales from 2001 to 2015
(Data Source: [1])

1.2 Seasonal Influences and Climate

Figure 3 shows the seasonal influences of electricity purchases on commercial and residential customers. Both sectors have greater electricity demands during the summer and winter seasons. Residential customers have sharp peaks in consumption during both summer and winter months. As an aggregate group, commercial customers have a large summer peak, but the winter peak is much smaller in comparison. Individual customers that do not use electricity as the primary energy source for heating may not experience a sharp peak in electricity consumption; however, electric loads, such as lighting and receptacle (portable electric heaters if the building is not kept warm enough) may increase during winter months. In the summer, refrigeration costs may rise for cold storage warehouses and food service (grocery stores) buildings. The heat dissipated by lighting, other electrical loads, and electrical equipment may also increase the demand for air conditioning load in the summer, especially for older installations where older electrical loads and electrical equipment tend to have greater heat losses and manufactured with lower energy efficiency ratings.

Some industrial processes are greatly affected by ambient temperature and humidity; therefore, the electrical energy demanded by those processes is also dependent on the seasons.

The type of heat and the geographic location of the facility determines summer and winter electricity demand for the building. The IECC climate region map [2], developed for the U.S. Department of Energy, is included as Figure 4 and first appeared in the 2004 edition of ASHRAE 90.1. It features eight main climate zones based on temperature; the zones tend to run in east-west bands subdivided by moisture condition. [3]

Thirteen IECC climate zones are defined in Table 1. The thermal criteria for the zones are based on the number of cooling degree days over 50°F (CDD50°F) and the number of heating degree days lower than 65°F (HDD65°F). As an example, ten heating degree days is equivalent to the average outdoor temperature of 55°F for a 24-hour period[2].

In its work developing representative commercial building models for energy consumption, the Department of Energy identified three additional climate zones. The most populated city in each of these sixteen (total) zones is listed in Table 1. In the DOE modeling and simulation work, two climate regions were found for climate zone 3B and were subdivided as 3B-California coast and 3B-other for the remaining areas of the climate zone [2]. The temperature and rainfall conditions which further subdivide the climate zones are described in Table 2.

---

[2] Mathematically, (65°F - 55°F) x one 24-hour period = 10 heating degree days. Another example: The average temperature is 70°F for twelve hours equates to (70°F - 50°F) x ½ of a 24-hour period = 10 cooling degree days.

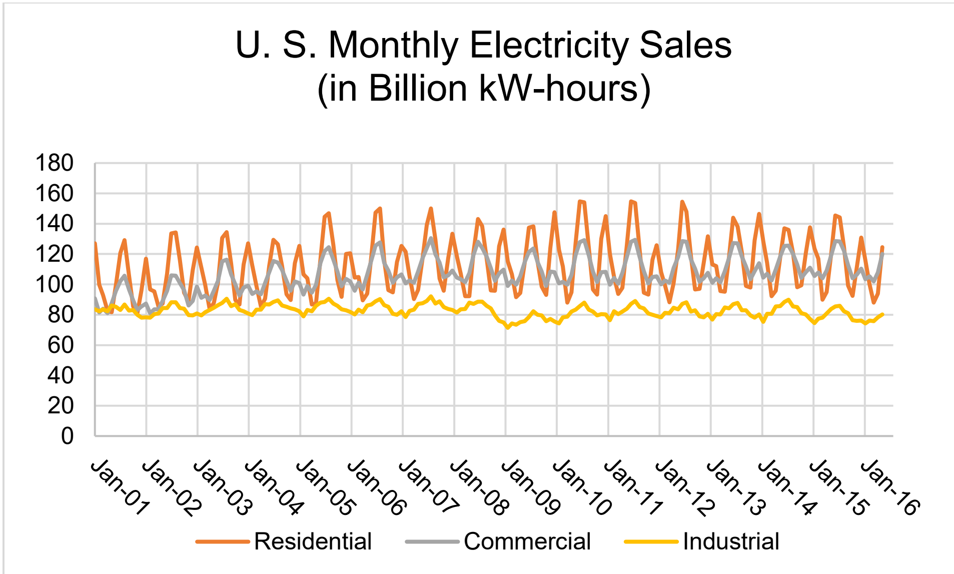


Figure 3. Monthly Electricity Sales in U.S. from 2001 to 2015
(Data Source: [1])

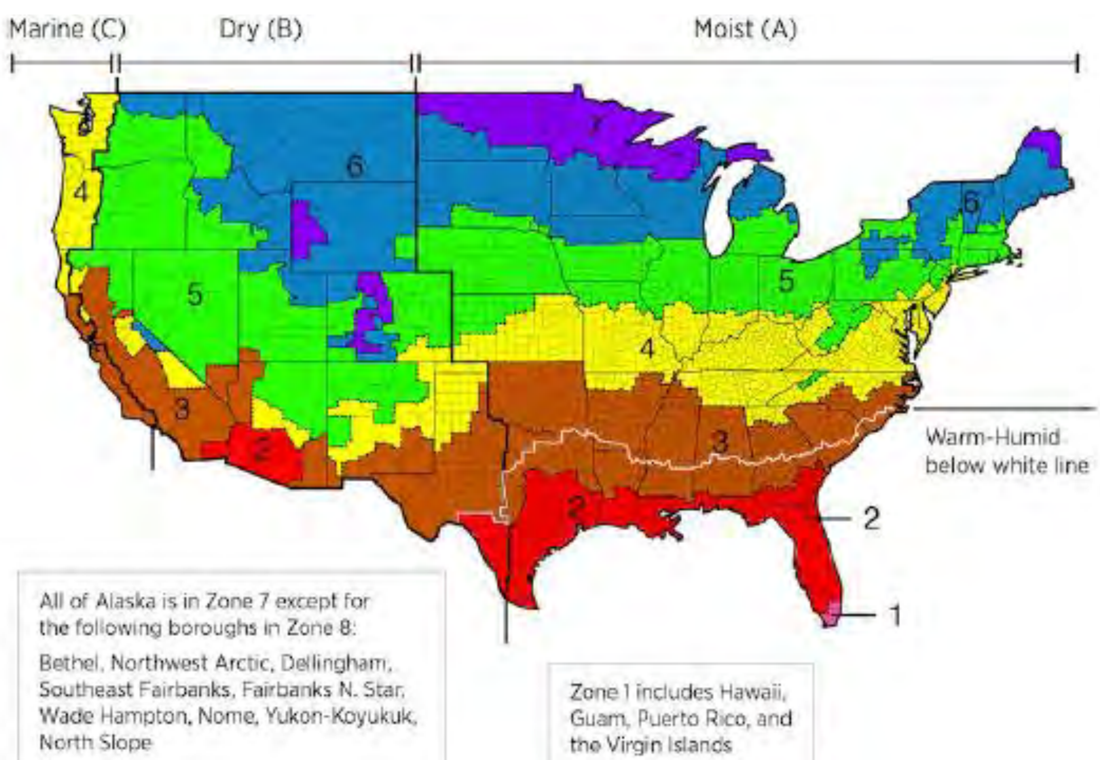


Figure 4. IECC Climate Regions in the U.S.
(Source: U.S. Department of Energy, and reference [4])

Table 1. IECC Climate Zones [2],[3],[4]

IECC	CDD50°F	HDD65°F	Temperature	Moisture	Most Populated City
1	> 9000		Hot	Humid	Miami
2A	> 6300		Hot	Humid	Houston
2B	> 6300		Hot	Dry	Phoenix
3A	> 4500	≤ 5400	Hot, Mixed	Humid	Atlanta
3B	> 4500	≤ 5400	Hot	Dry	Las Vegas (other) Los Angeles (CA coast)
3C		≤ 3600	Marine	Marine	San Francisco
4A	≤ 4500	≤ 5400	Mixed	Humid	Baltimore
4B	≤ 4500	≤ 5400	Mixed	Dry	Albuquerque
4C		> 3600, ≤ 5400	Marine	Marine	Seattle
5		> 5400	Cold		Chicago (**5A**) Denver (**5B**)
6		> 7200	Cold		Minneapolis (**6A**) Helena, MT (**6B**)
7		> 9000	Very Cold		Duluth, MN
8		> 12600	Subarctic		Fairbanks, AK

Table 2. IECC Climate, Precipitation, and Temperature Descriptions [3]

Climate Description	Precipitation, Annual (inches)	Temperature Description
Hot-Humid	> 20	During warmest six consecutive months, 67°F+ for 3000+ hours and/or 73°F+ for 1500+ hours
Hot-Dry	< 20	Monthly average > 45°F throughout year
Mixed-Humid	> 20	Monthly average < 45°F during winter months
Mixed-Dry	< 20	Monthly average < 45°F during winter months
Marine	Dry summer season Heaviest month 3+ times that of lowest	Warmest monthly mean < 72°F 27°F < Coldest monthly mean < 72°F Monthly average > 50°F at least four months

2 COMMERCIAL BUILDINGS

2.1 General Demographics for All Commercial Buildings [5]

Data collected from the Commercial Buildings Energy Consumption Survey (CBECS) provide much insight into the characteristics and energy usage of commercial buildings in the United States. A team of approximately six U.S. Energy Information Administration (EIA) employees supervises the CBECS study, which has recently been contracted out in the "tens of millions of dollars."[3] The most recent CBECS was conducted in 2013 to collect data for existing buildings and energy usage in 2012. The initial sample involved over 12,000 buildings, which was reduced to a final sample of 6,720 buildings. The final sample set was weighted to represent the total number of commercial buildings in the U.S., which the EIA estimates as approximately 5,557,000. The 2012 CBECS was based on climate zones as identified in Figure 4.

The total numbers and floor space of U.S. commercial buildings are displayed in Figure 5 based on general building size. Smaller commercial buildings (1,001 to 10,000 square feet) account for 72% of all commercial buildings, but only 19% of the total floor space. Larger commercial buildings (50,000 or more square feet) account for only 6% of all commercial office buildings, but 51% of the floor space. Figures 6 and 7 show the number of buildings and size (in mean square feet) by year of construction and region of the country. The median age of a building is 32 years ([5], Table B2). Historically speaking, it appears that as the U.S. population increases, more buildings are constructed and are larger in size. In Figure 7, the four census regions are represented by green columns and the regional subdivisions are represented by blue columns. For example, the South, which has the largest number of buildings, is subdivided into three areas: South Atlantic, East South Central, and West South Central. However, the largest commercial buildings (statistical average of floor space) are located in the Middle Atlantic area, part of the Northeast region.

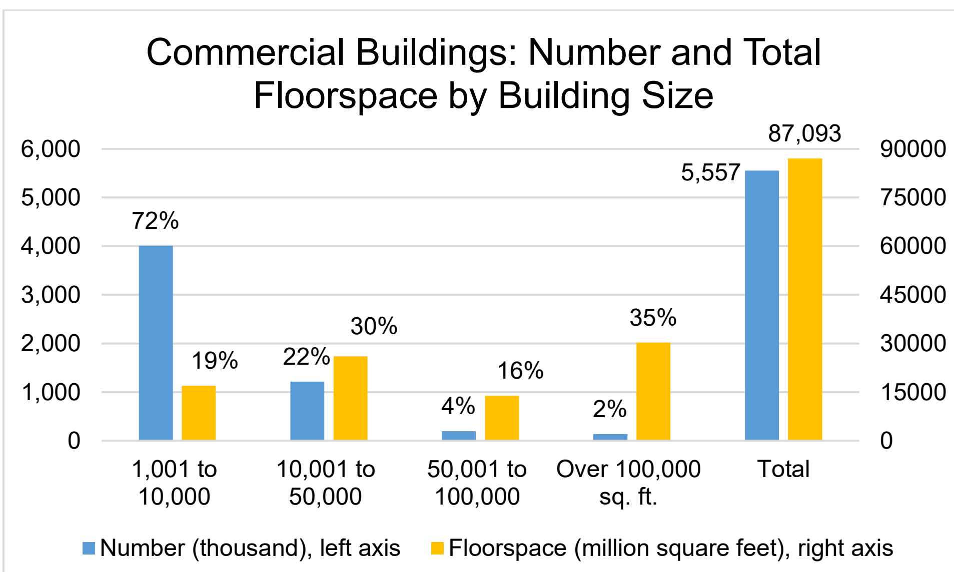


Figure 5. Commercial Buildings – Numbers and Total Floorspace Categorized by Size
(Data Source: Table B1 from [5])

---

[3] September 14, 2016 email from Joelle Michaels, EIA's CBECS Survey Manager.

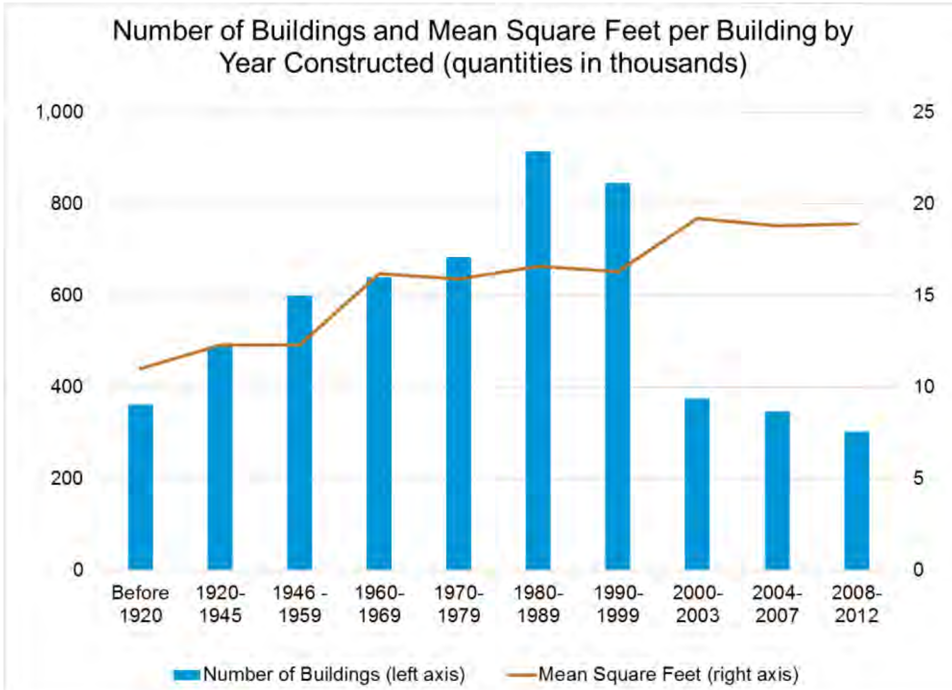


Figure 6. Commercial Buildings – Numbers and Mean Square Feet Categorized by Year
(Data Source: Table B1 from [5])

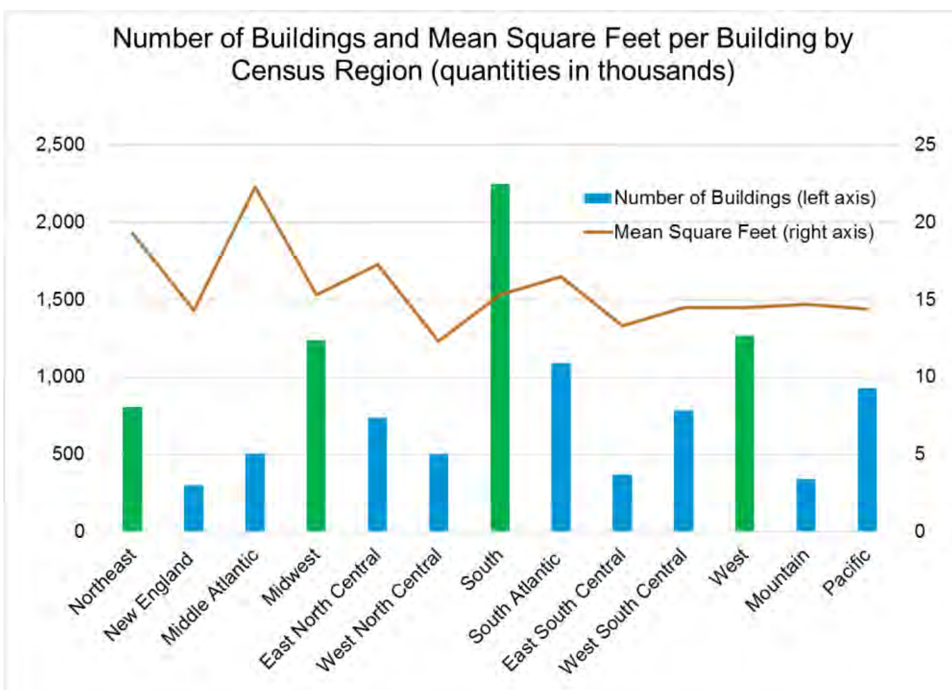


Figure 7. Commercial Buildings – Numbers and Mean Square Feet Categorized by Region
(Data Source: Table B1 in [5])

2.2 Commercial Building Types and Specific Demographics [5]

Sixteen building types have been identified by primary activity. This work will focus on five commercial building types:

- Education (e.g., K-12 schools, universities, day care, vocational training)[4]
- Healthcare, Inpatient (e.g., hospital, inpatient rehabilitation)
- Healthcare, Outpatient (e.g., medical office, outpatient rehabilitation, veterinarian)
- Lodging (e.g., hotel, dormitory, fraternity, nursing home, assisted living, shelter)
- Office (e.g., administrative, professional or government office; bank; city hall; call center)

Education buildings are used for academic or technical classroom instruction. Buildings on education campuses which are not primarily used for instruction are categorized by their primary functions; administration offices, libraries, student centers and dormitories are not identified as education buildings.

Healthcare buildings are used for patient diagnosis and treatment. If medical offices use diagnostic equipment, they are categorized as outpatient healthcare buildings; otherwise, they are categorized as office buildings.

Lodging buildings provide accommodations for short-term or long-term residents. Lodging may include simple amenities at motels or skilled nursing in nursing homes. Minimal supervision may be provided at dormitories and fraternities, while more extension supervision would be required at children's homes.

Office buildings cover a wide range of administrative, government, financial, and professional offices. They include general sales, non-profit, social service, and religious offices, as well as construction, plumbing, HVAC and other contractor offices.

Classrooms, student residence halls, offices, and even hospitals are often part of large university complexes. In fact, university complexes are communities with most, if not all, building types represented.

---

[4] In comments dated December 21, 2016, Mike Anthony stated, "Education facilities up to K-12 are governed by safety codes that recognize the behavioral characteristics of the occupants. Higher education facilities are governed by commercial codes. It may come as a surprise that classrooms in higher education have a 20 percent occupancy rate; and that most of the square footage in higher education is devoted to administrative activity."

The other eleven commercial building types are:

- Food Sales (e.g., grocery)
- Food Service (e.g., restaurant)
- Mercantile, Retail other than mall (e.g., liquor stores, automobile dealerships, art gallery)
- Mercantile, Enclosed and strip malls
- Public Assembly (e.g., cinema, museum, sports arena, funeral home, library, health club)
- Public Order and Safety (e.g., police station, fire station, courthouse, penitentiary)
- Religious Worship
- Service (e.g., post office, gas station, dry cleaner, repair shop, hair salon, copy/print shop)
- Warehouse and Storage
- Other (e.g., crematorium, laboratory, data center, airplane hangar)
- Vacant

As shown in Figure 8, office buildings comprise the highest percentage (19%) of the number of commercial buildings by type. Figure 8 also illustrates that the total floor space (19%) and electricity consumption (20%) of office buildings account for similarly high percentages. The building type, *Warehouse and Storage*, accounts for the second highest number of commercial buildings (13%) and total floor space (15%); however, by proportion, this building type consumes much less electricity (7%). Education buildings represent the third highest percentage of total square feet (14%) and the second highest percentage of electricity consumption (11%).

Figure 9 displays the mean size and mean operating hours per week of commercial buildings. Although inpatient healthcare occupies a small percentage of the total floor space for commercial buildings, the mean size of inpatient healthcare buildings, at 247,800 square feet, dwarfs all other building types. The second largest building type is lodging at 36,900 square feet. Inpatient healthcare (168 hours) and lodging (165 hours) typically around-the-clock (i.e., 24/7 operation). Food sales (121 hours) and public order and safety (113 hours) also have a high number of operating hours.

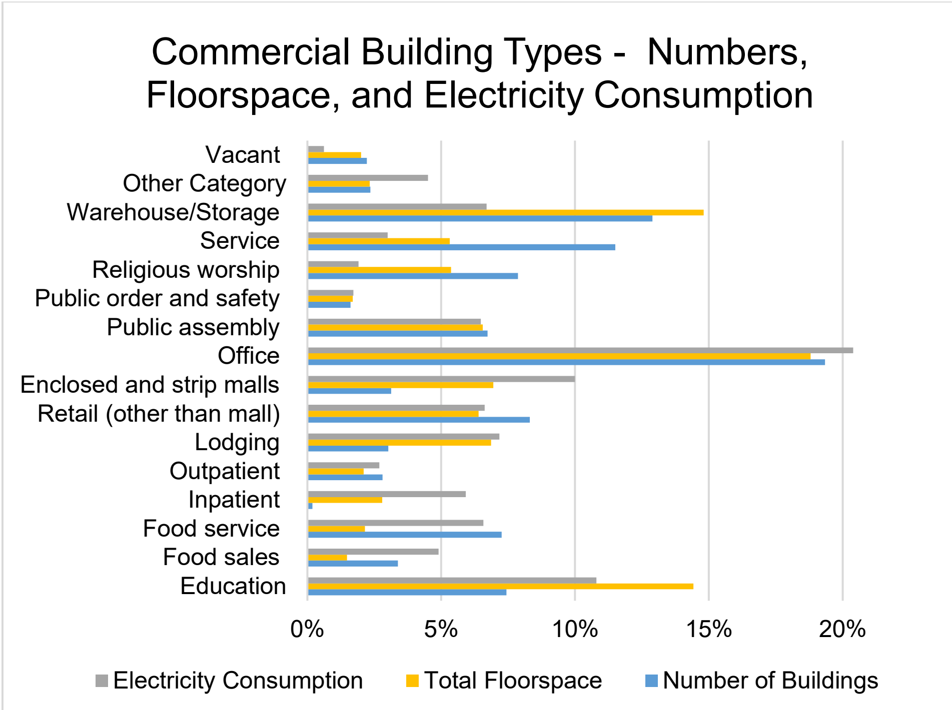


Figure 8. Commercial Building Types – Numbers, Floorspace, & Electricity Consumption
(Data Source: Table C13 in [5])

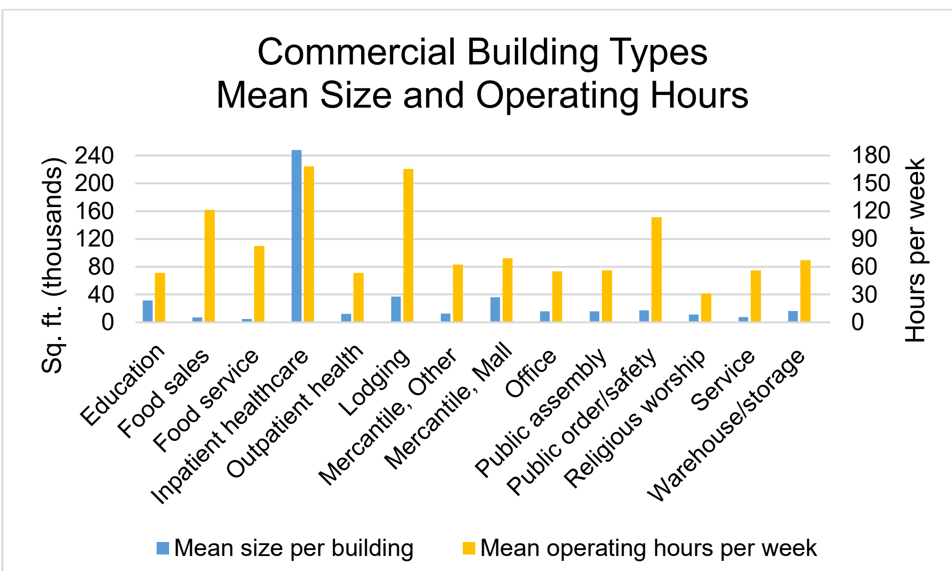


Figure 9. Commercial Building Types – Mean Size and Operating Hours
(Data Source: Table B1 in [5])

In the process of working, employees utilize electrical equipment, even if only as task lighting. Basic electrical safety in the workplace applies to all employees, not just electrical workers. Statistically speaking, as this numbers of employees increase, concern and attention to electrical safety should also increase. Therefore, a carefully designed and properly installed electrical installation is even more important when larger numbers of employees are involved. Figure 10 illustrates that education, healthcare (inpatient and outpatient), and office buildings account for 50% of the 104.9 million people working in commercial buildings. Electrical safety concerns also especially apply to lodging which provides housing for short- and long-term residents. In this research project, the commercial building category of lodging has been added to cover dormitories on university campuses, but it also addresses long-term healthcare needs provided by assisted living centers and nursing homes. Electrical safety, in the context of employee and resident safety, also covers proper operation, care, and maintenance of electrical systems and equipment. Improperly installed, operated, and maintained electrical systems and equipment could result in harmful and deadly fires.

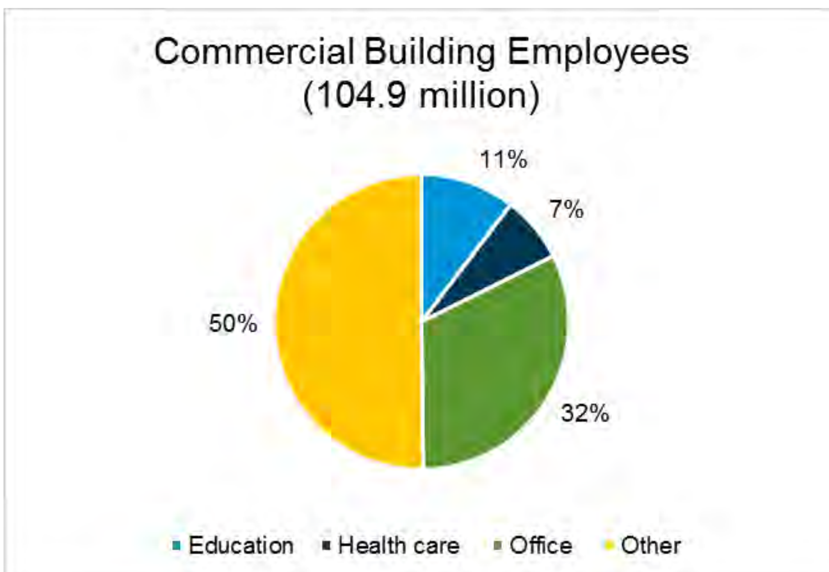


Figure 10. Percentage Employees by Commercial Building Type
(Data Source: Table B1 in [5])

2.3 Commercial Building Energy Usage by Geography [5]

As previously seen in Figure 8, the amount of electricity consumption depends on commercial building type. Figure 11 shows it also depends on climate. In hot, humid climates, the percentage of electricity consumption (18%) is notably higher than the percentage of total floor

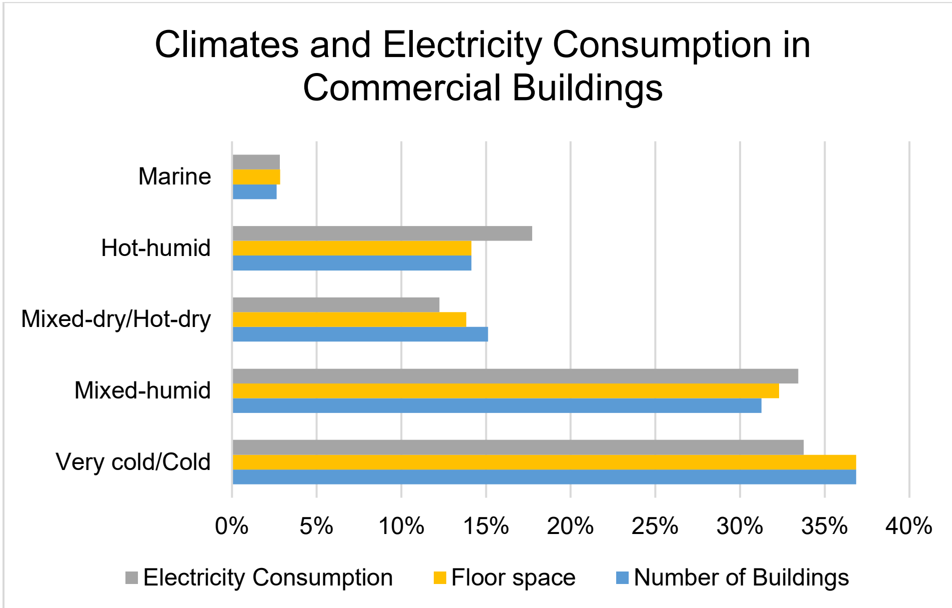


Figure 11. Electricity Consumption in Commercial Buildings Categorized by Climate
(Data Source: Table C13 in [5])

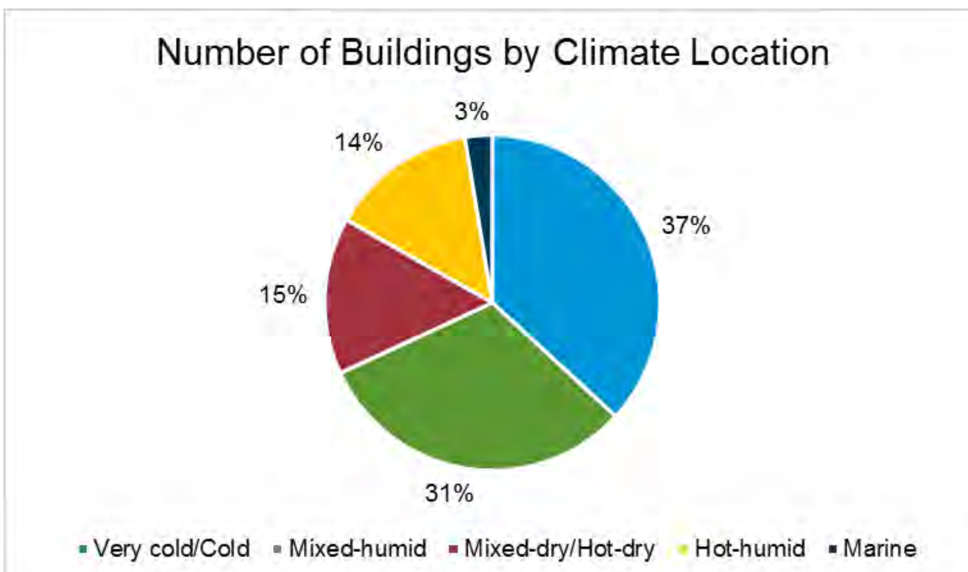


Figure 12. Number of Commercial Buildings (Percentage) Categorized by Climate
(Data Source: Table C13 in [5])

space (14%). Conversely, in cold and very cold climates, the percentage of electricity consumption (34%) is lower than the total floor space (37%). As seen in Table 1, colder climates have lower energy demands for air conditioning and have higher energy demands for heating.

The higher electricity consumption in hot, humid climates (per total floor space) in Figure 11 is likely due to the greater cooling needs in hot, humid climates; the lower electricity consumption in cold and very cold climates suggests that other energy sources, not electricity, are meeting the greater heating needs. The percentages of the total number of commercial buildings located in each climate are displayed in Figure 12. Over two-thirds of the buildings are located in mixed humid (zones 4A and part of 3A) and cold or very cold climate (zones 5, 6, and 7) zones [3].

Figure 13 shows the annual mean electric energy and power intensities for commercial buildings located in each climate. In 2012, the mean electric energy and power intensities were 14.6 kW-hour and 1.7 W per square foot for all climates represented in the study. The highest intensities were found in hot-humid climates at 18.4 kW-hours and 2.1 W per square foot. The mixed-dry and hot-dry climate region had the lowest intensities of 13.0 kW-hours and 1.5 W per square foot. The cold and very cold climate region may have been higher due to a higher electric heat load.

It must be remembered that mean power intensity differs greatly from the power intensity during peak consumption. For example, the power demand for air conditioning load is high during summer months and will peak in the afternoons especially on hot days. In climate zones with higher numbers of degree cooling days, air conditioning loads tend to have a higher power density demand. A building located in a hot climate has relatively few heating degree days; furthermore, energy for heating in any climate may be provided by another energy source, such as natural gas. A building might be designed with a high demand power density for air conditioning load with no or low electric power requirements for heating. A building in a cold climate might be designed for a low air conditioning power density but is might have no, low or high electric power requirements for heating, depending on the energy source(s) for heat.

Figure 14 shows the percentages of energy sources meeting the energy needs of commercial buildings by different census regions of the country. The South has the highest percentage of energy supplied by electricity (70%) and the lowest percentage of energy supplied by natural gas (24%). In the West, 60% of the energy is supplied by electricity, followed by 54% and 52% in the Midwest and Northeast, respectively. In contrast, the Midwest has the highest percentage of natural gas (41%), and the Northeast has the highest percentages of fuel oil (6%) and district heat (8%). In the 2012 CBECS, fuel oil is specified as distillate fuel oil, diesel, and kerosene; district heat is specified as steam or hot water from a utility or a campus central plant.

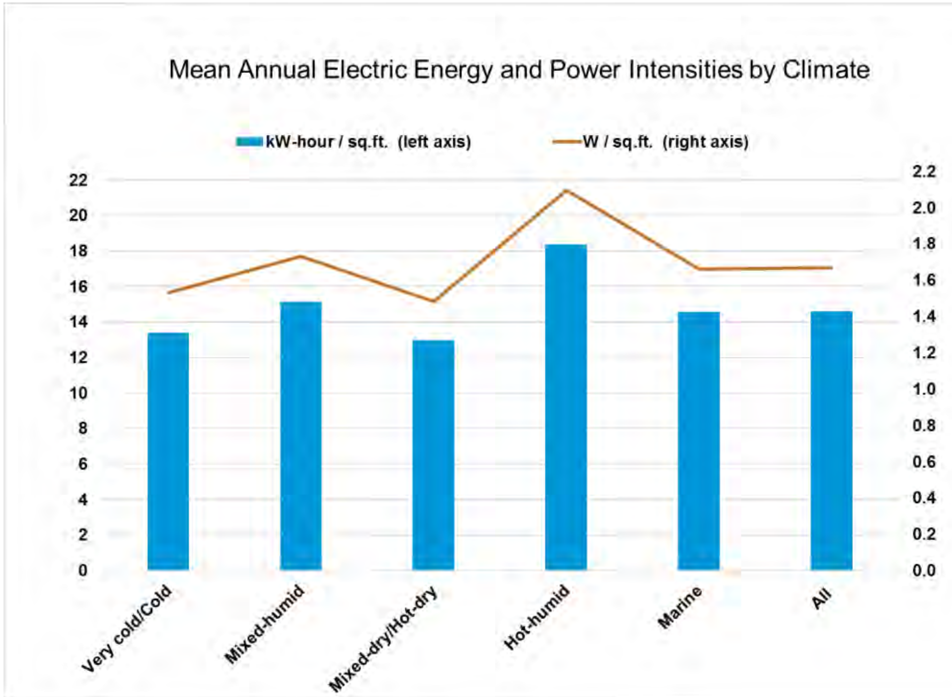


Figure 13. Mean Annual Electric Energy and Power Intensities Categorized by Climate
(Data Source: Table C13 in [5])

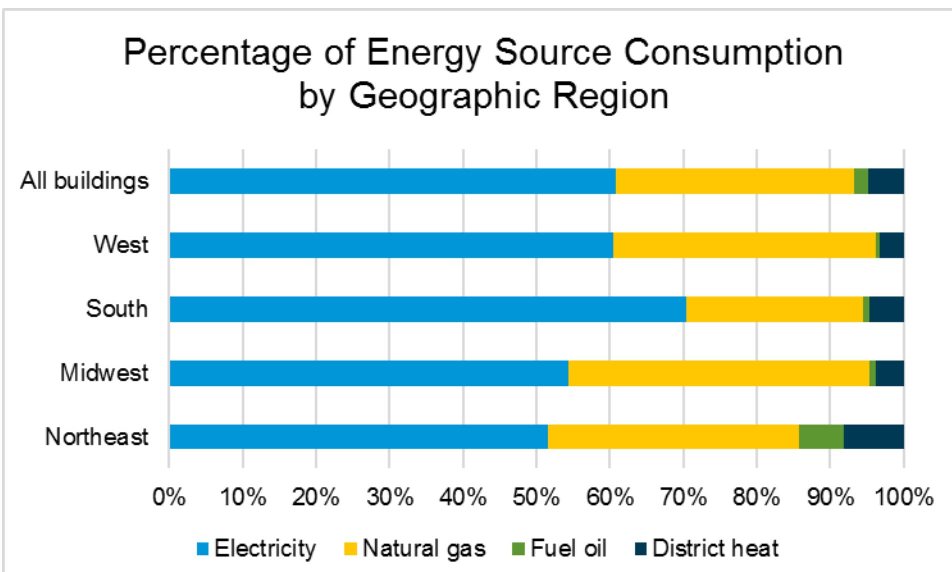


Figure 14. Percentage Energy Source Consumption Categorized by Geographic Region
(Data Source: Table C1 in [5])

Figure 15 shows that commercial buildings in the South also had the highest energy and power intensities at 16.1 kW-hours and 1.8 W per square foot in 2012. However, higher energy and power intensities do not necessarily imply that a higher percentage of the energy supplied

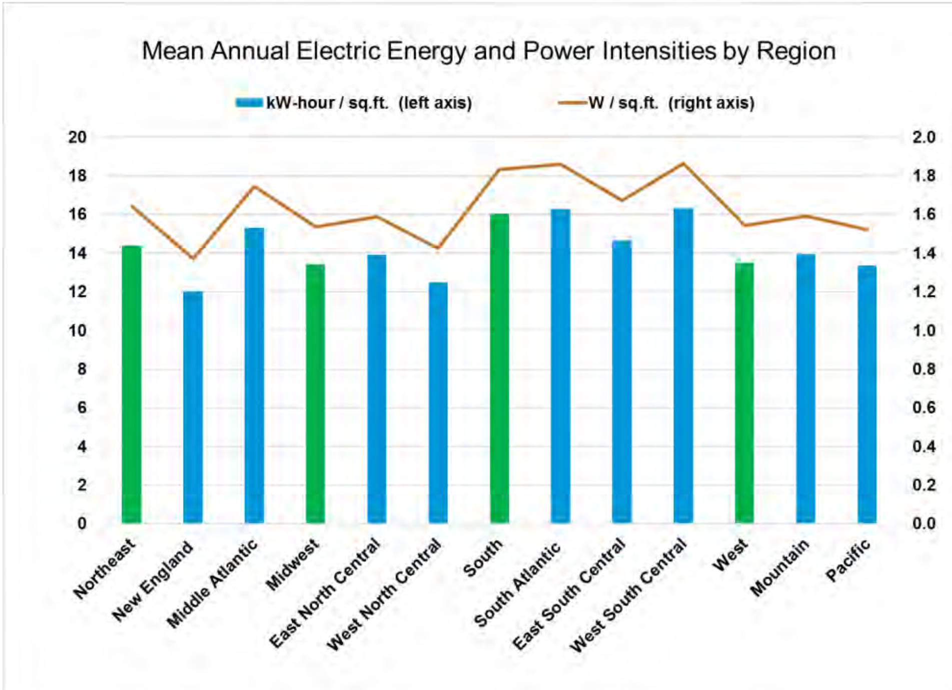


Figure 15. Mean Annual Electric Energy and Power Intensities Categorized by Region
(Data Source: Table C13 in [5])

to a building is in the form of electricity. Commercial buildings in the Northeast had the second highest electric energy and power intensities of 14.4 kW-hours and 1.6 W per square foot; in the Northeast, electricity also accounted for the lowest percentage of energy consumption by source. In Figure 15, the green columns represent the census regions and the blue columns to the right represent the subdivisions of the region.

2.4 Commercial Building Energy Usage by Building Type [5]

Figure 16 shows percentages of energy sources meeting the energy needs of commercial buildings by building type. Food sales, non-mall retail, and offices led in the highest percentage of energy needs met by electricity (79%, 77%, and 70%, respectively); not surprisingly, food sales, non-mall retail, and offices also had the lowest percentage of energy needs met by natural gas (20%, 20%, and 23%, respectively). Food sales buildings have a large refrigeration load. The highest consumers of district heat as a percentage of total energy are public assembly (13%), inpatient healthcare (11%), education (8%), office (6%), and lodging (5%).

By commercial building type, Figure 17 shows that food sales, food service, and inpatient healthcare require the most electricity per square foot of floor space. In 2012, their electric energy consumption was 48.7, 45.0, and 31.0 kW-hours per square foot, respectively. In comparison, offices consumed 15.9 kW-hours per square foot, and the electric energy intensity of all commercial building types was 18.4 kW-hours per square foot.

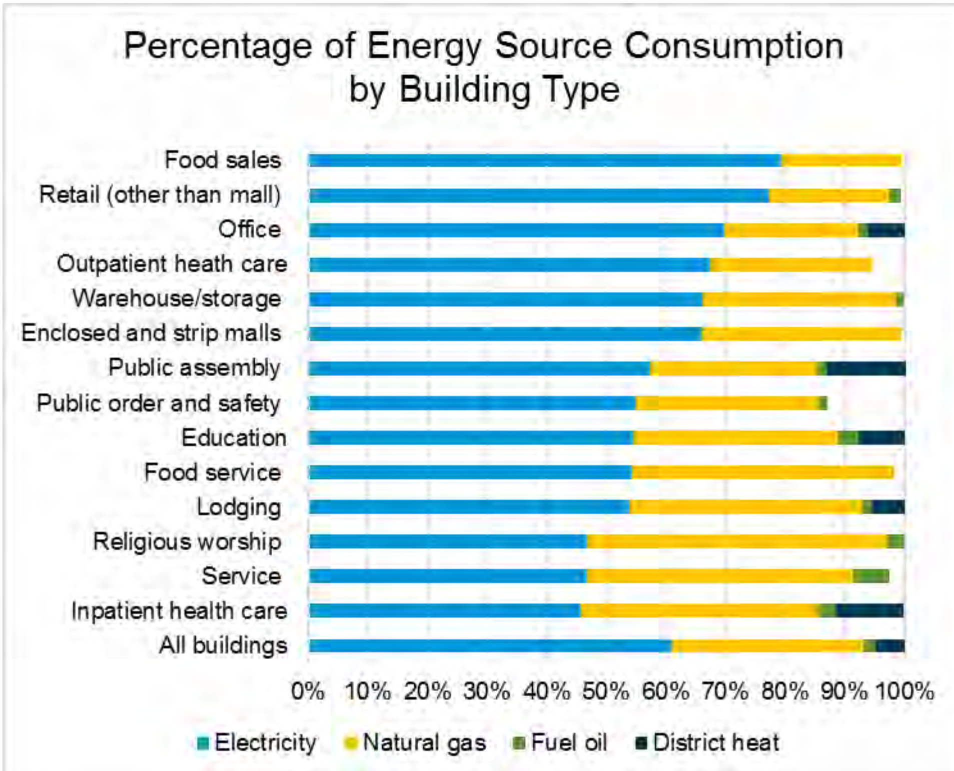


Figure 16. Percentage of Energy Source Consumption Categorized by Building Type
(Data Source: Table C1 in [5])

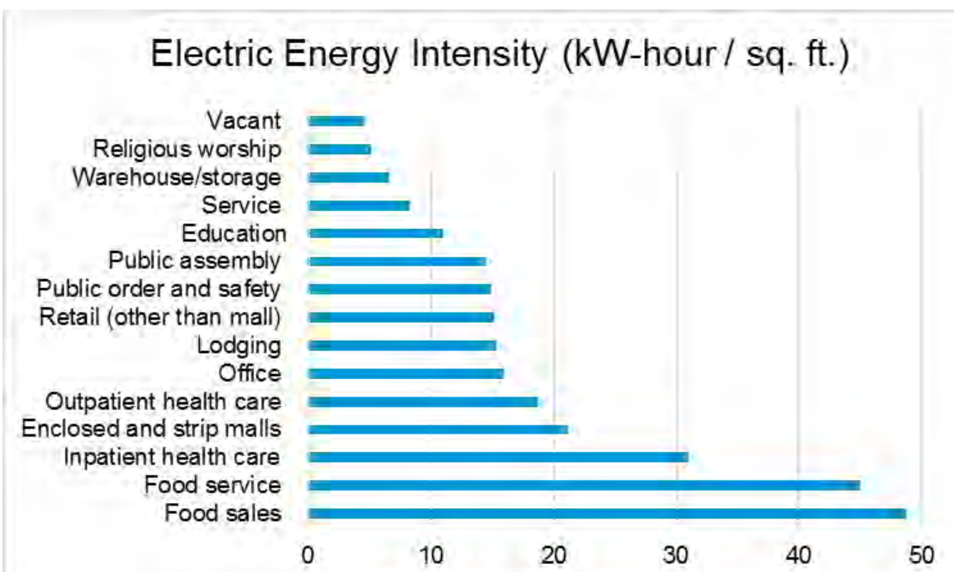


Figure 17. Electric Energy Intensity Categorized by Commercial Building Type
(Data Source: Table C13 in [5])

The mean electric power intensity for each building type in 2012 is displayed in Figure 18. As discussed earlier, the mean power intensity differs greatly from the demand power intensity; furthermore, these quantities differ from the power densities for which a building is designed. The power intensity of a building will change throughout the day to maintain thermal comfort, to adequately illuminate the spaces within the building, and to supply the electrical equipment so that employees can conduct their work activities and the building can achieve its function.

In most building types, the power intensity depends on the function of a building and the building's operating hours. The mean operating hours for the various types of commercial buildings was shown in Figure 9. Although long operating hours suggest long hours of adequate illumination and electrical equipment and device usage, long operating hours do not necessary result in high electric energy and power intensities. Figure 9 indicates that all inpatient healthcare and most lodging operate 24 hours a day, seven days a week. However, as Figure 18 shows, inpatient healthcare had a mean electric power density 3.5 W per square foot, but lodging was only 1.8 W per square foot.

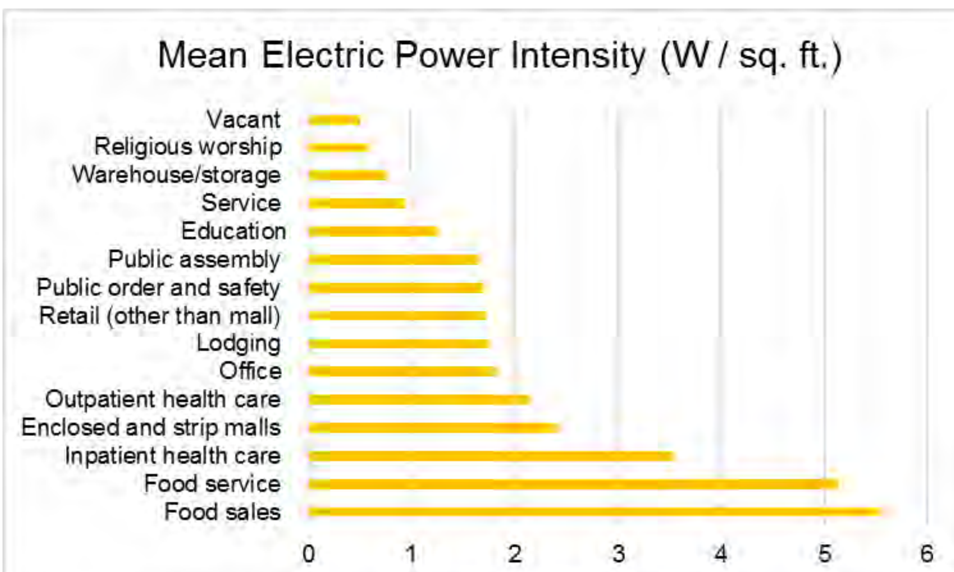


Figure 18. Electric Power Intensity Categorized by Commercial Building Type
(Data Source: Table C13 in [5], Note on terminology[5])

[5] The 2012 CBECS data and documentation classified commercial healthcare building types as "Inpatient health care" and "Outpatient health care" and the graphs in this report reflect the CBECS spelling. Various web sites delve into the correctness and usage of the terms "health care" and "healthcare." In response to a sponsor comment, the report author has used the term "healthcare" in the body of the report.

2.5 Electric Utility Commercial Building Loading

Figure 19 displays the average electric power intensity of various types of commercial buildings calculated from information released by Austin Energy in a public hearing [6]. The power intensities in Figure 19 are notably higher than those in Figure 18. One reason might be that the table produced by Austin Energy may be representative of buildings in the Austin, Texas area, a warm, humid climate with only 1,661 degree heating days in the last twelve months.[6] In Figure 19, restaurants and food stores account for the highest average loads ranging from 9.2 to 12.4 watts per square foot. Likewise, the 2012 CBECS found that food sales and food service (i.e., restaurants) had the highest mean electric power intensities, but the intensities were only 5.6 and 5.1 watts per square foot, respectively. Hospitals had the third

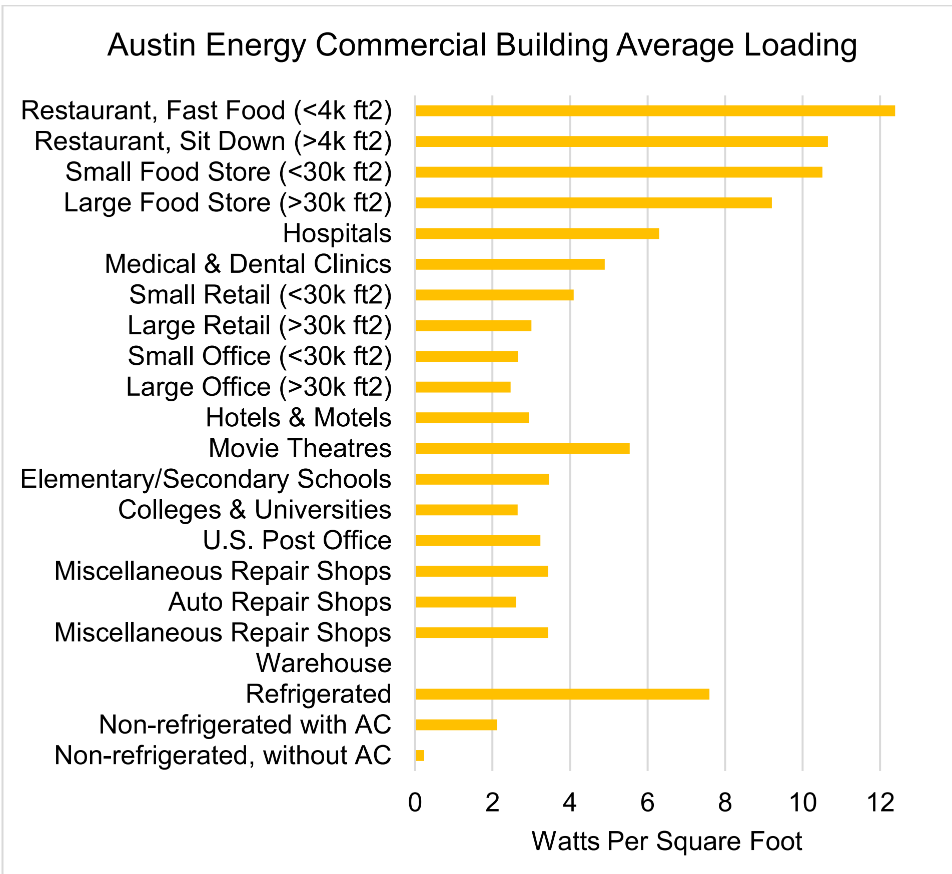


Figure 19. Austin Energy - Commercial Building Average Electric Power Intensity
(Data Source: [6])

---

[6]Calculated on the website www.degreedays.net using from data taken October 1, 2015 through September 30, 2016 at the Austin-Bergstrom International Airport.

highest electric power intensities in Figures 18 and 19; the 2012 CBECS was 3.5 watts per square foot, while Austin Energy was 6.3 watts per square foot. However, there was less deviation in office buildings. Austin Energy found that office building loading was 2.5 to 2.7 watts per square foot and the 2012 CBECS was 1.8 watts per square foot.

3 BUILDING END-USE LOADS AND ELECTRICITY CONSUMPTION

3.1 End-Use Load Types and CBECS Models [5]

The 2012 CBECS included estimations of the end-use consumption by energy source, including electricity.[7] The estimations were determined from end-use models based on equations and parameters found in ASHRAE, Illuminating Engineering Society of North America (IESNA), and other standard engineering handbooks. Up-to-date parameters were also taken from large-scale field studies of commercial buildings.

The engineering estimations were calibrated by cross-section regression models where the estimations were fit based on consumption per square foot. Where possible, the regression models were reconciled with a building's known energy consumption. The reconciliation ratio was applied to the modeled end-use estimates.

- Space Heating and Cooling

The models estimated the total energy needed for space heating and cooling. The amount of electric energy required to meet the heating and cooling energy needs was determined from equipment type and estimated efficiency. The calculations account for the building heat losses and gains as a function of conductance and annual heating and cooling degree days, based on the thermal properties of the roof and wall materials. The energy models also included the ventilation heat loss or gain as a function of external air volume brought into the building daily, the temperature difference between the inside and outside air, and the heat capacity of the air.

- Ventilation

  The model estimated supply and return fan energy use based on external air ventilation volumes. Variable-air-volume factors were estimated by climate zone. Static pressure differences were accounted for by system type and by floor space.

[7] Details released on March 12, 2016 about the CBECS end-use consumption estimates are summarized in this section. The estimation models were described on the following website: http://www.eia.gov/consumption/commercial/estimation-enduse-consumption.cfm.

- Water Heating

  Water heating was estimated based on 1) equipment type and efficiency; 2) building type and size; and 3) ground water temperature.
- Lighting

  The model estimated the electric energy required to supply interior and exterior lighting fixtures. Interior lighting calculations included: 1) the efficiency (in lumens per watt) of lamp system types used in building; 2) the recommended average illuminance levels by building type; and 3) average building operating hours.
- Cooking

  The model was based on the number and types of cooking equipment reported in the CBECS and the 2005 California Commercial End-use Survey (CEuS) sponsored by the California Energy Commission.
- Refrigeration

  The model factored in the reported number of refrigeration units but was primarily based on the CEuS intensity estimates and the building type.
- Computer and Office Equipment

  Electricity consumption for office equipment in all building types was estimated. Computer equipment included personal and laptop computers, monitors, servers, and data centers. Other office equipment included copiers, printers, fax machines, cash registers, and video displays.
- Other

  "Other" end-use equipment supplied by electricity was based on floor space and CEuS intensities for miscellaneous, process equipment, motors, and air compressors.

3.2 CBECS End-Use Load Consumption [5]

Figure 20 illustrates the end-use percentages of electricity consumption in commercial buildings. Lighting, ventilation, refrigeration, and cooling loads accounted for 64% of the electricity consumed in commercial buildings. Computing and office equipment accounted for 14% of the end-use electricity consumption.

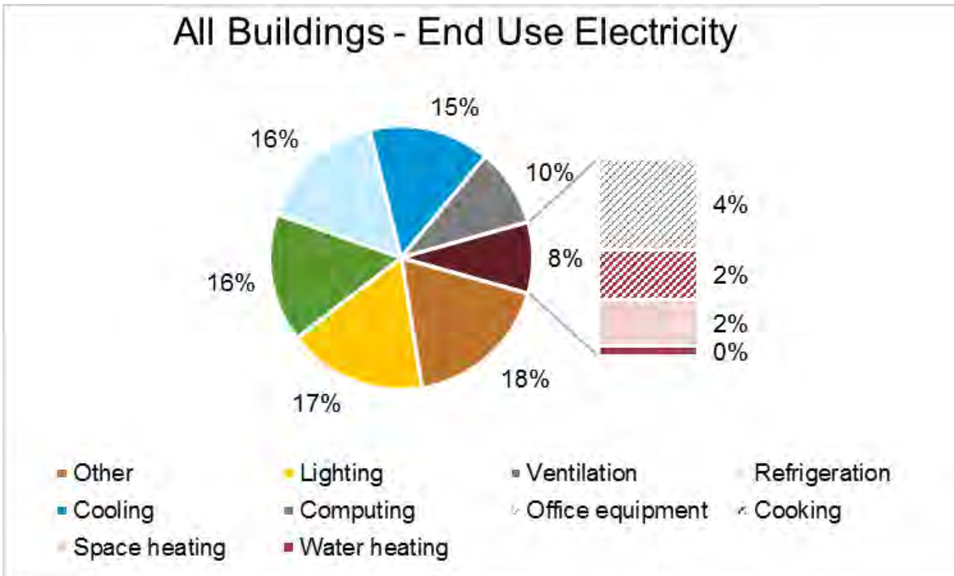


Figure 20. Percentage End-Use Electricity Consumption for All Commercial Buildings
(Data Source: Table E5 in [5])

Figures 21 and 22 show that electricity end-use consumption depends greatly on building type. At 70% and 40%, respectively, food sales and food service buildings lead in the highest percentage of refrigeration load. In contrast, refrigeration accounts for 3% of electricity consumption in office buildings. Outpatient and inpatient healthcare, public order and safety, public assembly, and office buildings have the highest percentages of air conditioning and ventilation load, ranging from 42% to 38%. In warehouse and storage and service buildings, lighting load accounts for 30% of the electricity consumption in the building; in comparison, the lighting load accounts for 16% to 18% of electricity consumption in offices, education, and healthcare buildings. Computing and office equipment account for high percentages of electricity consumption in office, education, lodging, and outpatient healthcare, at 24%, 22%, 17%, and 15%, respectively. Cooking accounts for 16% of electric energy usage in food service, followed by 5% in food sales and 3% in lodging.

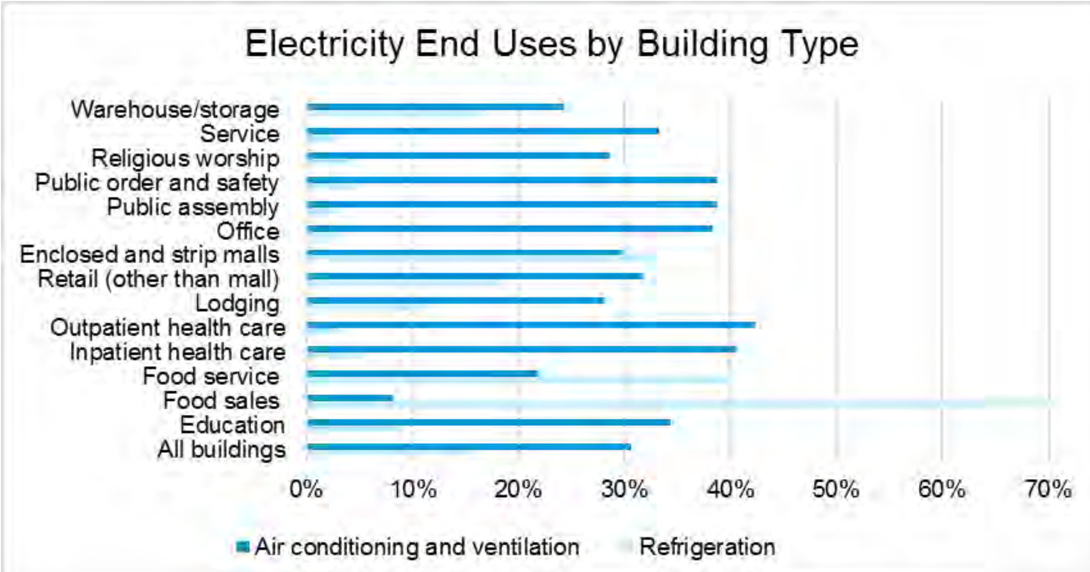


Figure 21. AC and Ventilation and Refrigeration Electricity Consumption by Building Type
(Data Source: Table E5 in [5])

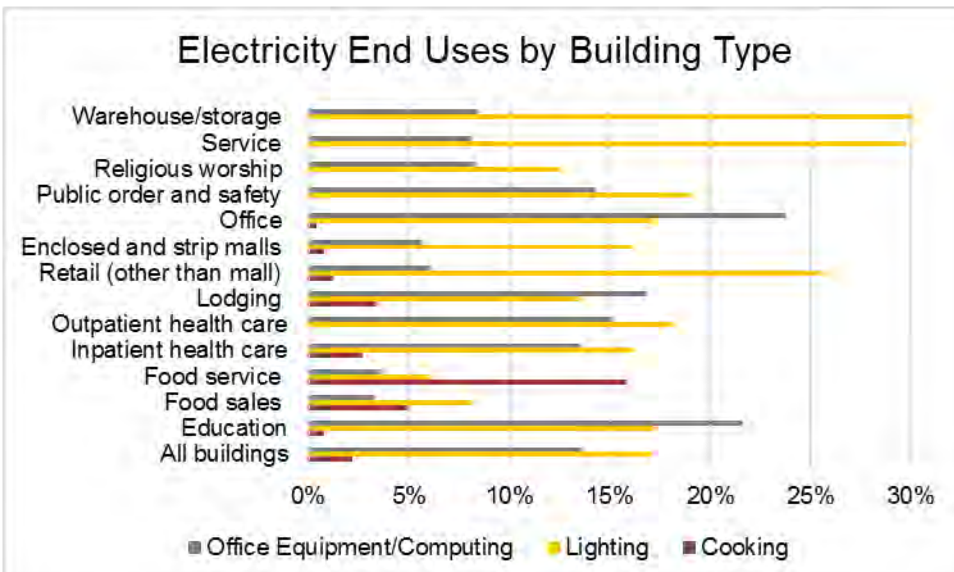


Figure 22. Office Equipment/Computing, Lighting, and Cooking Consumption by Type
(Data Source: Table E5 in [5])

The electric energy intensities for end-use equipment are shown in Figures 23 and 24 for various building types. Food sales and food service buildings had the highest intensities of refrigeration at 34.3 and 18.1 kW-hours per square foot; this is not surprising since refrigeration accounted for the highest percentage of electricity consumption (70% and 40%) in those building types. However, a high percentage of specific end-use consumption does not necessary imply a high electric energy intensity for that load. In enclosed and strip malls, refrigeration equipment accounted for 33% of electricity consumption, but its energy intensity was only 7.0 kW-hours per square foot. As shown in Figure 17, food sales and food service buildings had high electric energy intensities (48.7 and 45.0 kW-hours per square feet), but the density was much lower in enclosed and strip malls (21.1 kW-hours per square foot).

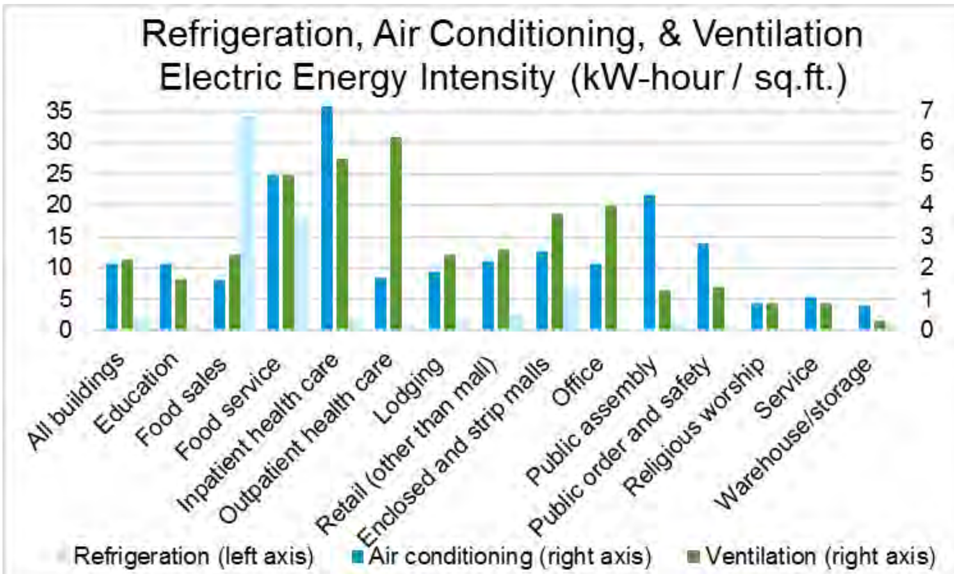


Figure 23. Refrigeration, AC and Ventilation Electric Energy Intensity by Building Type
(Data Sources: Tables C1 and E5 in [5])

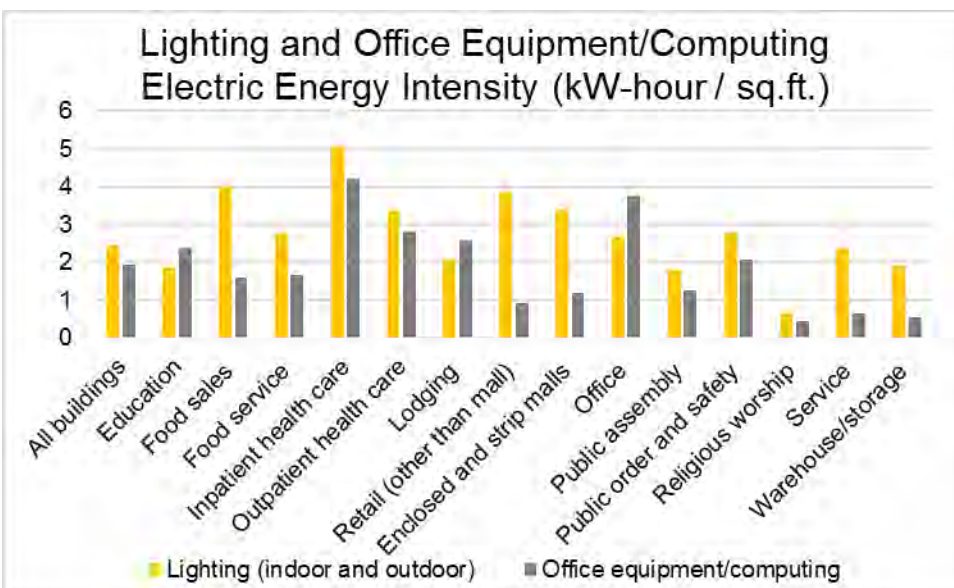


Figure 24. Lighting and Office Equipment/Computing Electric Energy Intensity by Type
Figure 24 (Data Sources: Tables C1 and E5 in [5])

Inpatient healthcare and food service had the highest air conditioning electric energy intensities of 7.2 and 5.0 kW-hours per square foot, and the second highest ventilation electric intensities of 5.5 and 5.0 kW-hours per square foot. In comparison, the air conditioning and ventilation electric energy intensities in office buildings were 2.1 and 4.0, respectively. The ventilation electric energy intensity was 2.3 kW-hours per square foot for all buildings, slightly higher than for air conditioning at 2.1 kW-hours per square foot.

The type of lighting system, illumination level required, and operating hours of the building type determined the lighting energy intensity. Inpatient healthcare and food sales had the highest electric energy intensities for lighting, 5.1 and 4.0 kW-hours per square foot. In comparison, office and warehouse/storage lighting had electric energy intensities of 2.7 and 1.9 kW-hours per square foot, which represented 17% and 30% of the building type's total electricity consumption, respectively.

With respective electric energy intensities of 4.2 and 3.8 kW-hours per square foot, inpatient healthcare and offices had the highest demand for computing and office equipment. Outpatient healthcare, lodging, and education followed with intensities between 2.8 to 2.4 kW-hours per square foot.

Refrigeration, air conditioning, and ventilation loads operate continuously, although power demand may greatly fluctuate throughout the day (and seasonally). Figure 25 illustrates the mean annual power intensities of these loads.

Power demands for indoor lighting will be high when the commercial building is operating. The indoor lighting demand is expected to be much lower when the building is not in operation, but some illumination is still required for life safety and security reasons. Outdoor lighting is more dependent on the season and will illuminate during dark hours. Power demand for computing and office equipment is high during business hours, but some computing and office equipment may be energized all the times. The mean annual power intensities of the lighting and computing and office equipment for commercial office buildings is listed in Table 3. Table 3 also displays the average power intensity if the lighting and computing and office equipment loads were energized only during building operating hours. As illustrated in Figure 9, the mean number of operating hours for office buildings was 55 hours per week in the 2012 CBECS.

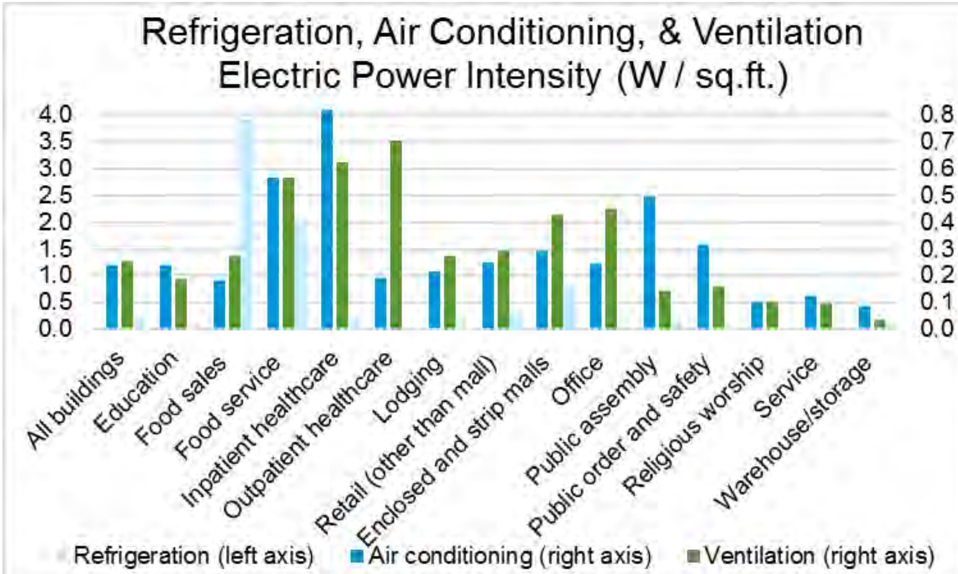


Figure 25. Refrigeration, AC and Ventilation Electric Power Intensity by Type
(Data Sources: Tables C1 & E5 in [5])

Table 3. Estimated Mean Power Intensities (W/ft^2) for Commercial Office Buildings*

End-Use Equipment	Continuous Operation	55 Hours Weekly
Lighting	0.31	0.94
Computing and Office Equipment	0.43	1.32

*Power intensities calculated from data in Tables B1, C1, and E5 in [5].

3.3 Miscellaneous Electric Loads in CDM[8] and Elsewhere

Miscellaneous electric loads (MELs) are usually defined as "the loads outside of a building's core functions of heating, ventilating, air conditioning, lighting, and water heating…Taken across the entire commercial building sector, MELs now account for roughly 30% of total energy use [7]." Limited studies conducted by Pacific Northwest National Laboratory (PNNL) determined the energy consumption for bank branches in a cold climate was: 45% for interior and exterior lighting, 23% for HVAC, and 32% for MELs [7].

In an earlier report section, Figure 20 illustrated that computers and other office equipment and "other" loads accounted for 32% of commercial building electricity consumption. Figure 14 illustrated the electricity accounts for 61% of energy consumption in all commercial buildings. Based on the mean data from the 2012 CBECS, it might be concluded that MELs

[8] CDM is the Commercial Demand Module of the National Energy Modeling System (NEMS) used by the Energy Information Administration (EIA), a section of the U.S. Department of Energy (DOE).

account for roughly 20% (32% x 61%) of total energy consumption in commercial buildings. The PNNL findings suggest that the data produced from CBECS may underpredict the actual MEL energy consumption, at least in some building types. Although CBECS collects some information on minor end-use equipment, the survey focuses on equipment stock and energy consumption of major end-use equipment. "Given the dispersed and increasingly varied nature of this equipment and appliances [MELS], stock, usage, and consumption data can be difficult to obtain [8]." The NEMS Commercial Demand Module (CDM) projects MEL energy consumption based on unit energy consumption and total stock for each MEL.

The U.S. Energy Information Administration contracted Navigant Consulting, Inc. and SAIC to update and to project MEL energy consumption data for incorporation into NEMS. In 2013, Navigant reported on the estimated number of thirteen miscellaneous electric loads installed in the U.S. and their estimated energy consumption. Table 4 lists the thirteen MELs and the unit and total annual energy consumption for each MEL during 2011. Commercial electricity consumption was 1,319 TW-hours in 2011 [8]; therefore, the MELs selected in the Navigant study represent an estimated 15% of the total electricity consumed by the commercial sector in 2011.

The thirteen commercial miscellaneous electric loads in Tables 4 and 5 were selected in a two-stage process beginning with 173 residential and commercials MELs. The initial commercial list included:

- non-road electric vehicles coffee makers elevators escalators
- other medical equipment fitness equipment office equipment arcades
- automated teller machines (ATMs) water purification/treatment loads fume hoods

During the initial screening, 38 commercial MELs were identified that had significant energy consumption and needed better characterization. Five of these prospective MELs and their estimated energy consumption are also included in Table 4. Other miscellaneous electric loads that were not selected included kitchen equipment (ovens, steamers, griddles, fryers, and broilers) with a significant combined annual energy consumption equal to 39.1 TW-hours [8].

When data was available for the thirteen selected MELs, usage was characterized, and energy consumption was estimated based on power draw in different states (active, sleep, or off). Table 4 also lists the power drawn during the active state. Power consumption is a composite and represents average unit consumption in the U.S. For medical equipment and kitchen ventilation equipment, sub-products were analyzed individually and energy consumption for a composite unit was calculated.

Table 4. Navigant MELs - Total & Unit 2011 Energy Consumption and Active Power Draw

Selected MELs	Total Energy (TWh)	Installed Units (thousands)	Unit Energy (kWh)[1]	Per Unit Active State (W)[1]
Distribution transformers	43	5,470	7,900	
Kitchen ventilation	41	790	52,000	8,071
Desktop computers	30	74,000	400	64
Servers in data centers	29	12,200	2,400	269
Monitors for PCs & laptops	18	93,000	198	38
IT equipment (routers, hubs, switches, security)	12	487,000	25	3
Commercial security systems	7.4	11,000	2500	290
Water distribution equipment*	6.6			
Lab refrigerators & freezers	4.5	1,000	4,500	975
Medical imaging equipment	2.7	178	15,000	22,774
Laptops (including netbooks)	2.1	63,000	34	21
Large video displays (>30") for advertising/entertainment	1.7	1,600	1,084	246
Large video boards for stadiums and arenas	0.2	1	152,000	190,000
Total	198.2			
Other Prospective MELs				
Ice makers/machines	11	2,600,000		
Printers	11	34,000,000		
Vending machines	11	6,600,000		
Televisions	3.8	16,000		
Irrigation systems	3.6			

[1]Appendix G in [8]; *external to the buildings and provided by the public water distribution system.

Most MELs listed in Table 4 were found in all the NEMS CDM building type categories identified later in Table 15. For some MELs, such as distribution transformers and security systems, MEL usage spread across all building types. For many MELs, usage predominated in a small number of building types. By definition, servers in data centers are located only in data centers. Large format video boards are only located in stadiums and arenas. Medical equipment is only located in inpatient healthcare facilities and small offices (outpatient healthcare) based on the 2003 CBECS building type definitions used in the NEMS CDM. Table 5 displays the energy consumption of each Navigant MEL in the predominant building type(s) as a percentage of the total energy the MEL consumes in all commercial building types.

Low-voltage distribution transformers (LVDT), on the customer-side of the utility meter, used 43 TW-hours of site electricity in 2011. The distribution transformer total and unit energy consumption in Table 4 is based on a composite of three transformer sizes listed in Table 6.

The number of transformers was based on the total electricity supplied to the building for other than HVAC and refrigeration loads. The analysis was based on a 1999 study done by the Cadmus group and the U.S. Department of Energy rulemaking engineering analysis[9]. Low-voltage distribution transformers topped the Navigant MEL list in energy consumption, but all transformer energy consumption represents energy loss. Unlike other MELs, transformers are not “end-use” loads; transformers are electrical equipment changing the supply voltage to a voltage that can be utilized by the end-use equipment. Navigant acknowledged that low-voltage distribution transformer losses “are highly dependent on site-specific sizing and site-specific loading profiles.” [8]

Table 6 provides the energy consumption of subcategory equipment for distribution transformers, servers in data centers and medical imaging equipment. Table 6 also includes the annual per unit mean power for the distribution transformers and data center servers. Although kitchen ventilation equipment was not included in the table, it was subdivided by small, medium, and large exhaust fan capacity. Commercial security systems largely consist of video surveillance, physical access control, and intruder and fire detection. Electronic article surveillance systems are typically found in retail and some food sales stores. The power consumption of commercial security systems depends on system type and on building size and type. The subcategory equipment for these MELs was used to develop their composite profiles.

Table 5. 2011 MEL Percentage Energy Consumption by Predominant Building Category

Selected MELs	% Energy Consumption[1]	Predominate NEM CDM Building Category
Distribution transformers	28	Mercantile and service
Kitchen ventilation	84	Education, food sales, and food service
Desktop computers	68	Education; Large office; Small office
Servers in data centers	100	Other
Monitors for PCs & laptops	72	Education; Large office; Small office
IT equipment	72	Education; Large office; Small office
Commercial security systems	---	No predominant building type
Water distribution	20	Warehouse
Lab refrigerators & freezers	100	Education; Healthcare; Other
Medical imaging equipment	100	Healthcare; Small office
Laptops (including netbooks)	67	Education; Large office; Small office
Large video displays (>30”)	41	Mercantile and service
Large video boards	100	Assembly
[1]Calculated from Appendix B in [8]		

[9] Federal Register / Vol. 77, No. 28 / Friday, February 10, 2012 / Proposed Rules 10 CFR Part 431, Energy Conservation Program: Energy Conservation Standards for Distribution Transformers.

Table 6. Subcategory MEL Equipment used in Composite Profile (Annual Basis for 2011)

Selected MELs	Total Energy (TWh)	Installed Units (thousands)	Unit Energy (kWh)	Annual Mean Per Unit Power (W)
Distribution transformers	43	5,470	7,900	902
25 kVA, 1 phase		600	2,200	251
75 kVA, 3 phase		4,100	6,600	753
300 kVA, 3 phase		800	19,200	2,192
Servers in data centers	29	12,200	2,400	274
Volume servers		11,800	2,000	228
Mid-range servers		340	8,000	913
High-end servers		38	50,500	5,765
Medical imaging equipment*	2.7	178	15,000	
MRI		12	111,000	
CT Scan		13	42,000	
Xray		78	9,500	
Ultrasound		75	760	
*Does not include approximately 140,000 dental X-ray and 48,000 mammography machines. Estimation based on seven days per week and may not be consistent with many locations.				

3.4 Receptacle and Plug and Process Load Studies

Different researchers use the acronym MELs in related but somewhat different contexts. “Miscellaneous electric loads” often cover a wide variety of equipment which does not fall under one of the main end-use load categories: heating, air conditioning, ventilation, refrigeration, water heating, lighting, and cooking (considered as an MEL in the Navigant study). Computer and office equipment are usually considered as an MEL, although the EIA NEMS commercial demand module (discussed in Section 4) categorizes it separately. Government sponsored research has been conducted on how to reduce the power consumption associated with receptacle load, referred to as “plug load.” Unlike major end-use loads which are hard-wired, the receptacle load has not historically been regulated by building energy conservation codes. In this context, the acronym MELs refers to “miscellaneous and electronic loads,” often referring exclusively to the receptacle load.

3.4.1 Lawrence Berkeley National Laboratory Office Receptacle Study

Researchers at Lawrence Berkeley National Laboratory (LBLN) conducted a study of plug-in loads in an office building on site [9]. The 89,500 square feet office building was inhabited by 450 workers. A total of 4,454 plug-loads were inventoried. From the total inventory, 455 plug-loads were carefully chosen to represent the plug-load usage in the building and were monitored for a minimum of six months, up to 16 months. The plug-loads were connected directly to meters which plugged into the receptacle outlets. Every ten seconds average power measurements were collected via a wireless metering system.

The categories for the inventoried devices and their percentage of the total 423 MW-hours estimated annual energy use is displayed in Figure 26. The *miscellaneous HVAC* category included fans and portable heaters. It is interesting to note that the *other* category, which included water coolers, accounted for 38% of the plug-in devices but less than 9% of energy use. The *imaging* category included copiers, facsimiles, printers, multi-machines, and scanners. Standard office and computer equipment categorized under *imaging*, *networking*, *displays*, and *computers* accounted for only 43% of the plug-in devices but 78% of energy use; computers alone accounted for over 50% of energy use. The *appliance* category (2.8% energy use) was included in the study because appliances are outside the business function of an office building.

The study concluded that metering for a two-month period would have provided a reasonable accurate estimate of annual energy consumption for most load categories. For categories such as miscellaneous lighting, in which usage might be impacted by seasons, longer metering periods are needed for better estimations. The LBLN study found the average power densities for the plug-loads were 1.1 W/ft^2 during the day and 0.47 W/ft^2 at night. Furthermore, the LBLN study estimates that plug loads account for 15% of building primary energy use in the United States, a much lower estimate than the PNNL study mentioned in Section 3.3.

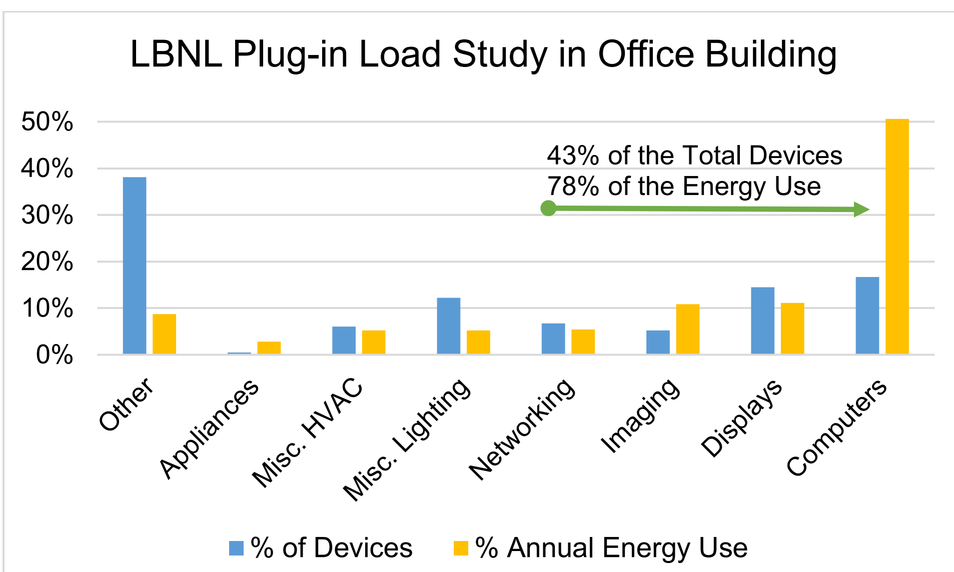


Figure 26. Plug Load Office Building Study at Lawrence Berkeley National Laboratories
(Data Source: [9])

3.4.2 University of Idaho & California PIER Studies on Receptacle Load Power

The University of Idaho conducted a study on six office buildings in Boise, Idaho to characterize the receptacle load profile and to explore the efficacy of different intervention techniques to reduce the energy consumption of plug loads [10]. Data logging equipment was placed at the panel feeders to record true power and energy consumption at fifteen-minute intervals. In panels with circuits supplying other load types, current loggers were used to record current which was subtracted from the total current load of the panel. In some panels with only a few receptacle loads, the circuits supplying the receptacles were monitored directly.

Data was collected for fifteen months, and loggers were downloaded every two to three months. The most common problem was data logger battery failure. On four sites, data was collected for three months before energy reduction interventions occurred. Baseline data was collected for twelve months before intervention on one site and the last site had no intervention.

The results of the University of Idaho study have been summarized in Table 7. Some of the less common receptacle loads included fountain pumps, handheld vacuums, massage chairs, and humidifiers. Two heaters were plugged in at one site and six at another. Fans were found on four sites.

Table 7. Summary of Results in University of Idaho's Receptacle Load Study*

Office type	Land records	World wide logistics	Architect	Elections office	Regulatory agency	Investment analytics
Square feet (ft^2)	4,544	13,688	1,288	1,550	13,072	13,688
FT employees*	31	94	6	7	49	100
FTE* / ft^2	147	146	215	221	267	137
Total plug devices	216	359	50	67	275	392
Devices / 100 ft^2	4.8	2.6	3.9	4.3	2.1	2.9
Devices / FTE	7.0	3.8	8.3	9.6	5.6	3.9
Weekdays						
Average W/ft^2	0.87	0.36	0.84	0.36	0.48	1.75
Peak Hours	6am-6pm	7am-6pm	8am-5pm	7am-5pm	8am-5pm	7am-6pm
Peak kW	6.25	10.5	1.5	1.25	9.5	28
Unoccupied kW	2.75	2.0	0.75	0.25	4.75	22
Peak* W/ft^2	1.38	0.77	1.16	0.81	0.73	2.05
Unoccupied* W/ft^2	0.61	0.15	0.58	0.16	0.36	1.61

*FTE is full-time employees. Data found in [10]. Peak and unoccupied W/ft^2 have been calculated from the peak and unoccupied kW provided in the University of Idaho report.

Other studies have found similar ranges of receptacle power density usage in office buildings. The results in Table 8 were presented by the New Buildings Institute in 2012 for the California Public Interest Energy Research (PIER) Program [11]. Table 8 includes average daytime, average night, and peak power densities for five office buildings in California and British Columbia. The peak to average daytime power density ratios varied from 1.33 (Vancouver) to 2.25 (Irvine Site 3). Average daytime lighting power densities, also included in Table 8, ranged from 0.2 W/ft^2 to 0.5 W/ft^2 and varied between average daytime receptacle power density (Rosemead) to only 20% its value (Los Angeles). The lighting power densities can also be compared with the lighting power allowances and minimum lighting power densities included in Section 5 on energy conservation codes and Section 6 on engineering practices.

Table 8. New Buildings Institute Receptacle and Lighting Load Office Study [11]

Office Location	Irvine CA Site 1	Irvine CA Site 2	Rosemead CA	Los Angeles CA	Vancouver BC
Square feet (ft^2)	8,328	1,500	16,500	8,024	9,000
Lighting Average Daytime W/ft^2	0.2	0.4	0.5	0.3	0.5
Plug Load Weekdays					
Average Daytime W/ft^2	0.8	0.8	0.5	1.5	0.6
Peak W/ft^2	1.6	1.8	0.7	2.1	0.8
Average Night W/ft^2	0.4	0.6	0.3	1.46	0.3

3.4.3 NREL Study on Plug and Process Load Power Density and Other Work

The National Renewable Energy Laboratory (NREL) conducted a study on the "plug and process" loads ("PPL"), which they defined as all loads other than heating, ventilation, air conditioning, and lighting. Buildings which had disaggregated plug and process were selected for the study. Submetering equipment was in already place for all buildings except the DOD and GSA offices. Tables 9 through 11 present the study results of plug and process load densities in buildings ranging from over 18,000 square feet to 365,000 square feet. The office power densities in Table 9 were measured from the four government offices of the Department of Defense (DOD), National Renewable Energy Laboratory (NREL), and General Services Administration (GSA). The buildings in Table 10 represent higher education buildings at Stanford University; the buildings contain classrooms, meeting areas, and faculty offices. The average ratios of peak to average power densities for the offices in Table 9 and the higher education buildings in Table 10 were 2.03 and 2.30, respectively [12].

Table 11 provides average power density of the plug and process load for ten offices. Note that the 0.64 W/ft^2 average density for the single corporate tenant with kitchen was fairly low in comparison with the two highest densities of 1.17 and 2.27 W/ft^2. The highest plug and process load power density was measured at the office of a single corporate tenant with laboratories.

It should also be noted that office buildings, as well as other buildings, house various space types. For example, the U.S. Navy office building (DOD) included in Table 9 contains a library, private offices, office areas with cubicles, two conference rooms, three kitchens, hallways, a print room, a mail room, and a reception area. The plug and process load densities in these different spaces may vary.

Table 9. Plug and Process Load Power Densities of Four Government Offices

Government Office Building	Area (square feet)	Average (W/ft^2)	Peak (W/ft^2)
DOD	18,818	0.24	0.52
GSA (with data center)	18,755	0.34	0.51
NREL	138,000	0.16	0.55
NREL (with data center)	220,000	0.77	1.25
Data center only		0.57	0.82

Table 10. Plug and Process Load Power Densities of Seven Stanford University Buildings

Number of Buildings	Area (square feet)	Average (W/ft^2)	Peak (W/ft^2)
1	115,110	0.23	0.41
1	49,360	0.30	0.64
1	83,130	0.16	0.42
1	26,326	0.40	1.08
3	113,584	0.28	0.63

Table 11. Plug and Process Load Power Densities of Ten Office Buildings

Office Building Type	Area (square feet)	Average (W/ft^2)
Multi-tenant with data center	50,725	1.17
Multi-tenant with data center	365,000	0.19
Multi-tenant with data center	191,799	0.37
Multi-tenant	173,302	0.49
Municipal	172,000	0.40
Single tenant with warehouse	94,621	0.19
Single Corporate tenant with data center	97,500	0.58
Single Corporate tenant with data center	195,721	0.36
Single Corporate tenant with kitchen	91,980	0.64
Single Corporate tenant with laboratories	222,616	2.27

Another study conducted by Baumann Consulting measured the “plug load” (i.e., receptacle load) power density of different space types located in an office occupying the fifth floor of a seven-story building in Washington, D.C [13]. The measured peak daytime demands in Table 12 are significantly higher than typical power densities listed in Tables 7 through 11 for office and higher education buildings. Table 12 is evidence that some space types might require higher receptacle demand power densities than other types and kitchens can have high demand densities. The average plug and process power density of the corporate office space with laboratory listed in Table 11 suggests that many lab spaces might also have higher power density requirements.

Table 12. Baumann Study: Plug Load Power Densities in Different Office Space Types*

Fifth-floor office in Washington, DC	Area (square feet)	Area % of 5th Floor	Average Evening (W/ft^2)	Peak Daytime (W/ft^2)
Office zones	4,890	81.6%	0.58	2.52
Conference zone	470	7.9%	0.35	1.85
Kitchen zone	246	4.1%	0.23	9.05
Other zones	384	6.4%	*Data sources: [13] and Figure 1 and Table 3 in [13]	
Fifth floor	5,990	100%		

3.4.4 Studies on Device Power Consumption

A study conducted by Ecos for the California Energy Commission (CEC) Public Interest Energy Research Program (PIER) involved inventorying the receptacle load at 47 offices, almost 7,000 plug-in devices [14]. A total of 470 plug-in devices were monitored at 25 offices for a two-week period. Data was collected at one-minute intervals. The report presented a careful analysis of the percentage of time many common device types are in active, idle, sleep, standby, and off states. The device types included: computers, monitors, imaging equipment, computer peripherals, lamps, coffee makers, and shredders. Table 13 provides the average power consumption during various states found for some common plug-in devices monitored in the study. The number of devices monitored is also included in the table.

It has been noted in various papers that device nameplate power rating is not representative of the heat that a building gains due to device operation. As Table 13 shows, a device consumes less power when it is not in the active state. The Baumann Study discussed in Section 3.4.3 also measured the power consumption of plug-in devices at 30-second intervals for at least 24-hours per device and at least three 24-hour periods on devices with highly variable usage (such as printers and copiers). The device nameplate power rating is compared with the average in-use and idle power consumption in Table 14. The number of devices represented in the study is also included in the table. It might be noted that the Baumann study involved an energy analysis simulating heat gains inside the building which rested on a lighting power density[10] of 1.1 W/ft^2 based on ASHRAE 62.1 (Table 4 in [13]). This density might be compared with the lighting power allowances and minimum lighting power densities included in Section 5 on energy conservation codes and Section 6 on engineering practices.

Table 13. Measured Power Consumption of Common Office Devices in Various States*

Device	Number	Active (W)	Idle (W)	Sleep (W)	Standby (W)
Desktop computer	61	78.9	45.6	3.2	2.2
Notebook computer	20	74.7	30.3	1.6	1.6
LCD display	84	34.2	26.4	6.2	0.9
Laser MFD	18	75.7	26.1	5.4	5.5
Laser printer	33	130.1	19.0		11.4
Inkjet printer	13	64.0	6.8	4.7	2.7
Computer speakers	18	6.0	2.4		1.7
External drive	2	28.4		10.7	1.0
Ethernet hub or switch	9	17.0	8.0	5.9	1.3
USB hub or switch	2	26.0	14.1	5.9	0.6
LCD television	2	58.2			3.1
Video projector	4	181.9		9.8	4.6
Portable CD player	7	18.0	3.0		1.3
Speakers (audio)	6	32.0	10.0		1
Coffee maker	10	464.0	40.3		1.8
Shredder	4	78.4			0.8
Space heater	4	937.7			1.0
Toaster oven	1	1057.9			0.0

*Devices and data selected from Table 11 in [14]

[10] In email dated December 5, 2016, Justin Lueker, author of [13], stated that "11.8 W/m^2, which translates to about 1.1 W/ft^2" was used. Table 4 of [13] had incorrectly included 127 W/ft^2 for the lighting power density in all occupied spaces, apparently mis-converting 11.8 W/m^2.

Table 14. Baumann Study - Device Nameplate and Idle and In-use Power Consumption*

Device	Number	Nameplate (W)	Idle (W)	In-use (W)
Laptop computer	11	80	0	40-70
Desktop computer	11	100-930	2.5	70-75
LCD display	33	25-40	0	25-40
LED lamp	11	11	0	7.6
Printer	1	1584	15	780 printing 130 scanning
Shredder	1	800	0	200
Server rack	1	--	1175	1175
Conference system	1	--	92.5	543
Refrigerator	1	180	0	100-105
Coffee machine	1	1250	3.3	1300
Toaster	1	1000		765
Microwave	1	1700	0.05	1540
Water cooler	1	700	0	130-160 chilling 553 heating

*Data sources: Tables 1 and 3 in [13]

3.4.5 Receptacle Load Power Densities in Real Estate and Building Design

In the abstract of [12], it is stated: "Tenants [of commercial buildings] require that sufficient electrical power is available for PPLs [plug and process loads] to meet the maximum anticipated load. Lease language often dictates a value of 5 to 10 W/ft^2 for PPLs….Overestimating PPL capacity leads designers to oversize electrical infrastructure and cooling systems."

Cooling requirements in buildings are partially determined by the heat generated by the lighting and electrical equipment, including receptacle load. The receptacle load can also influence peak heating loads. According to [13], the standard practice for HVAC sizing calculations is to assume a plug load density of 1 W/ft^2, published in ASHRAE Research Project RP-1055 (1999) for offices. According to [15], the 2009 ASHRAE Handbook – Fundamentals "states that a 'medium density' office building will have a plug load of 1 W/ft^2." Based on an analysis of results published in ASHRAE-sponsored research project RP-1482 (2010), "Update to Measurements of Office Equipment Heat Gain Data," reference [15] further asserts that peak plug loads as low as 0.25 W/ft^2 are possible. This assertion seems to be based on plug loads consisting of light usage of notebook computers with speakers and one printer per ten workstations.

What is not stated in papers addressing the receptacle demand power density required by tenants is that the estimated power density of a building may be based on the total receptacle load calculated from National Electrical Code Article 220 which requires 180 VA for single or duplex receptacles on one yolk. Furthermore, the power density required by tenants may also, in a sense, be expressing a need to have a space populated with an adequate number of receptacles.

4 EIA MODEL AND PREDICTIONS FOR COMMERCIAL BUILDINGS

4.1 NEMS Commercial Demand Module

The CBECS provides data for the Commercial Demand Module (CDM) of the National Energy Modeling System (NEMS) [15]. As part of NEMS, the CDM generates projections of the commercial sector energy demand for the nine Census division levels identified in Figure 7. Equipment purchases for the major end-use loads in a commercial building are based on a life-cycle cost algorithm which incorporates consumer behavior and time preference premiums. Equipment selection factors are also based on major energy source, such as electricity, natural gas, or distillate fuel oil. The seven major end-use loads in the CDM are heating, cooling, water heating, ventilation, refrigeration, cooking, and lighting. The CDM has also incorporated the three minor end-use loads: personal computers, other office equipment, and miscellaneous end-use loads (MELS). Miscellaneous end-use loading is represented in the “other” category in Figure 20, which illustrated that MELS (excluding computers and other office equipment) were attributed to 18% of the electrical energy consumption in all commercial buildings. Minor and renewable energy sources, as well as district energy services, are also included in the CDM.

The CDM defines eleven building categories based on the 2003 CBECS. Table 15 includes the building categories and ownership since projections for equipment decisions are impacted by these factors. The model is also used to assess how changing energy markets, building and equipment technologies, and regulatory initiatives impact the energy consumption of the commercial sector. The base year for the current CDM is 2003, corresponding to the 2003 CBECS.

The total building “service demand” depends on the building type, size, and location. The CDM models energy-consuming “service demands” because consumers do not directly utilize energy. End-use equipment is purchased to meet service demand for 1) new construction; 2) replacement of equipment at the end of useful life; and 3) retrofit of equipment with useful life remaining, but at the end of economic life. The total energy consumption depends on the average efficiency of the equipment supplying the service demand.

Table 15. Commercial Demand Module Building Categories, Floorspace, and Occupancy*

CDM Building Category	2003 CBECS Building Type	Total Floorspace (million ft^2)	% Govt. Owned	Non-Govt. % Owner Occupied	Non-Govt. %Non-owner Occupied
Assembly	Public assembly Religious worship	7,693	23	52	25
Education	Education	9,874	79	13	9
Food sales	Food sales	1,255	1	43	56
Food services	Food services	1,654	7	30	64
Healthcare	Inpatient healthcare	1,905	18	48	34
Lodging	Lodging	5,096	7	32	61
Mercantile/ Service	Mercantile	15,242	7	34	59
Office	Office	13,466	14	47	40
Two office types: Large (>50,000 ft^2) & small (≤ 50,000 ft^2), includes outpatient healthcare					
Warehouse	Warehouse	10,078	7	37	56
Other	Other	5,395	26	21	53
TOTAL		71,658	21	35	44

*Data Sources: Tables 1, E-4, and 8 in [15]

4.2 EIA 2015-2040 Projections for Commercial Buildings

The EIA projects that floor space and delivered energy consumption in commercial buildings will increase by 1.1% and 0.6% per year respectively from 2015 to 2040. The net result is a decrease in energy intensities due to higher efficiency lighting, heating, cooling, and ventilation systems; it is also due to more stringent building codes. The EIA reports an expected 0.3% per year reduction of electric energy intensity. However, the energy intensity of miscellaneous electric loads is expected to increase by a total of 11.5% [16].

5 COMMERCIAL BUILDING ENERGY CONSERVATION CODES

5.1 U.S. Department of Energy (DOE) Commercial Buildings Models

The DOE building models [2] aid in the development of energy codes and standards. Sixteen reference building energy models, listed in Table 16, have been developed for the U.S. Department of Energy in collaboration with the National Renewable Energy Laboratory (NREL), Pacific Northwest National Laboratory (PNNL), and Lawrence Berkeley National Laboratory (LBNL). The fifteen commercial buildings models (excluding the midrise apartment building model) represent over 60% of the commercial buildings in the United States. Table 16 provides the floor space and the number of floors for each reference model; the corresponding CBECS building type is also included. The remaining percentage of commercial buildings (less than 40%) may be similar to one or more of the reference models, but are not as easy to characterize by a representative type [2].

The building models were developed from the 2003 CBECS, which collected data on 5,215 buildings. The fifteen commercial building models represent 3,279 of the 2003 CBECS buildings with a floor space of 44 billion square feet (62% of the total floor space of the buildings in the study). The buildings used to develop the reference models accounted for 65% of the total energy consumption in the 2003 CBECS.

A version of the reference model for each building has three vintages: buildings constructed before 1980, buildings constructed after 1980, and new construction. About 78% of the U.S. population lives in five of the climate zones identified in Table 1. Population is an indication of geographic building distribution. But reference models have been developed for each of the sixteen climate zones discovered by the DOE; the most populated city in each of these zones appears in Table 1. The DOE developed 768 models to represent each unique combination of commercial building type, vintage, and location [2].

Table 16. DOE Reference Building Models and Equivalent CBECS Building Type

DOE Reference Building	Equivalent CBECS Building Type	Floor Area (in thousand ft^2)[1]	Floors[1]	Parking Lot Area (in thousand ft^2)
Large office	Office	498.6	12	8.9
Medium office	Office	53.6	3	86.8
Small office	Office	5.5	1	325.1
Primary school[a]	Education	74.0	1	14.7
Secondary school[b]	Education	210.9	2	59.3
Stand-alone retail	Retail, other than mall	25.0	1	35.0
Strip mall	Enclosed & strip malls	22.5	1	42.4
Supermarket	Food sales	45.0	1	63.8
Quick service restaurant	Food service	2.5	1	10.1
Full-service restaurant	Food service	5.5	1	22.3
Small hotel[c,d]	Lodging	43.2	4	33.7
Large hotel[d]	Lodging	122.1	6	88.5
Hospital[e]	Inpatient healthcare	241.4	5	77.5
Outpatient health care	Outpatient healthcare	41.0	3	82.9
Warehouse	Warehouse & storage	52.0	1	20.0
Midrise apartment	--	33.7	4	28.6
[a]650 students, [b]1200 students, [c]77 rooms, [d]1.5 occupants each room at 65% occupancy, [e]250 bed; Data Sources: [2] & [1]http://energy.gov/eere/buildings/commercial-reference-buildings				

The models consider the following: building occupancy and operating hours; ventilation requirements and air infiltration; and construction materials. The models incorporate the energy requirements of heating; air conditioning; ventilation; refrigeration; elevators; hot water service demand; commercial kitchens; plug and process loads; and lighting. Data in ASHRAE standards were used for many of the model parameters. The power densities of interior and exterior lighting loads were taken from ASHRAE 90.1-1989 for existing building stock and from ASHRAE 90.1-2004 for new construction. Energy demands for exterior lighting considered building type and specific lighting levels required for façade, main entry and other doors, canopies with heavy and light traffic, drive-throughs, and parking lots. ASHRAE 90.1-1989 and 90.1-2004 set parking lot power requirements at 0.18 and 0.15 W/ft^2 ([2], Table 27), respectively. Parking lot sizes for the reference building models ([2], Table 28) are also included in Table 16.

Based on an office occupancy rate of 200 square feet per person ([2], Table 4), it might be estimated that small, medium and large office buildings have 2493, 268, and 28 employees, respectively. The “plug and process loads” for office buildings were determined based on engineering judgment.

The annual mean energy intensities for new DOE reference model[11] office buildings in Miami are displayed in Figure 27; these intensities represent the total energy supplied by all energy sources, which includes electricity, natural gas, and other sources. For informational purposes in this report, Miami was selected because it had only an annual average of 124 heating degree days from 2011 to 2015 and, therefore, a low demand for heating, which might be supplied by natural gas or another non-electric source. Water heating and kitchen equipment (possibly supplied by natural gas or another source) do not account for a large percentage of energy consumption in office buildings. Therefore, the energy and power intensities displayed in Figure 27 should largely represent electric energy and electric power intensities with a low contribution from other energy sources.

The mean annual energy and power intensities for the DOE “small office” reference model in Miami are 12.9 kW-hours and 1.5 W per square foot. Based on the 2012 CBECS data, Figure 13 illustrates that the mean annual electric energy and power intensities of a commercial building (all building types) located in a hot, humid climate are 18.4 kW-hours and 2.1 W per

[11] New construction annual energy use intensities in kBtu/ft^2 for each of the 16 DOE reference models for each of the 16 reference cities is provided in [18].

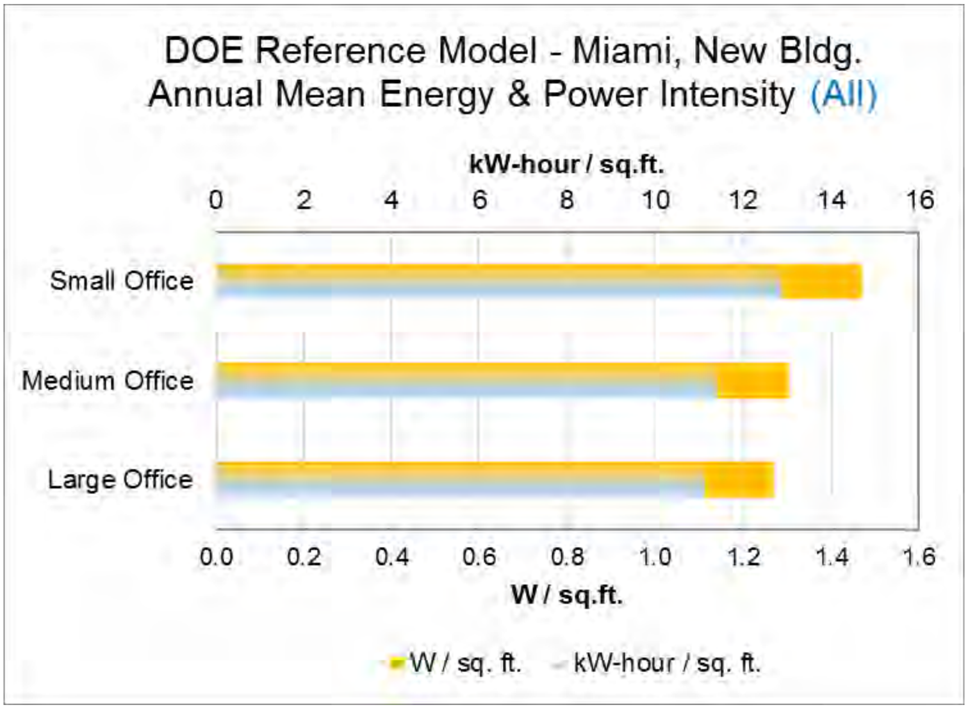


Figure 27. Energy & Power Intensities for DOE Reference Office Buildings in Miami
(Based on data provided in [18] obtained from http://cms.ashrae.biz/EUI)

square foot, respectively. Similarly, Figures 17 and 18 illustrate that the mean annual electric energy and power intensities of a commercial office building are 16.0 kW-hours and 1.8 W per square foot, respectively. When the differences between the data sets represented in the figures are considered, the intensities for new construction in Figure 27 correlate well to the intensities for all building types represented in Figure 13 and to the intensities for the CBECS 2012 office building category (all sizes) in Figures 17 and 18.

5.2 Historical Perspective, Energy Savings, and Coverage

The federal government passed the first energy conservation act in 1975. In 1978, the DOE was given the authority to establish mandatory minimum energy performance standards for appliances. Mandatory minimum energy performance standards have expanded, and coverage includes commercial appliances, lighting systems, motors, transformers, and HVAC equipment efficiencies established in 10 CFR §431. Since the Energy Policy Act of 1992, the U.S. Department of Energy (DOE) has taken an active role in the development, adoption, and impact analysis of model building energy conservation codes for residential, commercial, and federal buildings. [19], [20], [21] Building codes address the energy efficiency of the building envelope regarding fenestration, insulation, air barriers, and air leakage. Building codes address mechanical systems, specifically space and water heating, cooling, ventilation, refrigeration, and exhaust fan requirements. Building codes also address motor and transformer efficiency requirements, electric power and lighting systems, including automatic dimming (lighting) and shut-off requirements. [22], [23], [24]

The estimated site energy savings attributed to the adoption of residential and commercial building energy codes from 2011 to 2015 is 122 TBtu (all energy sources) with a cost savings of $3.0 billion [25, Table 9]. Data in [25, Table B.1] was used to calculate the projected electricity site energy savings for commercial buildings from 2010 to 2030 at 0.27 trillion kWh.

First published in 1975 as ASHRAE 90, ANSI/ASHRAE/IES Standard 90.1-2016, *Energy Standard for Buildings Except Low-Rise Residential Buildings* [22], provides the minimum requirements for commercial buildings. First published in 2000, the 2015 *International Energy Conservation Code* (IECC) [23] provides minimum energy conservation requirements for new commercial and residential buildings. The differences between the commercial building requirements for earlier editions of the ASHRAE 90.1 and IECC are covered in depth in [26]. Since ASHRAE 90.1 is the latest energy code standard released and probably considered more of a benchmark standard for commercial buildings than IECC, ASHRAE 90.1 will be briefly covered in this report.

5.3 ASHRAE 90.1 – General, Power, and Lighting Requirements

ASHRAE 90.1 [22], first published in 2001, establishes the minimum energy efficiency requirements for building design and construction and for maintenance and operation plans. It covers new construction and new systems and equipment in existing buildings except for low-rise residential buildings. The 90.1 standard covers hot water heating, elevators, and escalators. It specifies nominal efficiency levels for low-voltage distribution transformers in accordance with 10 CFR §431.

The standard requires installing energy measurement devices to monitor the total building load and the following building load categories: HVAC, interior lighting, exterior lighting, and receptacle circuits; however, other electrical load categories may account for up to 10% of each monitored load category. Energy usage must be recorded every 15 minutes, and the monitoring system must be able to store data for 36 months.

Automatic receptacle control is also required in at least 50% of general purpose receptacles (125 V, 15 and 20 A) in private offices, conference rooms, print/copy rooms, break rooms, classrooms, and individual workstations. Automatic receptacle control is required on at least 25% of branch circuit feeders installed for modular furniture not shown on construction documents. The control device should turn receptacles off at specifically programmed times or 20 minutes after the space becomes unoccupied.

ASHRAE 90.1 specifies lighting power densities (W/ft^2) for interior and exterior building spaces. Two methods are provided for interior lighting power allowance: a simple building area method and a more flexible space-by-space method. The installed lighting system should not exceed the total power allowed for illuminating the building. Space interior lighting should have a manual control and should be dimmable with at least one intermediate light level. Automatic partial or full shutoff is also required for most spaces 20 minutes after they become unoccupied.

With the building area method, the lighting power densities in Table 17 are used to determine the allowable lighting power for the building [22, Table 9.5.1]. If the building consists of one than one type listed in the table, then the total allowable lighting power is the sum of the lighting power for each area of the building.

The space-by-space method is similar but is a more detailed method of calculating and summing the allowable lighting power for all space types within the building. For example, office buildings might have open or closed offices. Office buildings often contain conference rooms, break rooms, restrooms, storage areas, stairwells, corridors, and other spaces. Furthermore, spaces like corridors require different illuminations levels depending on the building type and purpose. Table 18 includes a few select lighting power allowances for spaces commonly found in office buildings, including laboratories, computer rooms, and workshops [22, Table 9.6.1] sometimes found in engineering and research office buildings. Table 18 also displays the lighting power allowance for corridors in different building types. When the space-by-space method is employed, additional lighting power allowance is permitted for exhibits, retail areas, spaces using non-mandatory lighting controls, and certain room geometries.

For comparison purposes, the lighting power density allowances listed in IECC 2015 [23] Tables C405.4.2(1) and C405.4.2(2) have been included in Tables 17 and 18. The lighting power densities of IECC 2015 and ASHRAE 90.1-2013 are identical except as noted with yellow highlighting.

Table 17. ASHRAE 90.1 & IECC Building Area Method Lighting Power Density Allowances

Building Area Type	90.1-2016 (W/ft^2)	90.1-2013 (W/ft^2)	IECC 2015 (W/ft^2)
Automotive Facility	0.71	0.80	0.80
Convention Center	0.76	1.01	1.01
Courthouse	0.90	1.01	1.01
Dining: Bar Lounge/Leisure	0.90	1.01	1.01
Dining: Cafeteria/Fast Food	0.79	0.90	0.90
Dining: Family	0.78	0.95	0.95
Dormitory	0.61	0.57	0.57
Exercise Center	0.65	0.84	0.84
Fire Stations	0.53	0.67	0.67
Gymnasium	0.68	0.94	0.94
Healthcare Clinic	0.82	0.94	0.90
Hospital	1.05	1.05	1.05
Hotel/Motel	0.75	0.87	0.87
Library	0.78	1.19	1.19
Manufacturing	0.90	1.17	1.17
Motion Picture Theatre	0.83	0.76	0.76
Multi-Family	0.68	0.51	0.51
Museum	1.06	1.02	1.02
Office	0.79	0.82	0.82
Parking Garage	0.15	0.21	0.21
Penitentiary	0.75	0.81	0.81
Performing Arts Theater	1.18	1.39	1.39
Police Stations	0.80	0.87	0.87
Post Office	0.67	0.87	0.87
Religious Buildings	0.94	1.00	1.00
Retail	1.06	1.26	1.26
School/University	0.81	0.87	0.87
Sports Arena	0.87	0.91	0.91
Town Hall	0.80	0.89	0.89
Transportation	0.61	0.70	0.70
Warehouse	0.48	0.66	0.66
Workshop	0.90	1.19	1.19

Table 18. ASHRAE 90.1 & IECC Lighting Power Allowances for Selected Space Types

Common Space Types	90.1-2016 (W/ft^2)	90.1-2013 (W/ft^2)	IECC 2015 (W/ft^2)
Classroom/Training Room	0.92	1.24	1.24
Conference Room	1.07	1.23	1.23
Copy/Print Room	0.56	0.72	0.72
Computer Room	1.33	1.71	1.71
Electrical/Mechanical Room	0.43	0.42	0.95
Laboratory	1.45	1.81	1.81
Office – enclosed	0.93	1.11	1.11
Office – open	0.81	0.98	0.98
Restroom	0.85	0.98	0.98
Stairwell	0.58	0.69	0.69
Storage - < $50ft^2$	0.97	1.24	0.63
Storage - > $50ft^2$	0.46	0.63	0.63
Workshop	1.14	1.59	1.59
Corridor			
…in a facility for visually impaired	0.92	0.92	0.92
…in a hospital	0.92	0.99	0.99
…in a manufacturing facility	0.29	0.41	0.41
…all other corridors	0.66	0.66	0.66

5.4 Development of ASHRAE 90.1 Lighting Power Allowances[12]

The ASHRAE lighting power densities (LPD) have been developed by the 90.1 Lighting Subcommittee with support from a team at Pacific Northwest National Laboratory (PNNL). The LPDs are developed using spreadsheet models based on the IES recommended illumination levels for visual tasks required in specific building spaces. The models incorporate source efficacy data from efficient lighting products, typical light loss factors, and coefficient of utilization values for applicable luminaire types. Light loss factors represent the amount of light lost due to lamp and room surface depreciation and dirt accumulation.

[12] The first three paragraphs of this section were initially drafted by the report author based on [27], but were revised by Eric Richman at PNNL on October 27, 2016. In conversation with Eric Richman on September 8, 2016, he remarked that LED lighting systems had been added to the lighting sources represented in the model used to develop the lighting power allowance in ASHRAE 90.1-2016.

The coefficient of utilization represents the amount of the total lamp lumens which will reach the work plane in a specific room configuration (room cavity ratio) with specific surface reflectances. For the interior space models, ceiling, wall, and floor reflectances were selected as 70%, 50%, and 20% to represent most common building design practices. For each specific space type, appropriate room cavity ratios were chosen from 2 to 10 to represent common geometries for that space type.

Lumen power densities were developed for over 100 different space types and applications. Professional lighting designers on the subcommittee provided additional model input and oversite for design related issues such as task versus general lighting in spaces, appropriate lighting systems, and appropriate room cavity ratios for specific building areas. The ASHRAE space type power densities represent the power needed to illuminate typical spaces using reasonable efficient lighting sources and good effective design. Whole building LPD values are also developed using weighted averages of space LPD values and the mix of spaces in typical building types.

The following simple equations are not part of the ASHRAE 90.1 design process for lighting power allowance. They are general lighting design equations used in the zonal cavity method [28]. They are included here to help clarify the basic process of determining the total luminous flux (lumens), the number of luminaires (i.e., lighting fixtures), and the electric power needed to illuminate a space. Lighting design rests on providing adequate illumination (in lumens) for a space. Different spaces in a building (with different visual tasks) require different levels of illumination.

$$Luminous\ Flux\ (total) = \frac{Illuminance\ required\ for\ task\ (in\ fc\ or\ lux) \cdot floorspace}{coefficient\ of\ illumination \cdot light\ loss\ factor}$$

$$Number\ of\ luminaires = \frac{Luminous\ flux\ (total)}{Lumens\ per\ selected\ luminaire}$$

$$Electric\ Power\ (total\ in\ watts) = Number\ of\ luminaires \cdot Power\ required\ per\ luminaire$$

The placement of the luminaires must also meet certain spacing criteria [28].

6 ENGINEERING PRACTICES

6.1 Electric Utility Demand Load and Transformer Sizing for Commercial Buildings

Austin Energy released employee reference materials on evaluating customer demand load in a 2012 suit filed with the Public Utility Commission of Texas. The Austin Energy material included a table on commercial building demand in VA/ft^2, power factor, and load factor. Figure 28 displays the demand load per square foot in volts-amperes (VA) and watts, and the loading factor expressed as a percentage. Figure 19, developed from the Austin Energy table, shows that restaurants had the highest average power consumption.

As shown in Figure 28, fast-food and sit-down restaurants also have the highest demand load (32 and 25 VA/ft^2, respectively), but their load factors are less than 50%. Large and small food stores, refrigerated warehouses, and hospitals (with demand loads of 13.1, 20,6, 17.8, and 14.5 VA/ft^2, respectively) are the only occupancy types with load factors exceeding 50%, perhaps due to high refrigeration load and long operating hours. The 79% load factor of large food stores accounts for its relatively high average load of 9.2 watts per square foot (shown in Figure 19) even though the demand load is about average. Some occupancy types, including schools (17.5 VA/ft^2), have higher demand loads but only restaurants and small food stores have higher average power densities (shown in Figure 19).

The Austin Energy manual recommends several methods of estimating the demand load for commercial customers. The preferred method is estimating demand based on a similar customer, such as another business of the same franchise, comparable size, and located in the same climate zone. If this method is not feasible, the VA demand load is determined from the demand estimation per square foot for a similar occupancy type as shown in Figure 28. An estimated demand load is also calculated using the demand factors in Table 19 with the connected load, listed on the electrical plans submitted for the building. Depending on the proximity of the estimations, the demand load is assigned to equal the lesser demand or the demand based on occupancy type and building size.

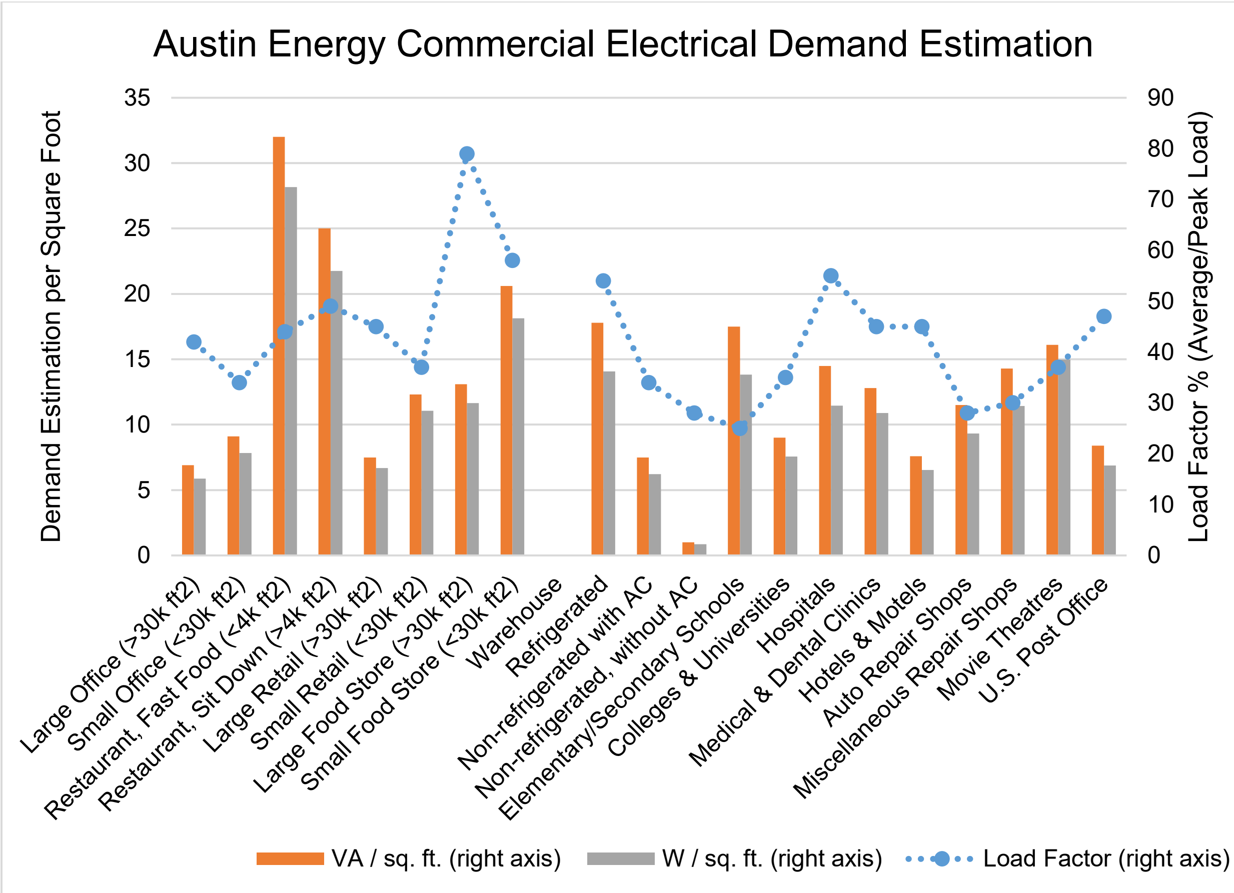


Figure 28. Austin Energy – VA and Power Demand Load in Commercial Buildings
(Data Source: [6])

Table 19. Austin Energy Demand Factors for Connected Commercial Loads

Austin Energy Demand Factors for Connected Commercial Loads			
General Lighting[a]	General Receptacles	Air Conditioning[b]	[a]May be adjusted based on application and hours of usage
0.8	0.1	0.8-1.0	[b]1.0, 0.9, or 0.8 for 1, 2-5, or 5+ units
General Power	Laundry	Water Heaters	
0.3	0.5-0.8	0.2	
Cooking	Refrigeration	Air Compressors	
0.3-0.5	0.5	0.2-0.5	
Elevators[c]	Escalators	Motors[d]	[c]Most operate less than 15 minutes
N/A	0.6	0.3-0.5	[d]Largest + 50% remaining motors

Austin Energy also provided guidelines for transformer loading. Table 20 includes some of the recommended loading ranges for three-phase, pad-mounted transformers based on a maximum load factor of 60% and a balanced three-phase load. A transformer secondary voltage of 208Y/120 V is available with transformer ratings from 75 to 750 kVA. A transformer secondary voltage of 277Y/480 V is available with transformer ratings from 75 to 2500 kVA.

Table 20. Austin Energy Three-Phase Pad-mount Transformer Loading Guidelines[a,b,c]

Transformer Nameplate kVA	Initial kVA Loading Range	kVA Loading Change-out Point
75	0-85	100
150	85-175	200
225	175-275	300
300	275-350	400
[a]For 61-75% load factor, limit initial loading to 75% nameplate, change out at 110%		
[b]For 76-90% load factor, limit initial loading to 70% of nameplate, change out at 100%		
[c]For 90-100% load factor, install next size and limit initial loading to 80%, change out at 100%		

6.2 Traditional Design Practices for Electrical Systems in Buildings

6.2.1 Building Demand Load, Panel, and Feeder Sizing

Consulting engineers and electrical system designers determine building loads by applying demand load factors to connected loads in a similar manner to Austin Energy's guidelines for their employees. In the design process, the first step is to identify (or estimate) the major equipment loads: heating, ventilating, air conditioning, electric water heaters, elevators (if any), and any other owner or tenant equipment. The engineer determines the lighting and receptacle load. The total demand load on the main panel or a sub-panel is based on the connected loads and the category demand factor for each type of connected load. The demand load on a panel might be calculated by organizing the connected loads into categories and the applying demand factors displayed in Table 21. [28]

It has been noted in [29] that the listed ampere requirements on packaged HVAC units are lower than NEC Article 440 requirements for calculating the ampacity of the multiple motors found in field installed air conditioning equipment. Comparisons of the power requirements of packaged HVAC equipment with the total ampacity that would be required to supply all the motors packaged inside the equipment validate this assertion.[13]

The National Electrical Code is a standard which specifies the minimum requirements for electrical installations. The National Electric Code is adopted (with or without amendments) by states. Final approval of the design and installation of an electrical system in a building rests on

---

[13] Based on the report author's experience reviewing the electrical and mechanical plans of several commercial buildings.

the authority having jurisdiction. In some circumstances, engineers may find it prudent to exceed code guidelines or comply with local regulations. [28]

The demand load at the main panel may be less than the sum of the demand loads on each panel. For example, the summer air conditioning load may be larger than the winter heat load. Rooftop air conditioning units are likely to be connected directly to the main panel, but electric resistance heat is likely to be connected directly to subpanels. Furthermore, the total receptacle demand load calculated at the main panel will be less than the sum of the receptacle demand loads on the subpanels. Consider three panels supplying connected receptacle loads of 10, 10, and 20 kVA with demand loads of 10, 10, and 15 kVA (summing to 35 kVA). The receptacle demand load on the main panel is 25 kVA.[14]

Table 21. Traditional Engineering Demand Factors for Building Loads*

Load Category	Demand Factor	Comments
Air conditioning	0 or 1	If heating and ac do not operate at the same time, the larger load has demand factor of 1.
Resistance heat & motors for heating	0 or 1	
Water heating	1	
Lighting	1.25	"Continuous," circuit loading cannot exceed 80%
Receptacle	1 x 1st 10kVA, 0.5 x remainder	180VA per receptacle is general minimum standard, see NEC 220.14 and 220.44
Motors	1	See NEC 430.24
Largest motor	0.25	See NEC 430.24
Other loads	1 or 1.25	1.25 for continuous, 1 otherwise
Kitchen	0.65 – 1.0	Depending on number of items, see NEC 220.56
Spare capacity	1	

*Demand factors from [28]

6.2.2 Branch Circuit Sizing and Protection

Branch circuits are directly connected to the end use equipment, including resistance heating, water heaters, motors (such as elevators), lighting fixtures, and receptacle load. Circuit breakers are not allowed to continuously carry 100% of their current loading. Therefore, for non-motor loads, the overcurrent protective device is the next standard size higher than 1.25 times the required load current. Wire size selection is based on the rating of the overcurrent protective device. [28]

---

[14] Correct use of receptacle demand factor in NEC Table 220.44 verified through email with Derek Vigstol, Senior Electrical Specialist at NFPA, October 14, 2016.

Determining the appropriate branch circuit wire size and overcurrent device is more complex for motor loads. For branch circuits supplying a single motor, the wire size should be selected as the next standard size higher than 1.25 times the motor's full load amp (FLA) rating. The sizing of the overcurrent protective device depends on the delay-time characteristics of the protective device. The appropriate sizing for a thermal-magnetic circuit breaker would be next standard size higher than 1.75 times the motor full load amps. For an overcurrent protective device such as a time-delay fuse, the device rating should be higher than 1.25 times the FLA. When a branch circuit serves several motors, the wire size is based on 1.25 times the FLA of the largest motor plus the sum of the FLAs of the smaller motors. The calculation is identical for time-delay overcurrent protective devices. For molded case circuit breakers, the calculation is similar except the largest motor FLA is multiplied by 1.75. [28]

Wiring sizing for feeders and branch circuits must also comply with voltage drop requirements.

6.2.3 In-House Transformers and Connecting Equipment Selection

Step-down transformers in building electrical systems are based on the demand load being supplied. The next size transformer higher than the calculated demand is selected. The size of the overcurrent protection device on the secondary must not exceed 1.25 times the rated secondary current. The size of the overcurrent protection device on the primary is selected as the next standard size higher than 1.25 times the rated primary current. The primary and secondary conductors are based on the overcurrent protective device ratings. [28]

6.3 NEC Lighting Requirements and Other Lighting Guidelines

6.3.1 NEC and NEC Comparison with ASHRAE Requirements

Interior and exterior lighting systems for buildings are designed to ensure adequate levels of illumination to meet the visual tasks required in a space. Appropriate selection and placement of lighting fixtures are equally important in the design process. Table 220.12 of the 2017 National Electrical Code specifies the minimum lighting load (in VA/ft^2) for specific occupancy types with two permitted exceptions. The first exception, added to the 2014 edition, allows the lighting load to comply with the energy code adopted by the authority having jurisdiction if a monitoring system is installed and the demand factors in Table 220.42 (applicable to dwelling units, hospitals, hotels, and warehouses) are not applied. The second exception, added to the 2017 edition, allows the minimum lighting power density to be reduced by of 1 VA/ft^2 for office and bank areas in a building which complies with an adopted energy code.

Table 22 shows that the minimum NEC lighting power densities (in VA/ft^2) have changed little since 1968, yet lighting technologies have advanced and have become much more energy efficient in the last fifty years. Also included in Table 22, the lighting power allowances (in W/ft^2) in ASHRAE 90.1, even the 2004 edition, are considerably lower than those in the NEC for most occupancy types. Furthermore, the commercial reference building model for new construction developed for the U.S. Department of Energy uses the lighting power allowances in ASHRAE 90.1-2004; this suggests that power requirements of modern lighting systems to provide adequate illumination are more in alignment with ASHRAE 90.1-2004 than the 2017 NEC.

It must be remembered that the minimum lighting power density requirements were likely included in the NEC to ensure that adequate illumination was provided for the visual tasks of the space. In the last half century, the light output efficiency (lumens per watts) has increased significantly. The U.S. Department of Energy has set minimum lamp efficiency requirements on some types of linear fluorescent and halogen lamps.[15] It should also be noted that at one time, office tasks included reading from paper and required higher illumination levels than current office tasks which focus on computer interaction and reading some higher quality printed material. Consequently, overhead lighting systems that were once designed to produce between 750 to 1000 lux can now be designed to produce between 300 and 500 lux [30].

[15] Effective July 14, 2012 40-205W Halogen PAR lamps and some linear T12, T8 and T5, and U-bend fluorescent lamps must meet 2009 DOE regulations established in Federal Register Vol. 74, No. 133, Part II Department of Energy 10 CFR Part 430 Energy Conservation Program: Energy Conservation Standards and Test Procedures for General Service Fluorescent Lamps and Incandescent Reflector Lamps; Final Rule, July 14, 2009.

Table 22. NEC (VA/ft^2) and ASHRAE 90.1 (W/ft^2) Lighting Power Density by Occupancy

Type of Occupancy	NEC 1968	NEC 1971	NEC 1981	NEC 2017	90.1-2004	90.1-2013
Armories and auditoriums	1			1		
Banks	2	5	3½	3½		
Barbershops & beauty parlors	3			3		
Churches	1			1	1.3	1
Clubs	2			2		
Courtrooms	2			2	1.2	1.01
Dwelling Units	3			3		
Garages – commercial (storage)	½			½		
Hospitals	2			2	1.2	0.94
Hotels, motels & apts. (no cooking)	2			2	1	0.87
Industrial commercial (loft) bldgs.	2			2		
Lodge rooms	1½			1½		
Office buildings	5		3½	3½	1	0.82
Restaurants	2			2	1.4	0.9
Schools	3			3	1.2	0.87
Stores	3			3	1.5	1.26
Warehouses (storage)	¼			¼	0.8	0.66
Assembly halls, & auditoriums*	1			1		
Halls, corridors, closets, & stairways*	½			½		
Storage spaces*	¼			¼		
*Except in individual dwelling units, See Table 18 for 90.1-2013 and 90.1-2016 allowances						

6.3.2 IEEE, IES, and Federal Lighting Recommendations

A joint IEEE I&CPS and IES committee[16] has been tasked with drafting a new IEEE Technical Book 3001.9 *Recommended Practice for Industrial and Commercial Lighting Systems*. The initial draft was rescinded and is under revision. When released, the IEEE Technical Book 3001.9 will not overlap with the IES Handbook contents and IES recommended practices; it will refer the reader to the appropriate work published by IES. The initial draft copyrighted in 2012 included the design lighting power densities and required illumination levels for federal buildings from the 2003 and 2005 PBS-P100, *Facilities Standard for Public Service Buildings* [31], released by the U.S. General Services Administration.

Table 23 lists the nominal average recommended illumination levels for various space types within a building as specified in the 2003 PBS-P100. Table 23 includes the lighting

[16] The committee is composed of members from the IEEE Industrial and Commercial Power Systems group and from the Illuminating Engineering Society of North America. Steven Townsend, 3001.9 Working Group Chair, responded to inquiry about technical book status in an email dated October 21, 2016, and attached rescinded draft standard to the response email.

demand load for building areas published in the 2005 PBS-P100; the estimated demand load did not stipulate maximum design values. Also included in Table 23 are the lighting power allowances calculated to comply with the 2014 PBS-100, which states that the lighting load must use 30% less energy than required by the ASHRAE 90.1-2007 space-by-space method. The 2014 PBS-P100 does recognize that the actual lighting power density demanded by a space is reduced when lighting controls are used to reduce the illumination levels. Lighting controls might be employed due to: partial illumination provided by daylight, lack of occupancy, or reduced light levels desired [31, 2014 ed., pg. 136].

Table 23. Recommended Illumination Levels and Lighting Densities in PBS-P100

Building Area	PBS-P100 2003 (Lux)	PBS-P100 2005 (VA/ft^2)	ASHRAE 90.1-2007 (W/ft^2)	PBS-P100 2014 (W/ft^2)
Office: Enclosed 1	500	1.5	1.1	0.77
Office: Open1	500	1.3	1.1	0.77
Conference/Meeting/Multipurpose	300	1.5	1.3	0.91
Classroom/Lecture/Trainings	500	1.6	1.4	0.98
Lobby	200	1.8	1.3	0.91
Atrium: first three floors	200	1.3	0.6	0.42
Atrium: each additional floor		0.2	0.2	0.14
Lounge/Recreation		1.4	1.2	0.84
Dining Area	150-200	1.4	0.9	0.63
Food Preparation	500	2.2	1.2	0.84
Restrooms	200	1.0	0.9	0.63
Corridor/Transition	200	0.7	0.5	0.35
Stairs	200	0.9	0.6	0.42
Active Storage		1.1	0.8	0.56
Inactive Storage		0.3	0.3	0.21
Electrical, Mechanical, and Telecommunication Rooms	200	1.3	1.5	1.05

6.4 Federal Recommendations in Building Electrical System Design

6.4.1 GSA's PBS-P100, Facilities Standards for the Public Buildings Service

The Public Buildings Service (PBS) of the U.S. General Services Administration (GSA) provides a workspace for 1.1 million federal civilian employees and is one of the top real estate holders in the United States. Most of the buildings are courthouses, land ports of entry, and federal office buildings. The PBS-P100, *Facilities Standards for the Public Buildings Service,* is a mandatory standard which covers the design and construction of new federal buildings and major renovations to existing buildings. [31, 2014 ed.]

The General Services Administration (GSA) tends to own and operate buildings longer than the private sector. Buildings may undergo major or minor renovations as the building function changes. "Electrical and communication systems should provide ample capacity for increased load concentrations in the future and allow modifications to be made in one area without causing major disruptions in other areas of the building [31, 2003 ed., pg.181]." GSA buildings are generally constructed to more exacting specifications, but all buildings should be designed and constructed with the life cycle of the building in mind.

6.4.2 PBS-P100 Advanced Building Metering and Control

New federal buildings must install advanced electric metering equipment. Meters must be capable of monitoring phase voltages, phase current, demand power consumption, power factor, and reactive power. Meters must communicate via MODBUS/TCP/IP. [31, 2014 ed]

6.4.3 PBS-P100 Demand Load Calculations

In PBS-P100 2014, the demand power requirements for the following connected load categories are established:

- Motor and equipment loads*
- Elevator and other vertical transportation loads*
- Lighting
- Receptacle
- Miscellaneous*
    - Security, communication, alarm, and building automation systems
    - Heat tracing
    - Kitchen equipment
    - Central computer servers and data centers
    - Uninterruptible power supply (UPS) and battery rooms
- *Must comply with power requirements and full-load efficiencies in ASHRAE 90.1-2004.

The lighting load requirements in PBS-P100 have been addressed in the Section 6.3.2. The minimum receptacle load power densities for typical installations is included in Table 24. Circuits for 120-V convenience receptacles must be limited to 1,440 VA (180 VA each).

Electrical systems are sized according to the total demand load from the load categories included in the bullet-point list and the spare capacity listed in Table 25. However, the 2014 PBS-P100 cautions:

Before adding the spare equipment ampacity to account for future load growth, it is important that the load study reflects actual demand loads rather than connected loads. The designer must apply realistic demand factors by taking into account various energy-conserving devices such as variable frequency drives applied to brake horsepowers, energy-efficient motors, occupancy sensors, and so on. The designer must also avoid adding the load of standby motors and must be careful to distinguish between summer and winter loads by identifying such “noncoincidental” loads. A “diversity factor” must be applied to account for the fact that the maximum load on the elevator system, as a typical example, does not occur at the same time as the peak air conditioning load. [31, 2014 ed., pg.153]

Table 24. 2014 PBS-P100 Minimum Receptacle Load Power Density

Building Area	Service Equipment W/ft^2	Distribution Equipment W/ft^2
Office: Enclosed	1.30	2.50
Office: Open	1.30	3.25
Non-workstation areas	0.50	1.00
Core and public areas	0.25	0.50
Technology/server rooms	50	65

Table 25. 2014 PBS-P100 Additional Spare Capacity

	Spare Ampacity	Spare Circuit Capacity
Panelboards for branch circuits	50%	35%
Panelboards – lighting only	50%	25%
Switchboards & distribution panels	35%	25%
Main switchgear	25%	25%

6.4.4 PBS-P100 Treatment of Harmonics

The branch circuit distribution system supplies equipment which generates harmonics.

Harmonic loads include:

- Computers Laser printers Copiers Fax machines File servers
- Variable Frequency Drives Electronic ballasts Telecommunication equipment

Harmonic distortion can cause overheating in transformer and conductor neutrals, motor failure, false tripping of protective devices, computer operational problems, and hardware component failures. K-rated transformers (K13 or higher) with a 200% neutral can be used to dissipate the additional heat generated by harmonic distortion. However, the 2014 PBS-P100 states that harmonic mitigating transformers are preferred since they cancel the harmonic frequencies. Panelboards supplied by K-rated or harmonic-mitigating transformers must be provided with a 200% neutral. [31, 2014 ed.]

7 OVERSIZING AND "RIGHTSIZING" TRANSFORMERS

A corollary of this project on evaluating the electrical feeder and branch circuit loading is the loading level of transformers. Previous work suggests that oversizing transformers results in increased transformer energy losses and greater arc flash hazards. One objective of addressing transformer efficiency in this section is to illustrate the importance of "right selecting" transformers to reduce transformer energy losses.

7.1 1999 Cadmus Transformer Loading Study [32]

A 1999 study on 89 low-voltage dry-type distribution transformers with three-phase 480-V primaries[17] and capacity ratings between 15 and 300 kVA determined that the average RMS load factor was approximately 16% of the transformer rating. Only 14% of the transformers had RMS average loads greater than 35%.

Table 26 illustrates that the group of twelve transformers rated 15 to 30 kVA had the highest average and maximum RMS load factors. The average and maximum RMS load factors increased as transformer capacity decreased in the four lower capacity groups (i.e., 15 to 30, 45, 75, and 112.5 to 150 kVA). The two largest capacity transformer groups (112.5 to 150 and 225 to 300 kVA) had maximum RMS load factors at approximately 35%; however, the average RMS load factors for the two groups deviated by about 8%. This deviation was attributed to the relatively small sample number and the diversity in the building operations (building types, hours, etc.).

Table 26. Measured Transformer Load Factor in 1999 Cadmus Study

RMS Load Factor	15-30 kVA	45 kVA	75 kVA	112.5-150 kVA	225-300 kVA
Average	23.4%	15.6%	14.0%	12.3%	19.9%
Maximum	62.4%	50.0%	40.2%	34.3%	35.6%
Minimum	1.3%	1.1%	0.9%	0.0%	11.0%
Number of Trans-formers (89 Total)	12	28	34	10	5

Transformer loading is expected to fluctuate; one or two phases may even be more heavily loaded. Transformer selection is usually based on the demand load with spare capacity for future load built into the calculation. The average peak loading factor of the transformers studied was only one-third of transformer capacity.

---

[17] Dave Korn, a principal investigator in the study, confirmed in email on October 17, 2016 that the transformers were three-phase 480 V on the primary, and "All or nearly all secondaries were 208V/120V."

The transformers were evenly selected from five building types: office, manufacturing, healthcare, school and institutions, and retail. Some buildings operated with one shift of workers and other buildings operated with two or three shifts. However, different building types and operating hours were found to cause little change in transformer loading. The transformers mainly served general lighting and receptacle load, which consisted primarily of office equipment and task lighting. Other loads included small water heaters, pumps, exhaust fans and other HVAC equipment, low-voltage manufacturing equipment, forklift battery chargers, and sign lighting.

All buildings had been constructed or modified in the last ten years. Most transformers had also been manufactured in the last ten years, but all were less than fifteen years old. In the initial phase of the study, 353 transformers in 43 buildings were observed. Nameplates on some were missing or inaccessible; 335 transformers were surveyed, and loading data was collected on 89 of those for a two-week period. Roughly 50% of the transformers surveyed were rated 45 or 75 kVA. By rise type, 80% of the transformers surveyed were 150°C temperature rise.

The transformers were between 90 and 98% efficient in power delivery. Winding losses are proportional to the square of the current flowing through the windings. The core losses are relatively constant and independent of transformer loading. Core losses account for a significant percentage of transformer losses when transformers are lightly loaded (0 to 30%); on the other hand, winding losses account for a significant percentage of transformer losses when transformers are heavily loaded (65 to 100%).

Spot measurements of power factor, total harmonic distortion and K-factor were taken when the transformer monitoring equipment was installed and removed. The roughly 80% of the measured K-factors (estimation based on Figure 4-5 in [32]) were 4 or less. K-factor is a metric of a transformer's ability to withstand harmonics. Higher harmonics are associated greater heat losses. A K-factor equal to 4 corresponds to a non-linear loading of 50% [33].

Table 27. 1999 Cadmus Study – Power Factor, Total Harmonic Distortion, and K-Factor

Spot Measurement	Power Factor	Total Harmonic Distortion	K-Factor
Average	0.87	21	2.7
Median	0.91	12	1.4

7.2 Transformer Loading and Efficiency

The U.S. Department of Energy mandates efficiency requirements and defines test procedures for measuring distribution transformer energy loss in the Code of Federal Regulations.

Transformer efficiency is a function of transformer loading; 10 CFR §431.196 specifies the evaluation of transformer load losses at 35% of rated load with an operating temperature of 75°C (55°C temperature rise above a 20°C ambient temperature). The regulation does not explain why 35% is the reference load level, although other work has suggested that the origin is a 1997 report which states: "…most low-voltage dry distribution transformers have a peak load of only about 50-60% of their rated capacity." It further states, "A per unit RMS load of 0.35 is a reasonable assumption." [34] As shown in Figure 29, maximum transformer efficiency also occurs in the vicinity of 35% loading.

Furthermore, Figure 30 shows that the power losses as a percentage of power supplied increase when transformers are more lightly and heavily loaded. The power lost as a percentage of power supplied to the EL-6 amorphous core is lowest from 10% to 40% of the rated load; furthermore, the losses are lower than the traditional core materials EL-4 and EL-5 for loading of 50% and less. The EL-5 standard core transformer has lower losses than the EL-4 and EL-6 at 60% the rated load and higher. However, the power loss as a percentage of power supplied for the EL-5 is lowest from 30% to 60% loading. Figures 29 and 30 use efficiency data for Eaton 45 kVA transformers with 480Δ-208Y V windings and 115°C rise type, but constructed using three different core materials.[18]

Transformers loaded close to the transformer rating are associated with higher power losses as a percentage of the power supplied. Power loss and supply calculations in Figures 30, 31, and 32 are based on loading at a 0.95 power factor, real power losses (W), and real power supplied (W). In Figure 31, real power losses are calculated for Eaton 480Δ-208Y V, 115°C rise, EL-5 (23QGD080) transformers rated at 30, 45, and 75 kVA supply loads ranging from 7.5 to 45 kVA.[19] The 30 kVA transformer does supply the 7.5 kVA load with the lowest power losses, 9 W in comparison with 15 to 16 W. However, Figures 31 and 32 illustrate that power losses for the transformers at these loading levels generally decrease as the transformer kVA rating increases. In Figure 32, Eaton 480Δ-208Y V, 150°C rise transformers with aluminum windings rated from 75 to 300 kVA supply loads from 75 to 225 kVA.[20]

[18] Robert Yanniello, Vice President of Engineering & Technology, Eaton's Electrical Systems & Services Group, provided the transformer efficiency data at loading levels of 10 to 100%, in 10% increments attached to email dated October 21, 2016.
[19] Robert Yanniello, provided the transformer efficiency data at loading levels of 10 to 100%, in 10% increments attached to email dated November 15, 2016. The efficiencies were linearly interpolated to determine the efficiencies at other loading levels.
[20] Robert Yanniello, provided a pdf file "DOE 2016 Tech Data 3-28-2016," attached to email dated October 21, 2016. The file contained efficiency data at 25, 50, 75, and 100% loading levels for Eaton

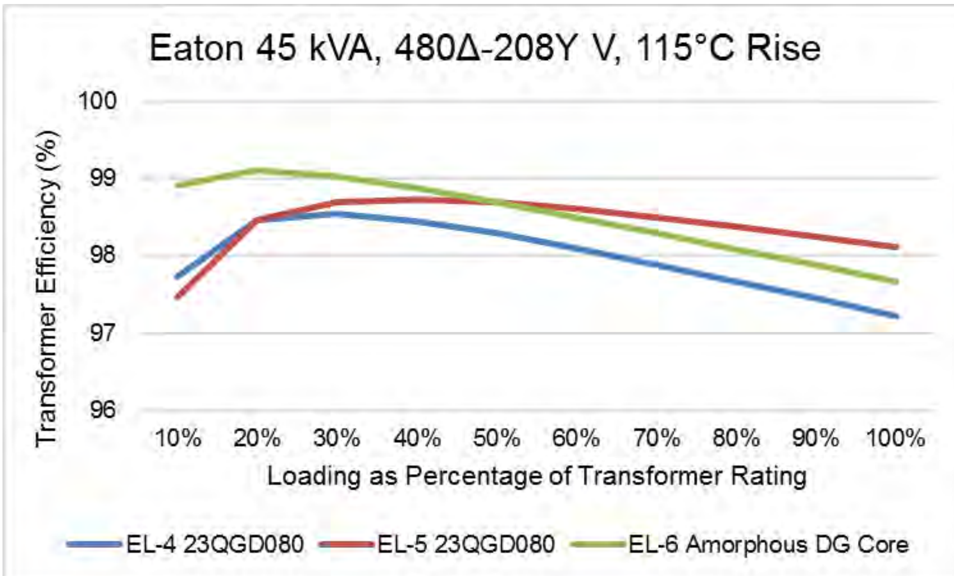


Figure 29. Efficiency Curves for Three Eaton 45 kVA, 480Δ-208Y-V Transformers

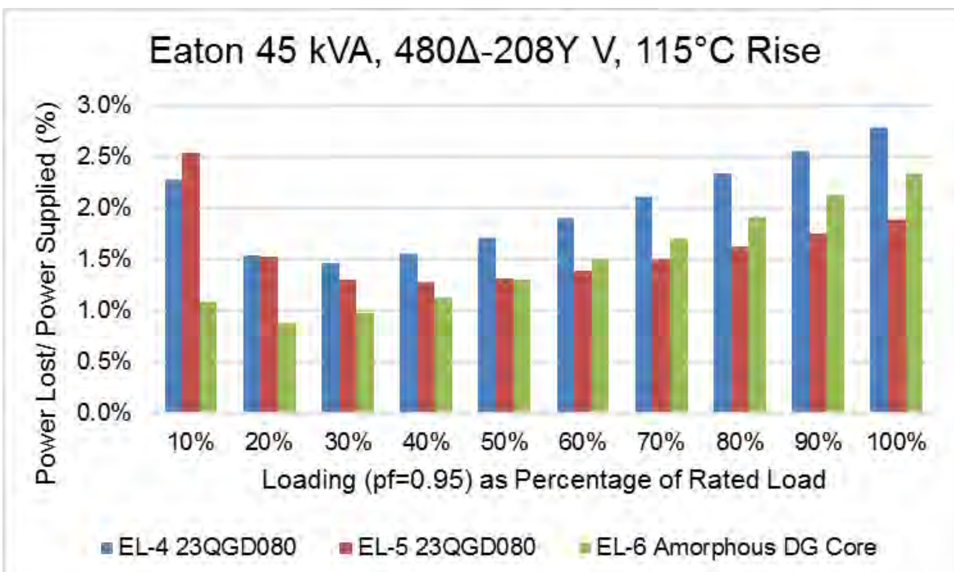


Figure 30. Power Losses as Percentage of Power Supplied for Three Eaton Transformers

---

transformers, including the three-phase 480Δ-208Y/120V, 150°C with aluminum windings (model V48M28T…) in Figure 32. Again, linear interpolation was used to determine other efficiency values.

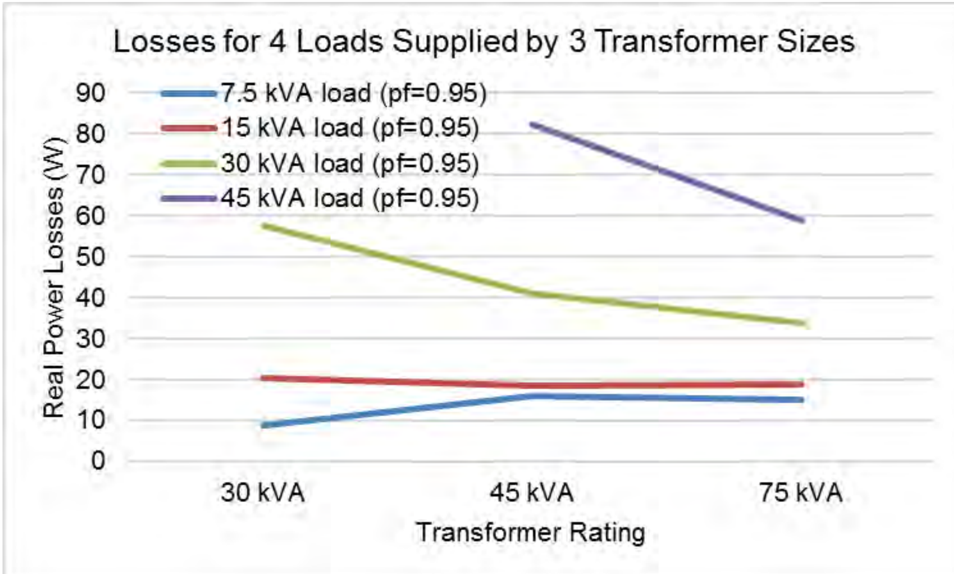


Figure 31. Power Losses: 7.5 to 45 kVA Loads Supplied by 30 to 75 kVA Transformers

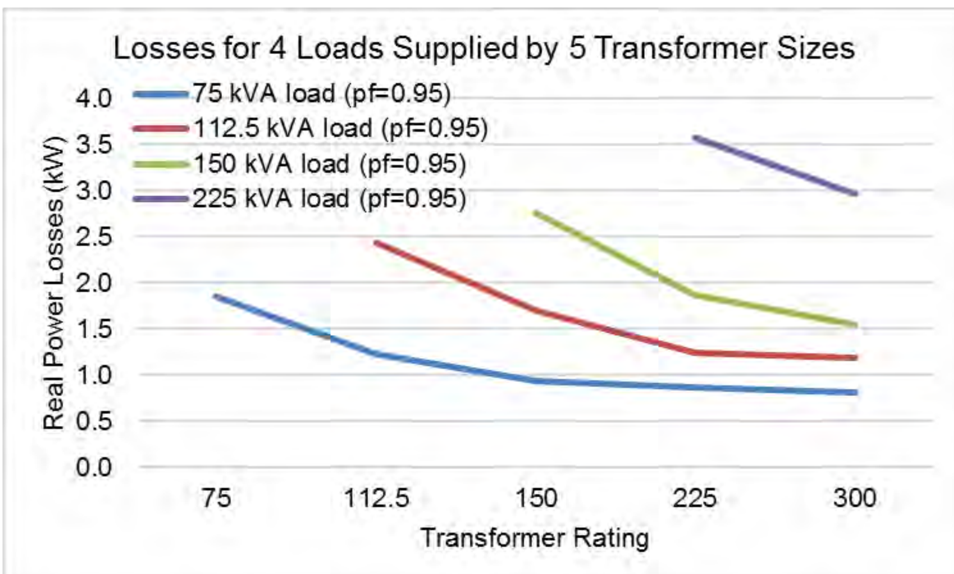


Figure 32. Power Losses: 75 to 225 kVA Loads Supplied by 75 to 300 kVA Transformers

Figures 29 and 30 illustrate that transformer efficiency is dependent on the core material. Transformer efficiency is also dependent on temperature-rise type. Figures 33, 34, and 35 show that transformer types with lower rather than higher rise temperatures are more efficient for all three Eaton 45 kVA, 480Δ-208Y V transformers in Figures 29 and 30 with traditional EL-4 and EL-5 refined steel cores, as well as the amorphous core EL-6. Transformers with a 150°C

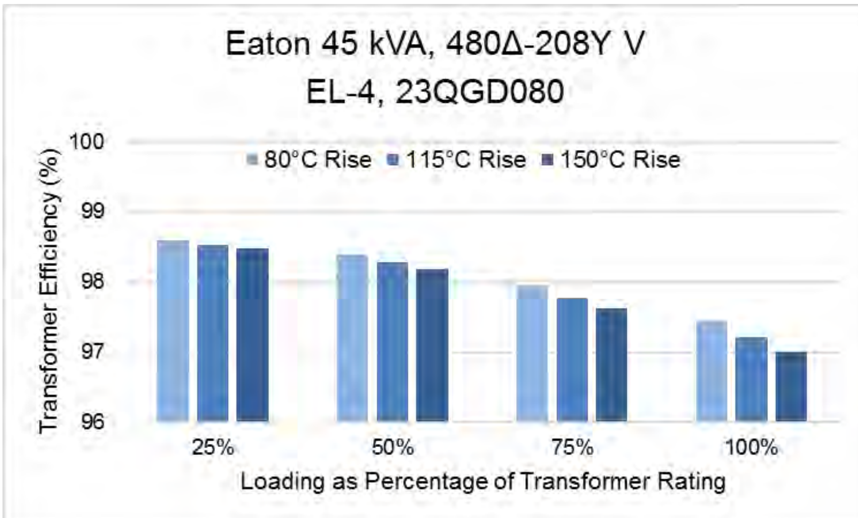


Figure 33. Efficiency as Function of Rise for 45 kVA, 480Δ-208YV, EL-4 Core Transformer

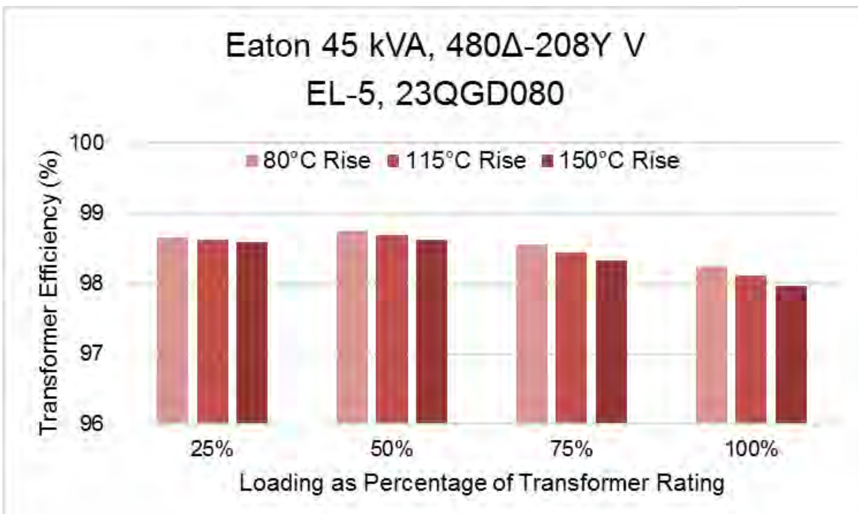


Figure 34. Efficiency as Function of Rise for 45 kVA, 480Δ-208YV, EL-5 Core Transformer

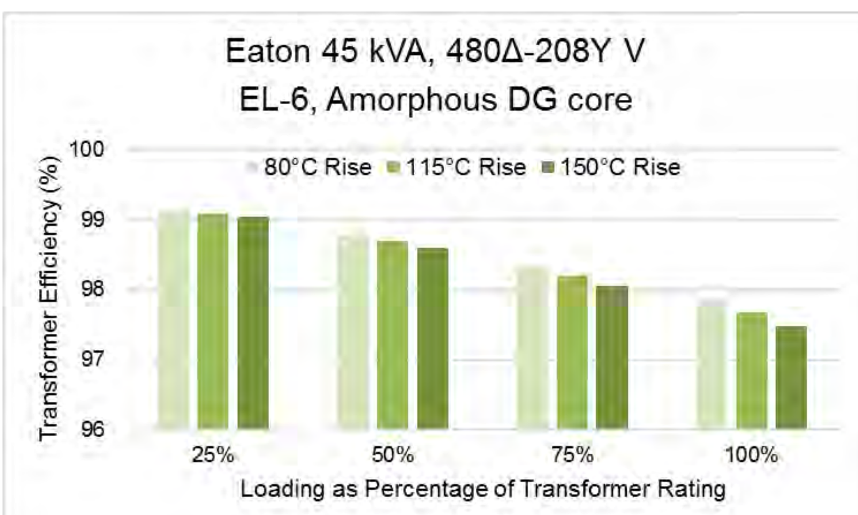


Figure 35. Efficiency as Function of Rise for 45 kVA, 480Δ-208YV, EL-6 Amorphous Core

temperature rise is the standard selection, but temperature rise specifications of 80°C and 115°C are also common. A temperature rise specification of 150°C allows the transformer temperature to rise 150°C (302°F) above the ambient temperature (20°C), so a fully loaded commercial transformer can exceed 300°F [35]. Data provided by Eaton on the percentage of three-phase transformers manufactured in 2016 by rise type is included in Table 28.[21] Single-phase transformers have similar percentages. Other manufacturers are expected to sell similar relative percentages.

When transformers with no K-factor rating (i.e., K-factor = 1) supply non-linear loads, the harmonics generated by nonlinear loads reduce expected transformer efficiency and can reduce transformer life. Harmonics increase transformer load and no-load losses, but the increase in eddy current losses is the most significant. Transformers with K-factors higher than one are specially designed to reduce eddy current losses in the windings. Core laminations may be individually insulated, and the size of the transformer core and windings may be increased [36]. K-factor, a weighting of the harmonic load current, is defined by the following equation, where n is the harmonic number and i_n is the magnitude of the harmonic current.

$$K - factor = \sum i_n^2 n^2 \ / \ \sum i_n^2$$

Pure linear loads have a K-factor of one. Higher harmonics are associated with greater heat losses.

Harmonics are commonly generated in building systems, and transformers are sometimes de-rated and oversized to compensate for the presence of harmonic current. However, selecting the appropriate K-factor transformer may be more economical [37] and is a better approach to reducing power losses. Data provided by Eaton on the percentage of three-phase transformers (115°C rise type) manufactured in 2016 by K-factor is included in Table 29. Single-phase transformers have similar percentages. Furthermore, other manufacturers are expected to sell similar relative percentages.

Table 28. Eaton Percentage of Transformers Manufactured in 2016 by Rise Type

150°C Rise	115°C Rise	80°C Rise
82%	14%	4%

[21] Robert Yanniello provided the data in Tables 28 and 29 in email dated October 21, 2016. The data represent ventilated, dry type distribution transformers with low-voltage primary and secondary windings. Mr. Yanniello provided clarification on the data in email dated November 21, 2016.

Table 29. Eaton Percentage of Transformers Manufactured in 2016 by K-Factor Rating

K-Factor = 1	K-Factor =4	K-Factor = 13	K-Factor = 9 OR K-Factor = 20
94%	2%	4%	<1%

7.3 Transformer Sizing and Arc Flash Hazards in Building Systems

The Request for Proposal soliciting contractors for this Phase I research project stated: "In addition, larger than necessary transformers that supply power to feeder and branch circuits expose unnecessary flash hazard to electricians working on live equipment." The author of this report does not necessarily agree that this statement is true for dry-type distribution transformers in building systems with low-voltage primary and secondary windings. This section provides the results of sample calculations for three typical 480 V building systems[22] listed in Table 30. The systems represent low-, medium-, and higher- capacity systems with available three-phase, RMS short-circuit currents ranging from over 14 kA to over 50 kA at the main distribution panel. Certainly, there are some "high capacity" systems with higher available fault currents, but a representative system has not been developed for this work.

Transformers which step down 480 V to 208Y/120 V are used in buildings systems to supply lower-voltage mechanical loads, including water heaters, various fans, sump pumps and ductless heat pumps, as well as other specialized equipment and receptacle load. Feeders supplying transformers with different ratings are sized according to transformer capacity and any overcurrent protective devices present. Feeder lengths are determined by the physical layout of the electrical system in the building.

Since feeder impedance is a function of length, shorter feeders, supplying in-house distribution transformers located near the main switchgear or main switchboard, tend to have less impedance than longer feeders. Feeders with larger ampacities supplying transformers with higher kVA ratings have less impedance per unit length than those supplying transformers with lower kVA ratings. None the less, the feeder impedance further decreases the available fault current at the transformer. For illustration purposes, the impedances of the feeders supplying the transformers have been neglected, so that the direct impact of different transformer ratings on potential arc current is not obscured by different feeder impedances.

Figures 36 and 37 display the faults currents calculated at the secondary of 480-208Y/120 V transformers rated from 15 to 300 kVA supplied by "low," "medium," and "higher"

[22] The three typical systems were developed for use in [38] and later used in [39].

Table 30. Three Typical 480-V Building Systems

Capacity	Low	Medium	Higher
Utility System kVA and X/R	100,000kVA X/R=6	250,000kVA X/R=8	500,000kVA X/R=10
Utility Transformer kVA and X/R (%Z = 5.32)	750 kVA X/R=5.7	1,500 kVA X/R=8.1	2,500 kVA X/R=8.3
Main Feeder (40') Conductor Size and Conduit	4 sets 4 #350 kcmil, 3" conduit	6 sets 4 #400 kcmil, 3" conduit	11 sets 4 #500 kcmil, 3" conduit
Service Entrance Rating (A)	1,200	2,000	4,000
Service Entrance Impedance	19.1mΩ, X/R=5.3	9.37mΩ, X/R=7.1	5.51mΩ, X/R=7.5
Available 3-phase RMS Isc (A)	14,528	29,578	50,304
IEEE 1584-2002 Iarc (A) [a]	8,610	15,575	24,249

[a] 1584 Iarc based on arcing in an enclosure and an arc gap width of 1.25".

capacity systems. The available three-phase, RMS short-circuit currents are determined from the following equations:

$$Isc_{secondary} = \frac{120}{Z_{secondary}}$$

$$Z_{transformer} = \left(\frac{208^2}{VA\ Rating}\right) \cdot \left(\frac{\%Z_{transf}}{100}\right) \cdot \left(\cos\left(\arctan\left(\frac{X}{R}\right)_{transf}\right) + j\sin\left(\arctan\left(\frac{X}{R}\right)_{transf}\right)\right)$$

$$Z_{secondary} = Z_{up\ to\ transformer} \cdot \left(\frac{208}{480}\right)^2 + Z_{transformer}$$

Some values associated the transformer impedance calculation are included in Table 31, based on Eaton 480Δ-208Y V, 150°C rise transformers[23] with aluminum windings rated from 15 to 300 kVA.

The impedance of the transformer has a far more limiting effect on the available fault current than the impedance of the electrical system up to the location of the transformer for the three typical systems in Table 30. (The system impedances referred to the transformer secondary are 3.58, 1.76, and 1.03 mΩ, respectively.) For the transformers rated up to 112.5 kVA, the available three-phase, short-circuit current does not even reach 7 kA. At higher transformer ratings (150 kVA and higher) in Figure 36, the transformer impedance decreases and the limiting effect of the electrical system impedance on the available short-circuit current becomes more evident in lower and medium capacity systems.

[23] In email dated November 29, 2016, Robert Yanniello attached excel file "Tech Data as 06-06- 2016," providing Eaton transformer %Z, X, and R (all at Trise +20°C) data.

Table 31. Impedance for 480Δ-208Y/120 V, 150°C Rise, 15 – 300 kVA Transformers

kVA Rating	%Impedance	X/R	Impedance (mΩ)*	Catalog Number
15	3.74	0.50	107.9	V48M28T15EE
30	2.44	0.48	35.2	V48M28T30EE
45	3.51	0.97	33.7	V48M28T45EE
75	3.61	1.31	20.8	V48M28T75EE
112.5	4.37	1.92	16.8	V48M28T12EE
150	3.46	1.72	10.0	V48M28T49EE
225	4.29	2.86	8.2	V48M28T22EE
300	4.45	2.62	6.4	V48M28T33EE

*The magnitude of the transformer impedance is with respect to the secondary winding.

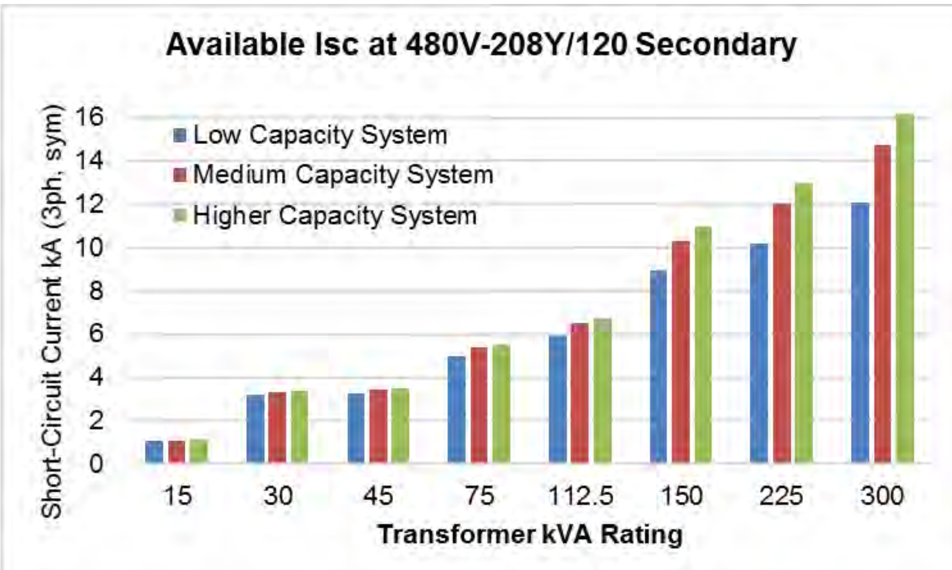


Figure 36. Available Short-Circuit Current at Transformer Secondary in Typical Systems

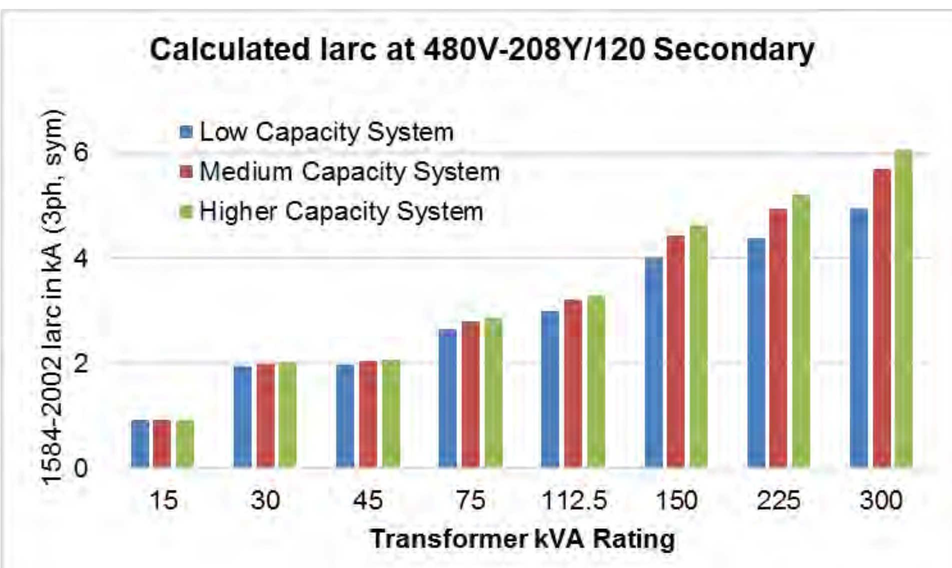


Figure 37. 1584-2002 Arc Current at Transformer Secondary in Typical Systems

The three-phase arc currents have been calculated using the IEEE 1584-2002 [40] arc current model based on a three-phase voltage of 208 V and a gap width of 1 inch in an enclosure. The calculated arc current at the transformer secondary only exceeds 6 kA (6,075 A) for the 300 kVA transformer in the higher capacity system. Furthermore, the 1584-2002 arc current equation tends to overpredict low-voltage, low-magnitude arcing faults currents. In addition, it is difficult to sustain arcing at 208 V (three-phase), especially for lower-magnitude short-circuit currents, wider gaps (including 1 inch), and equipment configurations which do not create a protected space that can be easily ionized.

Moreover, the greatest threat posed by electrical arc flash hazards is burn injury. Burn injury not only depends on the total incident energy but also depends on the rate of heat transfer. The heat flux of lower-magnitude arc currents is less intense, and heat is lost in the vicinity of the arc. The 1584-2002 calculated incident energies after 100 ms are displayed in Figure 38. The calculated incident energies at a distance of 18” are based on a panel configuration in a grounded electrical system. The calculated incident energies (which inherently assumes a sustainable arc) do not reach 2 cal/cm^2 even for a 300 kVA transformer in a higher capacity system.

Figures 37 and 38 demonstrate that “oversizing” in-house 480-208Y/120 V transformers one size higher does not pose a significant risk of the arc flash hazard generated at the transformer secondary. For electrical systems in commercial buildings, the service transformer size is typically determined by or negotiated with the electric utility provider. Tables 19 and 20

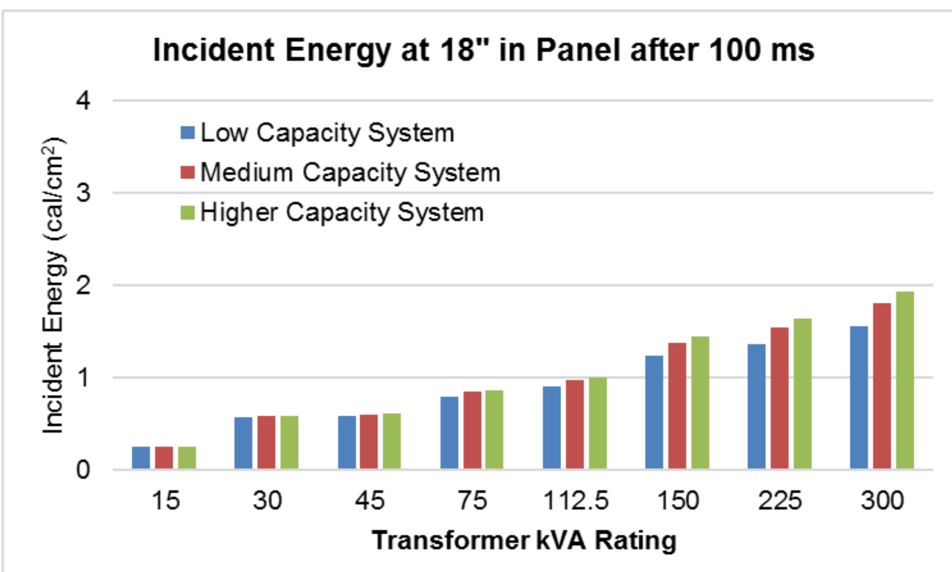


Figure 38. 1584-2002 Incident Energy after 100 ms at Secondary in Typical Systems

illustrated that electric utilities may size transformers based on different capacity requirements and different demand factors than established in the National Electrical Code.

8 DATA COLLECTION AND ANALYSIS PLAN FOR EVALUATION OF ELECTRICAL FEEDER AND BRANCH CIRCUIT LOADING PROJECT PHASE II

8.1 Motivation for Project

Although electrical systems are utilized from the bottom up, they are designed from the top down. When a building is constructed, the transformer supplying the main feeder is installed before the procurement of all electrical equipment serving the building. Engineers determine the building power requirements based on the connected and demand load calculations subdivided into the following (or similar) categories:

- Receptacle Lighting Heat Cooling Motor Other Spare

The “Heat” load might consist of electric heating elements in the HVAC system, permanent space heating, and water heaters. In a commercial building, the “Motor” load might include elevators, exhaust fans, and pumps required for building function. The “Other” load might consist of any dedicated building equipment identified early in the design process. The “Heat,” “Cooling,” “Motor” and “Other” loads are based on known building service demands. The power required for these loads may be determined from the specified equipment or estimated from other equipment capable of meeting the service demand.

Spare capacity may be added to one or all building panels to accommodate both anticipated and unforeseen additional load growth. Panel and feeder sizing are based on the demand power requirements and often include spare capacity.

Branch circuit requirements for receptacle load power density are specified in NEC 220.14. The receptacle load is calculated at 180 VA for each single or multiple receptacles on one yolk. Equipment with four or more outlets is calculated at a minimum of 90 VA per receptacle. For feeder and service-load calculations, NEC 220.44 permits that the receptacle demand load may be calculated as 100% of the first 10 kVA plus 50% of the remaining kVA. Many practicing engineers question the 180 VA design requirement in today’s changing technology market and with changing receptacle usage. Moreover, the NEC 180 VA requirement dates back 1937. The National Electrical Code has been adopted statewide in 47 states, and its enforcement lies upon the authority having jurisdiction. However, even engineers in areas with statewide adoption have been known to not always adhere to the NEC. A review of a few sets of electrical plans uncovered three variations of the NEC feeder and service-load receptacle calculations, in addition to engineering judgment in the branch circuit design.

Like heat, cooling, motor, and other loads, lighting fixtures are fixed loads with specific power requirements. The Illumination Engineering Society has set guidelines on the illumination levels required to adequately light a space for specific work tasks. Engineers and lighting designers design fixture layouts to provide adequate illumination levels. But it has also been estimated that up to 40% of all lighting projects are designed by electrical contractors.[24] The NEC specifies the minimum lighting load power density by occupancy type in Table 220.12 and included as Table 32 here.[25] As Table 32 illustrates, the load requirements have largely been in effect since at least 1968 with few modifications, yet lighting technologies have advanced and become much more energy efficient in the last fifty years.

Table 32. NEC (VA/ft^2) and ASHRAE 90.1 (W/ft^2) Lighting Power Density by Occupancy

Type of Occupancy	NEC 1968	NEC 1971	NEC 1981	NEC 2017	90.1-2004	90.1-2013
Armories and auditoriums	1			1		
Banks	2	5	3½	3½		
Barbershops & beauty parlors	3			3		
Churches	1			1	1.3	1
Clubs	2			2		
Courtrooms	2			2	1.2	1.01
Dwelling Units	3			3		
Garages – commercial (storage)	½			½		
Hospitals	2			2	1.2	0.94
Hotels, motels & apts. (no cooking)	2			2	1	0.87
Industrial commercial (loft) bldgs.	2			2		
Lodge rooms	1½			1½		
Office buildings	5		3½	3½	1	0.82
Restaurants	2			2	1.4	0.9
Schools	3			3	1.2	0.87
Stores	3			3	1.5	1.26
Warehouses (storage)	¼			¼	0.8	0.66
Assembly halls, & auditoriums*	1			1		
Halls, corridors, closets, & stairways*	½			½		
Storage spaces*	¼			¼		
***Except in individual dwelling units**						

[24] Statement made in email from Mark Lien, Illumination Engineering Society (IES) Industry Relations Manager, September 9, 2016.
[25] Table 32 is identical to Table 22. Section 8, the data collection plan, has been written as a separate document which can be reviewed independently of earlier report Sections 1 – 7.

The commercial reference building model for new construction, developed for the U.S. Department of Energy, uses the lighting power densities of ASHRAE 90.1-2004. Lighting power densities for ASHRAE 90.1 building area types equivalent to NEC occupancy types are listed in Table 32 for comparison purposes. The lighting power densities of ASHRAE 90.1-2013 and even 90.1-2004 differ significantly from the 2017 NEC.

Two exceptions to the NEC lighting power density requirements are permitted. The 2014 edition permitted an exception if the building complies with local energy codes and a monitoring system is installed. In the 2017 NEC, the lighting load specified by Table 220.12 for office and bank areas may be *reduced by* 1 VA/ft^2 when the local authority has adopted an energy code specifying an overall lighting density less than 1.2 VA/ft^2. At least 45 states have energy conservation codes in effect. California has its own state code, and part of Hawaii has a locally adopted code. Other states except Vermont have adopted ASHRAE 90.1-2004 or a later edition. In many states, the adopted energy codes are not enforced. However, even before state adoption of NEC's 2014 edition, engineers in various areas nationwide have based lighting power density requirements on local energy conservation codes (and therefore likely lower than NEC requirements).

The National Electrical Code may be considered the Gold Standard for the design and installation of electrical equipment. For the NEC to remain the unrefuted standard nationwide, the requirements of the NEC must be well-founded and up-to-date with today's technology and building design. At one time, the NEC focused exclusively on the design and installation of electrical equipment. Today it also encompasses safety issues addressed by NFPA 70E, *Standard for Electrical Safety in the Workplace*; these issues include electric shock, arc flash hazards, and other forms of electrical injury. Recent NEC 2017 exceptions in Section 220.12 demonstrate that the NEC is also becoming responsive to growing national concern for energy conservation.

U.S. government passed its first energy policy act in 1975. Since the Energy Policy Act of 1992, the U.S. Department of Energy (DOE) has taken an active role in the development, adoption, and impact analysis of model building energy conservation codes. The DOE also establishes minimum efficiency standards for appliances and equipment, which includes mandating greater efficiency requirements for transformers effective January 2016. For several years, government entities and electric utility providers have publicized the energy saving benefits of replacing older electrical equipment, including transformers and lighting fixtures, with new more energy efficient equipment. Financial incentives are often given.

There has been recent interest in “rightsizing” transformers to reduce energy losses associated with older oversized transformers. A 1999 Cadmus study of in-house low-voltage dry-type transformers found the average RMS loading of transformers at 16% of capacity [32]. A Navigant study on miscellaneous electric loads (MELs) estimated 43 TW-hours of energy loss generated by low-voltage dry-type transformers in commercial buildings in 2011 [8]; this transformer energy loss was higher than the energy consumption of any of the other thirteen MELs in the study.

Environmental science focuses on the importance of sustainability in new building construction. Sustainability is becoming a more important issue in the electrical system design in buildings. Specifying oversized electrical equipment might be viewed as wasteful of national and planetary resources. “Rightsizing” equipment may save in capital investment. Excess capacity may lead to higher available fault current and concern has been expressed about the potential for greater electrical safety hazards, including arc flash hazards.

The intent of this research study is to evaluate electrical feeder and branch circuit loading given present NEC requirements, electrical safety, and energy conservation and sustainability issues.

The lighting and receptacle loads are of particular interest because of the long-standing minimum power densities established by the NEC. The lighting and receptacle load power densities in new building construction need to be measured to ensure that the NEC requirements reflect today’s technology and usage in building spaces. However, design requirements for receptacle power density (which is not a “fixed” load) also need to accommodate the anticipated future growth in plug-loads and the development of unforeseen new types of plug-loads over the life cycle of the building.

Finally, many commercial buildings are provided 480 V which is stepped down to 208Y-120 V by in-house transformers. The research project recommends monitoring load levels on all transformers within the building and supplying the main service.

8.2 Relevance of Project Focus

In June 2016, electric utilities had close to 150 million customer accounts, including 18.3 million commercial accounts. Assuming each customer has at least one electrical service feeder, the number of service feeders must be close to 150 million and the numbers of distribution feeders and branch circuits must exceed a billion. Feeders and branch circuits might be considered pipelines for electricity. In 2015, residential, commercial, and industrial sectors purchased over 3.7 trillion kW-hours of electricity.

The U.S. Energy Information Administration (EIA) estimated that, in 2012 in the United States, there were close to 5.6 million commercial buildings with a total floor space over 87 billion square feet. The EIA also estimated that lighting accounted for 17% of all electricity consumption; furthermore, miscellaneous electric loads including computing and office equipment accounted for 32% of the total electricity consumption. In the 2012 Commercial Building Energy Consumption Survey (CBECS) funded by the EIA, office buildings alone accounted for 19% of the total number of commercial buildings, 19% of the total floor space, and 20% of electricity consumption.

A study on the electrical feeder and branch circuit loading in commercial buildings will provide substantive data, more valuable than estimation, on the major and minor end-use loads in commercial buildings in the U.S. The average age of a commercial building is 32 years. The results of this project may also serve as an impetus for retrofitting equipment to realize energy savings and quality enhancements. In addition, new data on transformer loading and measured power losses of working transformers might warrant a reassessment of the transformer efficiency test procedures specified by the U.S. Department of Energy. The results from this project will provide NEC code-making panels data to reassess current NEC branch-circuit, feeder, and service load calculations, particularly for lighting and receptacle load. The results of this project may stimulate additional national, standards, and professional group discussion on energy conservation and sustainability, specifically regarding building electrical systems.

8.3 Selection of Study Type and Participating Study Buildings

8.3.1 Objective

The objective is to locate fifty[26] commercial buildings where electrical feeder loading can be monitored for one calendar year. Previous studies in the reliability of electrical equipment found that at least forty samples were needed for the results to be statistically meaningful [41]. Ten additional office buildings have been added to enhance the statistical value and to compensate

[26] In December 21, 2016 email, Bob Arno stated: “I do have one concern minor in nature, I would target double the facilities for data collection in the anticipation of achieving solid data on 50. I know this will add additional cost but anticipating equipment failure, facility pullout, Murphy’s law, this is an effort you will want to do only once with positive results.” The report author agrees that monitoring additional sites will enhance the value of the data collected. It will be left to Phase II project personnel to double the sites monitored if resources are available.

for any sites withdrawing, data being lost, or any unforeseen event which might reduce the value of the building's contribution to the study.

8.3.2 Types of Commercial Buildings

Three potential groups of commercial buildings have been identified for study. The group selected for study may depend on budget, interest, and Phase II sponsorship.

8.3.2.1 Commercial Building Type Option 1 Study

- Fifteen of the Sixteen Commercial Building Types as identified in the 2012 CBECS
    - 192 buildings total -- 12 for each of type except offices and none for vacant
    - 12 for office buildings up to 50,000 ft^2 and 12 for those over 50,000 ft^2

An electrical feeder and branch circuit loading study is needed for different types of commercial buildings. The 2012 CBECS, costing in the tens of millions, collected detailed information about 6,720 commercial buildings to project the energy consumed by major and minor end-use loads in all commercial buildings. Although the study collects information about building electricity usage, the specific energy consumption of end-use loads is not measured; it is estimated based on survey information about building HVAC equipment, lighting types, general numbers of computer and office equipment, etc.

The U.S. Department of Energy has developed its Commercial Building Reference Models from the 2003 CBECS and information found in ASHRAE standards. The U.S. Department of Energy, the U.S. Energy Administration (a sector of the DOE), and standards need data on the electricity consumption of specific load types in all commercial building types. The U.S. government might use this information to help shape energy policies and to develop more accurate models for electricity consumption. Consumption data on heating, cooling, ventilation, and refrigeration equipment would shed light on demand and mean power consumption with respect to "nameplate" requirements, building needs, and electrical system design requirements. Inventory information and nameplate power requirements for lighting and receptacles would shed light on usage and power demand requirements.

Furthermore, the U.S. Department of Energy mandates efficiency requirements and defines test procedures for measuring distribution transformer energy loss in the Code of Federal Regulations. Transformer efficiency is a function of transformer loading; 10 CFR §431.196 specifies transformer loading during the testing at 35% of rated load. If 35% loading is not representative of transformer loading, the DOE test procedure may not provide a good assessment of energy loss in working transformers.

Different building types may have different load profiles and transformer loading.

8.3.2.2 Commercial Building Type Option 2 Study

- Large University Campuses
  - 137 commercial buildings, with a focus on 50 office buildings as follows:
  - 25 offices up to 50,000 ft^2 and 25 offices over 50,000 ft^2
  - 25 residence halls, 25 education buildings, 25 laboratories, 12 hospitals

Large university complexes might benefit from this study on electrical feeder and branch circuit loading because the results might help bring about changes in standards which might ultimately reduce capital investment in new construction. Results may also provide evidence for realizing energy savings through decisions to retrofit older, lossy equipment. Older equipment also has a higher probability of failing, interrupting service, and even starting a fire; furthermore, it is more likely to pose an electrical hazard not only to maintenance workers but also to end users, including students. New equipment may also bring additional benefits such as improved lighting quality.

8.3.2.3 Commercial Building Type Option 3 Study

- Fifty Commercial Office Buildings
  - 25 offices up to 50,000 ft^2, ideally equally divided into three groups: 1,000-10,000 ft^2, 10,000-25,000 ft^2, and 25,000-50,000 ft^2
  - 25 offices over 50,000 ft^2, ideally with 10 offices over 100,000 ft^2 and 5 over 200,000 ft^2

The Request for Proposal issued by for the Fire Protection Research Foundation stated the initial focus was commercial office occupancies.

8.3.3 Geographic Distribution of Study Buildings

The monitoring sites should be selected to represent different climate zones, time zones, and Census regions. Many aspects of climate can influence daily power requirements, including temperature, humidity, precipitation, cloud cover, and winds. In offices conducting interstate business, time zones might influence operating hours. In different regions of the country, building construction and engineering design practices may differ due to climate differences and local building and energy conversation codes.

Site locations should be selected to represent each IECC climate region shown in Figure 39[27], but a higher percentage of monitoring sites should be concentrated in climate zones with higher population densities which also have greater building densities. A population density map produced by the United States Census Bureau has been attached as Appendix A.

[27] Figure 39 is identical to Figure 4. See footnote 26.

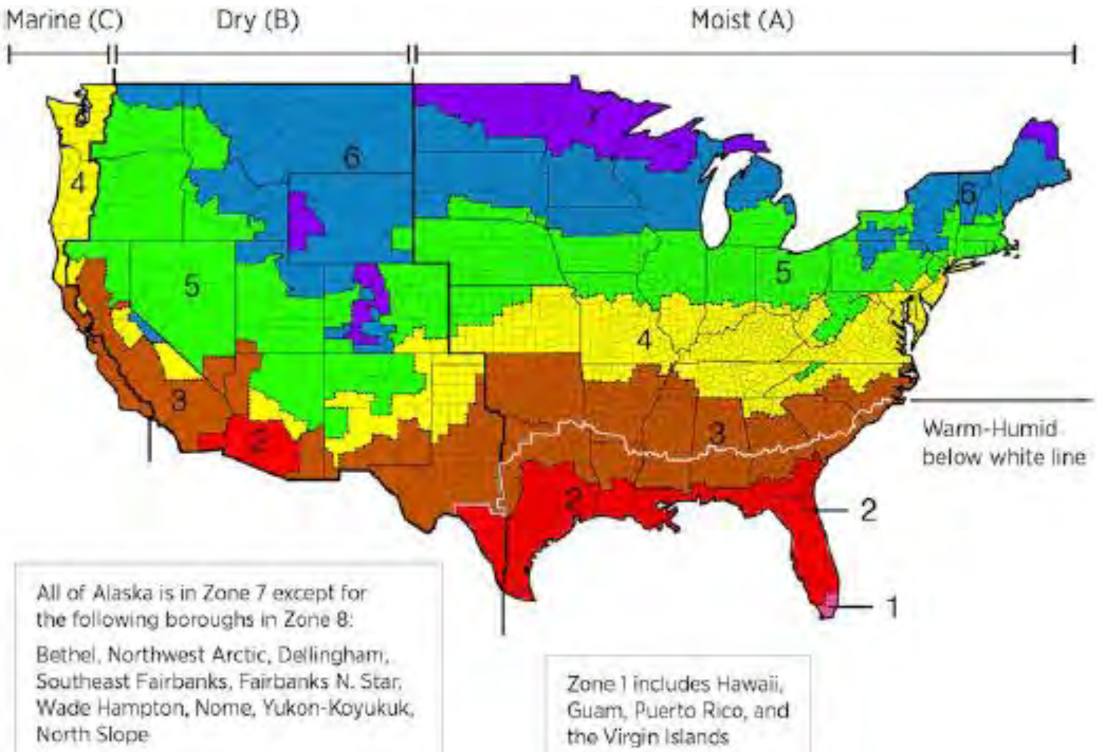


Figure 39. IECC Climate Regions in the U.S.
(Source: U.S. Department of Energy, and reference [4])

Table 33. Geographic Selection and Number of Monitoring Sites

	13 IECC Zones	3 DOE Added	Most Populated City	Office	Residence Halls	Education	Labs	Hospitals
1	1		Miami	1				
2	2A		Houston	5	4	4	4	2
3	2B		Phoenix	2				
4	3A		Atlanta	5	3	3	3	1
5	3B	Other	Las Vegas	3				
6	3B	CA-coast	Los Angeles	3	4	4	4	2
7	3C		San Francisco	3				
8	4A		Baltimore	7	4	4	4	2
9	4B		Albuquerque	1	2	2	2	1
10	4C		Seattle	3				
11	5	5A	Chicago	7	4	4	4	2
12	5	5B	Denver	4	2	2	2	1
13	6	6A	Minneapolis	3				
14	6	6B	Helena, MT	1	2	2	2	1
15	7		Duluth, MN	1				
16	8		Fairbanks, AK	1				
			Total	50	25	25	25	12

The distribution of site selection is suggested in Table 33, modeling a study focusing on university campuses (Building Type Option 2). If all major commercial building types (Building Type Option 1) are selected for study, the geographic distribution for each building type should be similar to the distribution for the hospital geographic distribution in the table. If the commercial office building study (Building Type Option 3) is conducted, office buildings should be selected as in Table 33. Ideally, site selection for the two main groups of 25 office buildings (based on size) should be distributed as residence halls, education, or laboratories in the table.

8.3.4 Criteria for Building Selection

Prospective buildings should be less than three years old (preferably two) with all equipment installed and operating. The building should be functioning at designed capacity (regarding building function, the number of employees, etc.). Prospective buildings should submit electrical plans, including panel schedules and riser diagram.

Site selection should be based on the disaggregation of loads so that the power consumption of different load types can be determined. Figure 40 illustrates feeder monitoring when load types are disaggregated at the main switchboard (a site ranked “optimal”). Buildings with electrical system riser diagrams similar to Figure 40[28] are likely to be equipped with building automation systems and advanced metering systems to monitor power requirements and energy consumption. Figure 40 is the ideal candidate for System Monitoring Option 1 or 2, discussed in Section 8.4. System Monitoring Option 1 or 2 may also be feasible for an electrical system with a riser diagram similar to Figure 41, which may be ranked “optimal” or “good.” However, monitoring and personnel resources for data collection will be more intensive and expensive.

Sites with a riser diagram similar to Figure 42 may be ranked “acceptable.” For illustration purposes, Monitoring System Option 3, monitoring receptacle and lighting loads, is shown in Figures 41, 42, and 43. Prospective buildings with riser diagrams similar to Figure 43 do not rank “optimal,” “good,” or “acceptable.” Ideally, such buildings should not be selected for monitoring. However, such buildings may provide some limited data as shown in Figure 43, if building owners are willing to provide it and research funding is limited. However, metrics such as average or demand lighting or receptacle power density for the building cannot be determined from partial building data and utilization levels in specific building zones vary.

[28] In reviewing the draft report, Bob Wajnryb, Senior Electrical Engineer at The Ohio State University, stated in an email dated December 16, 2016: “Based on personal experience, Figure 40 does not often occur.” The report author agrees.

8.3.4.1 Ranking Prospective Sites

- Optimal – All lighting and receptacle loads on dedicated panels
- Good – 90% of all lighting and receptacle loads in building are on dedicated panels
- Good – Panels with receptacle and lighting loads are 90% dedicated to respective load
- Acceptable – 80% of all lighting and receptacle loads in building are on dedicated panels
- Acceptable – Panels with receptacle and lighting loads are 80% dedicated

8.3.4.2 Additional Consideration Factors in Site Selection

- Building size
- Building service voltage
- Monitoring resources (number, type, and cost) required for building study
- Number of in-house transformers and their rating
- Primary energy sources for heating, cooling, and hot water

Ideally, selected buildings will have management and contact personnell interested in participating in the project and willing to assist.

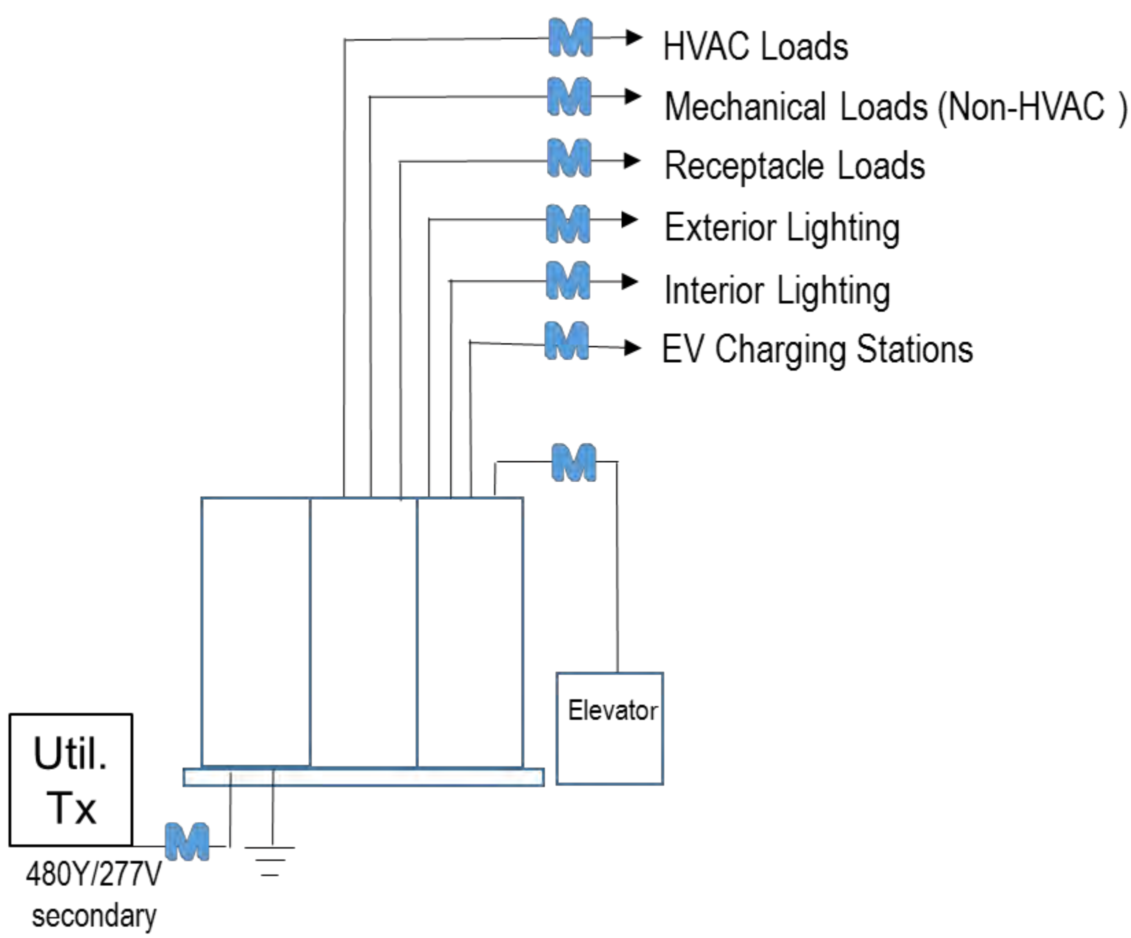


Figure 40. Monitoring Optimal Site with Load Separation

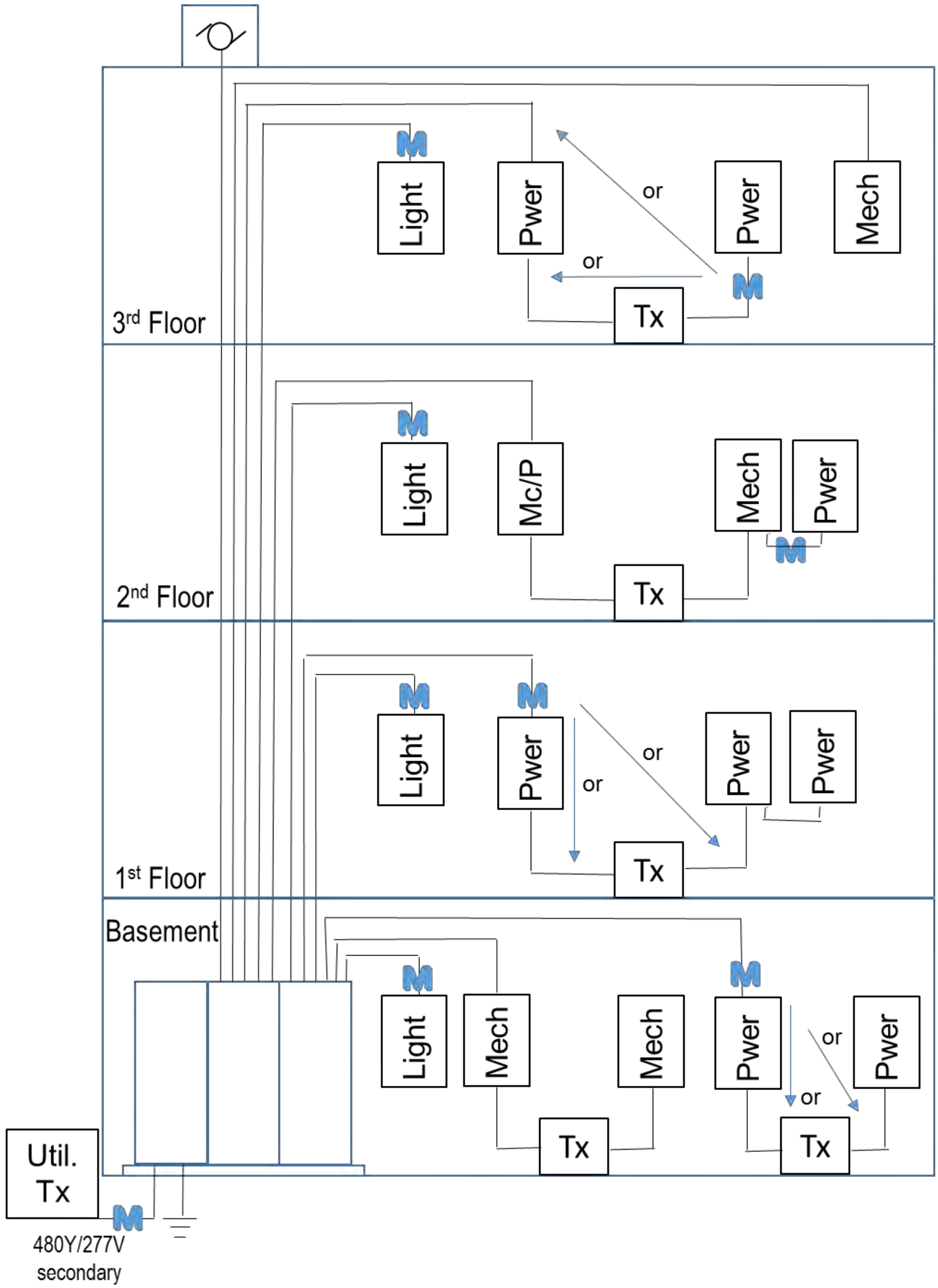


Figure 41. Monitoring “Good” or “Optimal" Site

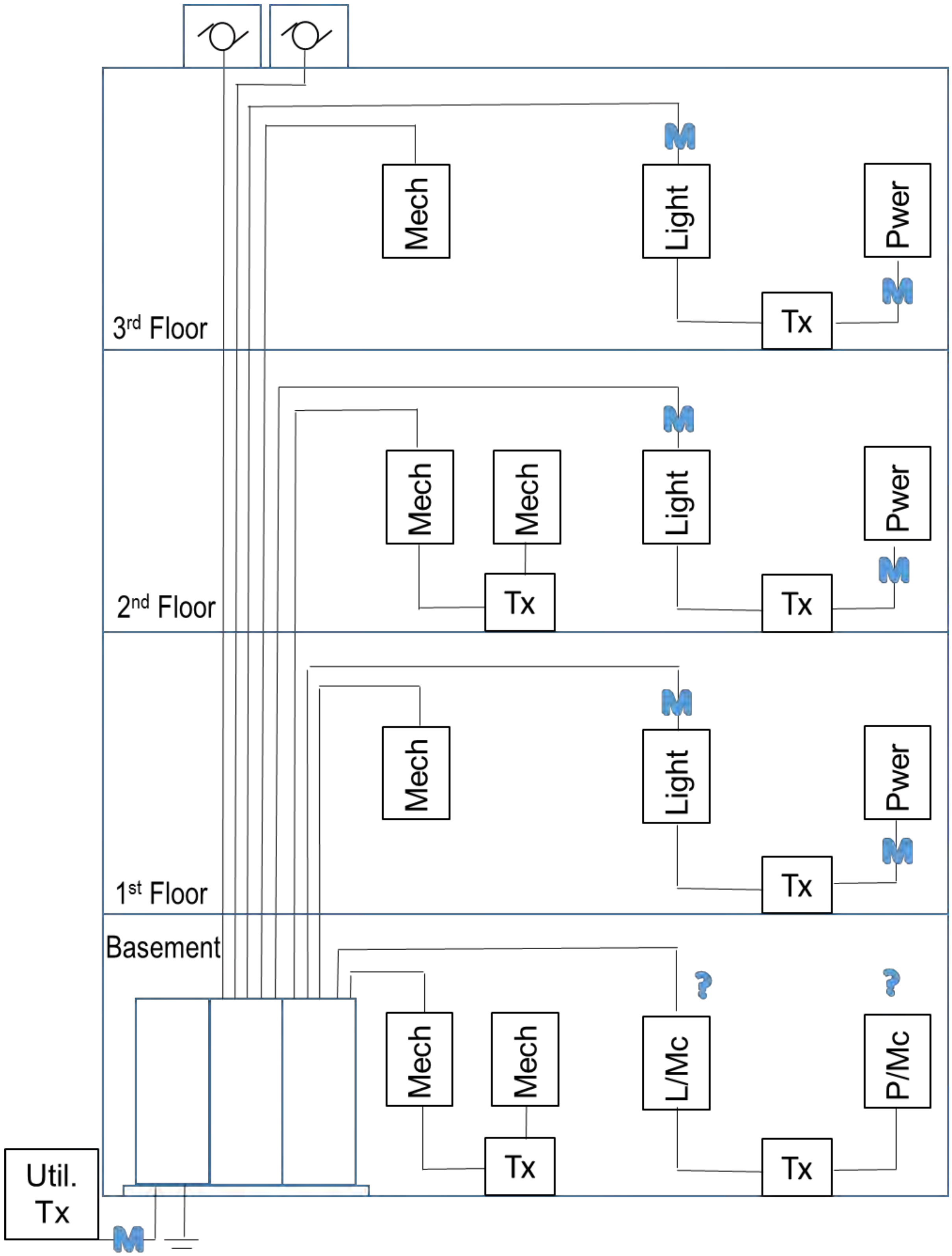


Figure 42. Monitoring Acceptable Site

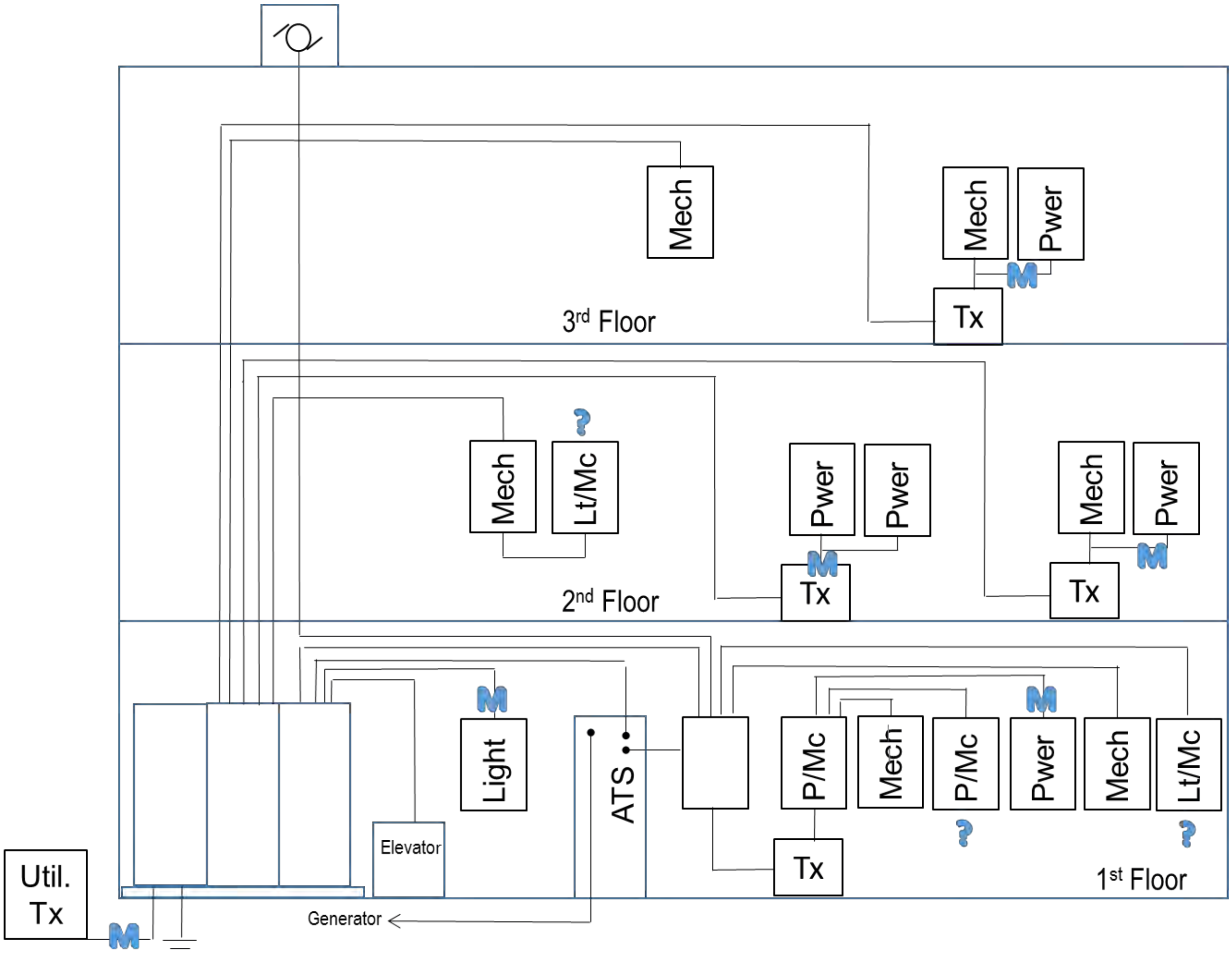


Figure 43. Monitoring a Site Not Meeting "Optimal," "Good," or "Acceptable" Ranking

8.3.5 Required Building Documents and Information[29]

1. Electrical plans, including outdoor lighting plan and lighting fixture schedule
2. For all on-site transformers, the following nameplate information: manufacturer name, model, and date; capacity; type (temperature rise); impedance; K-factor rating; primary and secondary voltages (and currents where specified); primary and secondary winding connection type
3. Mechanical plans with detailed HVAC and other mechanical equipment load information (including manufacturer and model information) for mechanical loads powered by electricity

[29] Bob Yanniello commented in December 15, 2016 email: "This is certainly a very inclusive list. Upon seeing it, I question if we could ever afford to capture it for the number of sites we felt were needed for a statistically accurate sample size." The report author has attempted include as much detail as possible. Phase II project personnel should omit details which are not considered essential at that time.

4. Two-years of utility load data (including the year which monitoring takes place)
5. Building size (should be included on drawings)
6. General description of building function and how employees carry out work (in an office building, if work primarily conducted through telephone and computer use, do employee tasks involve engaging with the general public, etc.)
7. Photos of the building, representative interior spaces, and major equipment including the parking lot, main entry, office areas, reception area, breakroom or kitchen, corridor, server/IT room, mechanical and electrical room, RTUs, transformers, etc.
8. Numbers of full-time and part-time employees and the target number of employees (with quarterly updates during the monitoring period). Additional employee demographics on age, gender, and race desirable if available.
9. If other buildings in addition to offices are selected for study, additional building benchmark information will need to be provided. For example, hospitals would need to provide the number of beds and monthly reports on utilization. Educational buildings would need to provide student capacity and utilization.
10. Building operation and maintenance manuals
11. General building operating schedule and fixed or flex employee work hours on weekdays and weekends
12. General building schedules for heating, cooling, and ventilation (automatic, occupancy sensing or manual, location specific; fixed by time of day, day of week, season; determined by employee comfort or directly controlled by employees)
13. Schedule for lighting operation (automatic, occupancy sensing, or manual, fixed by time of day, day of week, season)
14. Schedule and response time of any automatic or occupancy sensor controlled receptacles
15. Any building policies for turning off office equipment, computers, and monitors during weekdays, evenings, or weekends
16. Inventory of items connected to receptacles (including manufacturer name and year, model, power requirements if available). Receptacle inventories should be labeled by building floor and space areas (as can be identified on building plans). Inventories can be self-reported by employees (including cleaning and maintenance staff) and updated or verified quarterly. The inventory list should also contain corded-equipment or tools (such as vacuum cleaners and drills) which are connected to receptacles on an as-need basis.
17. Any energy conservation codes or standards to which building was constructed (should be included in drawings)

8.3.5.1 Collection of Building Information

Project management will generate form documents to collect building information from building contact personnel. Preferred document form is an Excel file for easy organization and analysis. Excel files might also be transformed for use in Access.

8.4 Site Monitoring

The request for proposal stated: “The goal of this project is to develop a data collection plan to provide statistically significant load data for a variety of occupancy and loading types to provide a technical basis for considering revisions to the feeder and branch circuit design requirements in the National Electrical Code.” A large-scale project to evaluate electrical feeder and branch circuit loading would be significantly enhanced by expanding the study to include harmonics, power quality, power reliability, and voltage stability issues.

8.4.1 System Monitoring Options

The extent of electrical system monitoring in the buildings selected to participate in the Phase II research project depends on the interests of the sponsors and funds raised. It also depends on the level of load disaggregation in the buildings selected for site monitoring and the presence of existing advanced metering systems. Five options for monitoring the electrical systems in the study buildings are presented in Table 34.

The subsequent paragraphs in this section discuss the data to be collected for System Monitoring Option 1, which will facilitate the greatest gain in knowledge for undertaking a research project of this magnitude. If one of the lesser monitoring options is selected, the extent of monitoring should be cut back as appropriate to the selected monitoring option and the capabilities of the monitoring equipment used in the study. Similarly, the discussion of

Table 34. System Monitoring Options for Study Buildings

	Five Options for System Monitoring
1	Monitor all loads, harmonics and neutral current measurements (at least spot) on transformers and receptacle panels; continuous or two-month monitoring or spot measurements on receptacle branch circuits; obtain detailed service data (power quality and reliability and voltage stability)
2	Monitor all loads
3	Monitor lighting and receptacle loads
4	Monitor receptacle (or lighting) load
5	Monitor receptacle load, including branch circuits, no restriction on building age

data analysis in Section 8.5 addresses System Monitoring Option 1. If one of the lesser monitoring options is selected, the data analysis will be more limited, based on the monitoring option selected and the data available for analysis.

The following require continuous one-year monitoring[30] of current, voltage, and power. Some project sponsors like government agencies may prefer monitoring all sites during a single calendar year beginning on January 1 and ending on December 31. Otherwise, it may be easier to begin monitoring once a suitable monitoring site has been identified and the site is ready to participate; conducted in this manner, the window of data collection for all sites should be 18 months or less.

- Main service feeder (may be provided as electric utility data, but need current and voltage harmonic content)
- All feeders supplying panels (will also provide information about transformer loading)
- All motor control centers
- All individual loads rated over 10 kVA, including any RTUs, elevator motors, dock equipment, water heaters, and large pumps. Exception: When HVAC equipment such as fan powered terminals and fixed space heating equipment are fed from a dedicated panel, monitoring the panel is sufficient.
- Also, current harmonics and power may be monitored on all feeders supplying transformers. (Power loss may be calculated as power supplied to feeder supplying transformer subtracted from power supplied to downstream feeder supplying panel.)

Ideally, the lighting panels would be dedicated to the lighting load. However, if other loads are fed from lighting panels, they should be continuously monitored individually, unless they represent less than 20% of the panel's demand load.

In larger buildings supplied by 480 V service equipment, 208 V panels primarily serve receptacle load. However, a wide range of miscellaneous equipment may also be served; these loads include ductless air conditioners and heat pumps, water heaters, low-voltage lighting, and smaller mechanical loads including dock equipment, pumps, fans, and electric vehicle charging stations. Ideally, the building will have low-voltage panels dedicated to receptacle load.

However, monitoring dedicated receptacle panels does not provide sufficient information about the power requirements of receptacle branch circuits. Receptacles are placed throughout buildings to provide convenient and easy access to electric power. In office buildings, receptacle locations include office areas, conference rooms, break rooms, kitchens, restrooms, hallways, reception areas, filing and storage rooms, server/IT rooms, and exercise rooms. Receptacle

[30] Robert Arno, Project Technical Panel member, believes one year of monitoring is required for scientifically valid data. Mr. Arno, a manager at Harris Corporation, is an IEEE Fellow and Chairman of the IEEE Standard 493, Gold Book.

load varies according to space, scheduling, time of day, and day of the week. It was concluded in [9] that plug-load monitoring for two[31] months was needed to provide a sound estimate of receptacle energy consumption. The report author initially suggested that branch circuits be monitored during the coldest months to capture portable heater usage and seasonal task lighting, although portable fans and dehumidifiers may be used during warmer months. However, project sponsors[32] have commented that space heaters are often used in warmer weather, and fans are used during winter months, depending on an individual's personal comfort level. Therefore, for accurate branch-circuit receptacle load measurements, it seems that one year of monitoring is necessary.

8.4.2 Monitoring Equipment

Monitoring equipment cannot be selected until after Phase II further develops. These developments must include the selection of commercial building study type and system monitoring option and on the amount of funds raised for the project. The selection of monitoring equipment depends on existing metering equipment already on site; it may also be constrained by the building electrical system and cooperation of the building owners and site personnel.

This section is intended to provide a preliminary look at some equipment types. Monitoring options provided by other manufacturers may be more desirable regarding capabilities, better pricing especially in large quantity, or even possible sponsorship through equipment donation. A more comprehensive study of monitoring equipment should be conducted after further development of the Phase II project. Four different metering devices have been included in the following bullet point list. Additional information published by the manufacturer about this equipment is included in Appendix B.

- Main Feeder Monitoring: GE EPM 4600 Multi-feed Power and Energy Metering System
  - Monitoring 6 feeders at main switchboard, estimated cost $6,200 plus roughly $75 per split-core current transformer ($75x3x6), total estimated[33] = $7,550
  - EPM 4600 also available for monitoring 8 feeders
  - Monitors phase and feeder – W, VA, VAR, current, voltage, power, power factor, and neutral current and frequency

[31] A plug-load study at Lawrence Berkeley National Labs [9] found that a 2-month study of plug-loads was long enough to estimate annual energy consumption with reasonable accuracy. The study monitored 455 plug loads for at least 6 months and many for over a year. The monitored plug-loads were selected from 4,454 inventoried plug-loads in an 89,500 square feet office building on site.

[32] In December 15, 2016 email, Robert Yanniello remarked that lighter summer clothing may cause some office employees to feel cold in air conditioning. In December 16, 2016 email, Bob Wajnryb stated, "Many times have come across space heaters in use in warm weather and fans in use in the cold weather depending on the individual."

[33] Cost provided by John Levine of Levine, Lectronics, and Lectric, Inc. in email on November 29, 2016.

  - Built-in RS-485 and USB communications; Ethernet and WiFi optional
  - Data logger for voltage, frequency, and energy usage at 15-minute intervals. May record for a minimum of 68 days to over a year, depending on options
- Panel Metering: Honeywell E-Mon Class 3400 Smart Meter[34] (and Data Logging)
  - Split core current sensors allow installation in existing systems
  - Stores kW and kVAR data for up to 72 days in 15-minute increments
  - Display also shows voltage, current, and power factor per phase
  - Built-in Ethernet and RS-485 Communications
  - Price: $950-$1,109 – for 200A and 400A 120/208V and 277/480V panels[35]
- Panel Metering: Onset Data Loggers for Real Power or Phase RMS Currents[36]
  - 250A Accu-CT split core current transformer, $45x3=$135
  - H22-001 Hobo Energy Logger $364, FlexSmart TRMS $95x2 = $190, USB Interface cable $59, estimated system cost = $748 for monitoring RMS three phase currents or $793 for RMS neutral current also
  - UX90-001 State logger $92, WattNote transducer for 208Y/120V panel $229, HOBOware Pro software $99, input voltage lead set $75, estimated system cost $630 for monitoring three-phase power
  - Length of data storage variable, likely over a year for three-phase power
- Panel and Branch Circuit Monitoring: GE ASPMETER-A Metering Panelboard
  - Monitors panel phase currents, voltages, powers, and pfs, also neutral current
  - Monitors panel kVA, total pf, average three-phase and phase voltages, frequency
  - Monitors branch circuit current, power, and power factor
  - MODBUS RTU Communication, sample frequency < 2 seconds
  - Panelboard with GE ASPMETER-A, B, or C options, approximate cost $6,250[37]

If loads are disaggregated at the main switchboard, as shown in Figure 40, the GE EPM 4600 metering system might be ideal. The EPM 4600 collects a wide range of measurements. It contains onboard memory for voltage and energy storage. More importantly, it should be fairly easy to establish communication with one central monitoring device so that the wide range of measurements can be accessed real time. For electrical safety reasons, the main switchboard would need to be shutdown to install the GE EPM 4600 in an existing switchboard.

For more limited panel metering, a trusted Honeywell E-Mon meter is a good option. In addition to kW and KVAR usage, the meter displays current, voltage, and power factor which could be transferred via a MODBUS (or other) communication protocol. If running communication lines is not feasible, at least real and reactive power consumption is stored in memory.

---

[34] Another manufacturing representative (not identified to protect privacy) remarked to the report author in December 2016 that for pricing and reliability, E-Mon devices are hard to beat.
[35] Quote provided by Jake Wamble at Mayer Electric, Marietta, GA on November 4, 2016.
[36] Quotes provided by Rebecca Fish from Onset Computer Corporation on December 14, 2016.
[37] Cost estimate provided by Michael Seal, GE Energy Connections, in email dated December 12, 2016.

Onset Computer Corporation data loggers may be a good option when running communication lines is not an option or economy is essential. For a cost of $630, the UX90 data logger should be able to store three-phase power measurements recorded at 15-minute intervals for over a year. The Onset H22 Energy logger can record a wide variety of measurements. It can be configured to store the three phase currents for $748, or $793 if the neutral current is added.

A panelboard monitoring system like the GE ASPMETER-A is an excellent device for monitoring current and power consumption at a panel's branch circuits and mains. The ASPMETER is not a data logger; therefore, communication would need to be established with the panel. The GE ASPMETER is a complete panelboard which would replace an existing panelboard in a building. Panelboard replacement may be an attractive option in older buildings on university campuses where the panelboard is old and valuable knowledge can be gained through the installation of a new panelboard. The GE ASPMETER-A or similar product would provide data for consideration of the NEC's general requirement of 180 VA per receptacle in branch-circuit load calculations.

8.4.3 Method of Data Collection on Site and to Project Personnel

The project should provide an internet location where each monitoring site can upload the requested documentation and information. If the data is not accessible to project personnel via the Internet, but instead is collected by on-site employees (by downloading from device storage or LAN), data should be uploaded monthly (or more frequently). In buildings equipped with advanced monitoring, real-time data may be accessible to project personnel via the Internet.

8.5 Data Analysis[38]

8.5.1 Evaluation of Lighting Load

1. Review electrical drawings and lighting schedule; note the primary type of lighting used in different building spaces.
2. Calculate building lighting power densities from connected and demand load on panel schedules. Compare with NEC lighting power density. (If time and building layout permit, calculating lighting power density for office area specifically may be a useful comparison.)

---

[38] Bob Yanniello commented in December 15, 2016 email: "…I question if we could actually fund such an exhaustive data analysis?" However, Bob Arno commented in December 21, 2016 email: "I think it will be very beneficial and not too costly to add in the power Reliability and Quality. This data will be beneficial to many areas of NFPA and other organizations."

3. Review measured data. Observe any hourly, weekly, and seasonal patterns. Record peak power. Calculate mean power and other useful statistics.
4. Compare measured data with panel schedule connected and demand load.
5. As feasible from measured data, calculate peak and mean lighting power densities. Compare with power densities in Step 2.

8.5.2 Evaluation of Receptacle Load

1. Review electrical drawings. As feasible with a time constraint, record the number of receptacles assigned to each branch circuit. Compare receptacle count with connected and demand load listed on receptacle panel and the main distribution panel schedules.
2. Review measured branch circuit and panel data. Observe any hourly, weekly, and seasonal patterns. Record peak power. Calculate mean power and other useful statistics. Identify any correlations between space type and branch circuit loading.
3. Compare measured data with panel schedule connected and demand load.
4. With results of Step 3, comment on NEC receptacle VA requirements and panel and main service receptacle load after receptacle demand factors applied.
5. Review receptacle inventory. As feasible and time permits, analyze power requirements of the inventoried plug-in equipment and compare with measured load and calculated load. Comment on NEC receptacle VA requirements.

8.5.3 Evaluation of Other Loads

1. Review electrical and mechanical drawings and panel schedules. Note presence or absence of electrical heating, cooling, and hot water equipment. Note connected and demand load for “large” loads (over 10kVA) and any panels which exclusively serve one type of equipment (other than lighting and receptacle).
2. As feasible, compare panel schedule connected and demand load requirements with power requirements listed on the mechanical schedule. (Ideally, these will be manufacturer requirements, if not look up manufacturer requirements as time constraints and feasibility permit).
3. Review measured data. Observe any hourly, weekly, and seasonal patterns. Record peak power. Calculate mean power and other useful statistics.
4. Compare measured data with panel connected and demand load, and also with manufacturer requirements for any “large” loads monitored.

8.5.4 Evaluation of In-House Feeder Sizing and Transformer Loading

1. Review and comment on transformer power loss with reference to expected efficiency based on DOE requirements. As feasible and time permits, compare measured losses with estimations based on standard transformer tables and efficiency curves.
2. Review and comment on harmonic content. Calculate K-factor, if not directly measured. Compare measured K-factor with transformer K-factor rating, and K-factor rating recommended for load type.
3. Compare NEC feeder size requirements with feeder size and peak and mean measured loading. Note impact of spare capacity added to panels.
4. Compare panel schedule connected and demand load on panel served by transformer with transformer capacity, and peak and mean transformer loading.

8.5.5 Evaluation of Main Feeder Size and Service Transformer Loading

1. Review and comment on transformer power loss with reference to expected efficiency based on DOE requirements. As feasible and time permits, compare measured losses with estimations based on standard transformer tables and efficiency curves.
2. Review and comment on harmonic content, including in the context of IEEE 519.
3. Calculate K-factor, if not directly measured. Compare measured K-factor with transformer K-factor rating, and K-factor rating recommended for building type.
4. Review the measured load data. Observe hourly, weekly, and seasonal patterns. Note if main service loading similar to previous year. Calculate peak and mean power density for the building.
5. Compare connected and demand power requirements of main service panel, feeder size, and transformer rating, and feeder size and transformer rating needed to meet peak power measured.

8.5.6 General Evaluation of Power Quality

1. Note any power interruptions and duration.
2. Review voltage data. Comment on voltage stiffness and relationship to levels established in ANSI C84.1. Note the presence and frequency of any voltage fluctuations, sags, or surges.
3. Review and comment on harmonic levels.

8.6 Deliverables

The final deliverables will be:

- The report containing an extensive loading evaluation of each site and a comparison of sites, noting commonalities and differences.
- An executive summary with a database or one more spreadsheets. Key site information will be provided, including square foot, year of construction, number of employees, DOE geographic region, service voltage, and energy source for heating, cooling and hot water. Other summary information will include mean and peak power consumption (W/ft^2) of lighting, receptacle, HVAC, and other loads as applicable. Transformer capacity and mean and peak power requirements will also be included.
- Individual site archives: all requested documentation and information and data.

8.7 Budget

The budget depends largely on research project sponsorship and the commercial building study type selected. If universities sponsor the project, provide the monitoring equipment, and provide a working staff to install the equipment and supervise data collection on site, the only out-of-pocket expense would be for project management. Project management costs might be estimated to cover a two-year period from project inception to delivery of the final report. Otherwise, depending on the project scale and the buildings selected for study, project costs could reach $1 or even $2 million.

9 REFERENCES

[1] U.S. Energy Information Administration (part of the U.S. Department of Energy), http://www.eia.gov/electricity/data.cfm.

[2] Michael Deru, Kristin Field, Daniel Studer, Kyle Benne, Brent Griffith, and Paul Torcellini (NREL), Bing Liu, Mark Halverson, Dave Winiarski, and Michael Rosenberg (PNNL), Mehry Yazdanian, Joe Huang, and Drury Crawley, *U.S. Department of Energy Commercial Reference Building Models of the National Building Stock,* NREL/TP-5500-46861, February 2011.

[3] Michael C. Baechler, Theresa L. Gilbride, Pam C. Cole, Marye G. Hefty, and Kathi Ruiz, Pacific Northwest National Laboratory, *Building America Best Practice Series Volume 7.3, High Performance Home Technologies: Guide to Determining Climate Regions by County*, August 2015, PNNL-17211 Rev. 3.

[4] Energy Vanguard *U.S. Climate Zones*, http://www.energyvanguard.com, accessed September 10, 2016.

[5] U.S. Energy Information Administration Commercial Building Energy Consumption Survey (CBECS), 2012 CBECS Survey Data, http://www.eia.gov/consumption/commercial/data/ 2012, accessed from September through December 2016.

[6] Austin Energy, *Customer Demand Load and Revenue Evaluations*, v. 1.1.0, June 1, 2012, located in Texas Public Utilities Commission Docket No. 40827, Response to OPC 1-47, Attachment 1.

[7] Emily Rauch and Michael Baechler (PNNL) and Greg Sullivan (Efficiency Solutions, LLC), *Assessing and Reducing Miscellaneous Electric Loads (MELs) in Banks*, prepared for U.S. Department of Energy, PNNL-20973, September 26, 2011.

[8] *Analysis and Representation of Miscellaneous Electric Loads in NEMS*, prepared by Navigant Consulting, Inc. and SAIC for the Energy Information Administration, December 2013.

[9] Steven Lanzisera, Stephen Dawson-Haggerty, H.Y. Iris Cheung, Jay Taneja, David Culler, Richard Brown, “Methods for Detailed Energy Data Collection of Miscellaneous and Electronic Loads in a Commercial Office Building,” *Building and Environment*, 2013, vol. 65, pp. 170-177.

[10] Brad Acker, Carlos Duarte, and Kevin Van Den Wymelenberg, *Office Plug Load Profiles*; Technical Report 20100312-01, Integrated Design Lab, University of Idaho, prepared for Idaho Power Company, March 13, 2012, Boise, ID.

[11] Cathy Higgins, “Office Plug Loads Energy Use and Savings Opportunities,” presentation on January 26, 2012, for the California Public Interest Energy Research Program; credit of data source: New Buildings Institute.

[12] Michael Sheppy, Paul Torcellini, and Luigi Gentile-Polese, “An Analysis of Plug Load Capacities and Power Requirements in Commercial Buildings,” National Renewable Energy Laboratory, NREL/CP-5500-61528, presented at the 2014 ACEEE Summer Study on Energy Efficiency in Buildings, Pacific Grove, California, August 17-22, 2014.

[13] Justin, Lueker, Annie Marston, Raghuram Sunnam, and Oliver Baumann, Baumann Consulting, “Simulating Empirically-Determined Plug Loads to Improve the Knowledge of Design Loads and Assess Building Performance Improvement Opportunities,” ASHRAE and IBPSA-USA SimBuild 2016 Building Performance Modeling Conference, Salt Lake City, UT, August 8-12, 2016.

[14] Laura Moorefield, Brooke Frazer, and Paul Bendt, *Office Plug Load Field Monitoring Report*, April 2011, California Energy Commission, PIER Energy-Related Environmental Research Program, CEC-500-2011-010.

[15] Christopher K. Wilkins, Mohammad H. Hosni, "Plug Load Design Factors," *ASHRAE Journal*, May 2011, pp. 30-34

[16] *Commercial Demand Module of the National Energy Modeling System: Model Documentation 2014*, U.S. Energy Information Administration, August 2014.

[17] *Annual Energy Outlook 2016 with projections to 2040*, U.S. Energy Information Administration, Washington D.C., DOE/EIA-0383(2016), August 2016.

[18] ASHRAE Standard Benchmark Energy Utilization Index, October 2009, http://cms.ashrae.biz/EUI, accessed December 7, 2016.

[19] *The History of Energy Efficiency*, January 2013, Alliance Commission on National Energy Efficiency Policy.

[20] O.V. Livingston, P.C. Cole, D.B. Elliott, and R. Bartlett, Pacific Northwest National Laboratory, *Building Energy Codes Program: National Benefits Assessment, 1992-2040*, March 2014, PNNL-22610 Rev1 report, prepared for U.S. DOE under contract DE-AC05-76-RL01830.

[21] Stephanie J. Battles, "Historical Perspective on Energy Codes and Appliance Standards," Energy Information Administration 2008 Energy Conference, April 7-8, 2008, Washington, D.C.

[22] ANSI/ASHRAE/IES Standard 90.1-2016, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, 2016, ASHRAE, Atlanta, GA.

[23] *2015 International Energy Conservation Code*, May 2014, International Code Council, Inc., Country Club Hills, Illinois.

[24] *2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings*, CEC-400-2015-037-CMF, June 2015, California Energy Commission.

[25] R.A. Athalye, B. Liu, D. Sivaraman, R. Bartlett, and D.B. Elliott, Pacific Northwest National Laboratory, *Impacts of Model Building Energy Codes*, October 2016, PNNL-25611 report, prepared for U.S. DOE under contract DE-AC05-76RL01830.

[26] Eric Makela Jennifer Williamson, and Erin Makela, Pacific Northwest National Laboratory, *Comparison of Standard 90.1-2010 and the 2012 IECC with Respect to Commercial Buildings,* September 2011, PNNL-20720 report, prepared for the U.S. Department of Energy under Contract DE-AC05-76RL01830.

[27] Eric E. Richman, Carol C. Jones, JoAnne Lindsley, "An Empirical Data Based Method for Development of Lighting Energy Standards," *Journal of the Illuminating Engineering Society*, vol. 28, no. 2,1999.

[28] John H. Matthews, *Introduction to the Design and Analysis of Building Electrical Systems*, Van Nostrand Reinhold: New York, 1993.

[29] Michael A. Anthony, Thomas L. Harman, and James R. Harvey, "Rightsizing Commercial Electrical Power Systems," *IEEE Industry Applications Magazine*, July/August 2016, pp. 41-46.

[30] Eric E. Richman, Pacific Northwest National Laboratory, "Requirements for Lighting Levels," 2015, found on a federal government website in October 2016 (which can no longer be found), but still available from various document sites on the web. The document appears to have been created for Army facilities and has a page 2 header, *Energy and Water Conservation Design Requirements for SRM Projects*.

[31] *Facilities Standards for the Public Buildings Service*, U.S. General Services Administration, Office of the Chief Architect, editions March 2003, March 2005, and March 2014.

[32] David L. Korn, Gene E. Fax, and James J. Siegmund, Cadmus Group, *Low-Voltage Transformer Loads in Commercial, Industrial, and Public Buildings*, prepared for Northeast Energy Efficiency Partnerships, Inc., December 7, 1999.

[33] "Ch. 2 What are Harmonics?", K-Factor Training Federal Pacific, http://federal pacific.com/ training/k-factor/chapter-2.htm, accessed on October 12, 2016.

[34] P.R. Barnes, S. Das, B.W. McConnell, and J.W. Van Dyke, Oak Ridge National Laboratory, *Supplement to the "Determination Analysis" (ORNL-6847) and Analysis of the NEMA Efficiency Standard for Distribution Transformers*, Report ORNL-6925, September 1997, prepared for the U.S. Department of Energy under contract DE-AC05-96OR22464.

[35] Kenneth Duane Harden, "Optimizing Energy Efficiency Standards for Low Voltage Distribution Transformers," Master's Thesis, Purdue University, Fort Wayne, Indiana, May 2011.

[36] Edvard Csanyi, "Transformer Extra Losses due to Harmonics," Electrical Engineering Portal, posted June 22, 2012, http://electrical-engineering-portal.com/transformer-extra-losses-due-to-harmonics.

[37] "K-Factor Defined," Application Note AN102, Xitron Technologies, http://www.xitrontech.com/assets/ 002/5787.pdf, accessed December 11, 2016.

[38] Tammy Gammon, "Improved Arcing-Fault Current Models for Low-Voltage Power Systems (<1 kV)", Ph.D. Thesis, School of Electrical Engineering, Georgia Institute of Technology, Atlanta, GA, 1999.

[39] H. Bruce Land and Tammy Gammon, "Addressing Arc-Flash Problems in Low-Voltage Switchboards: A Case Study in Arc Fault Protection," *IEEE Transactions on Industry Applications*, vol. 51, no. 2, March/April 2015, pp. 1897-1908.

[40] IEEE Standard, 1584-2002, *IEEE Guide for Performing Arc-Flash Hazard Calculations*, The Institute of Electrical and Electronic Engineers, New York, New York, 2002.

[41] Peyton S. Hale, Robert G. Arno, and D. David Dylis, "Reliability and Availability Data Collection Program for Power Distribution, Power Generation, and HVAC Components of Commercial, Industrial, and Utility Installations," *IEEE Systems Technical Conference on Industrial and Commercial Power 2005*," Saratoga Springs, NY, 2005, pp. 199-203.

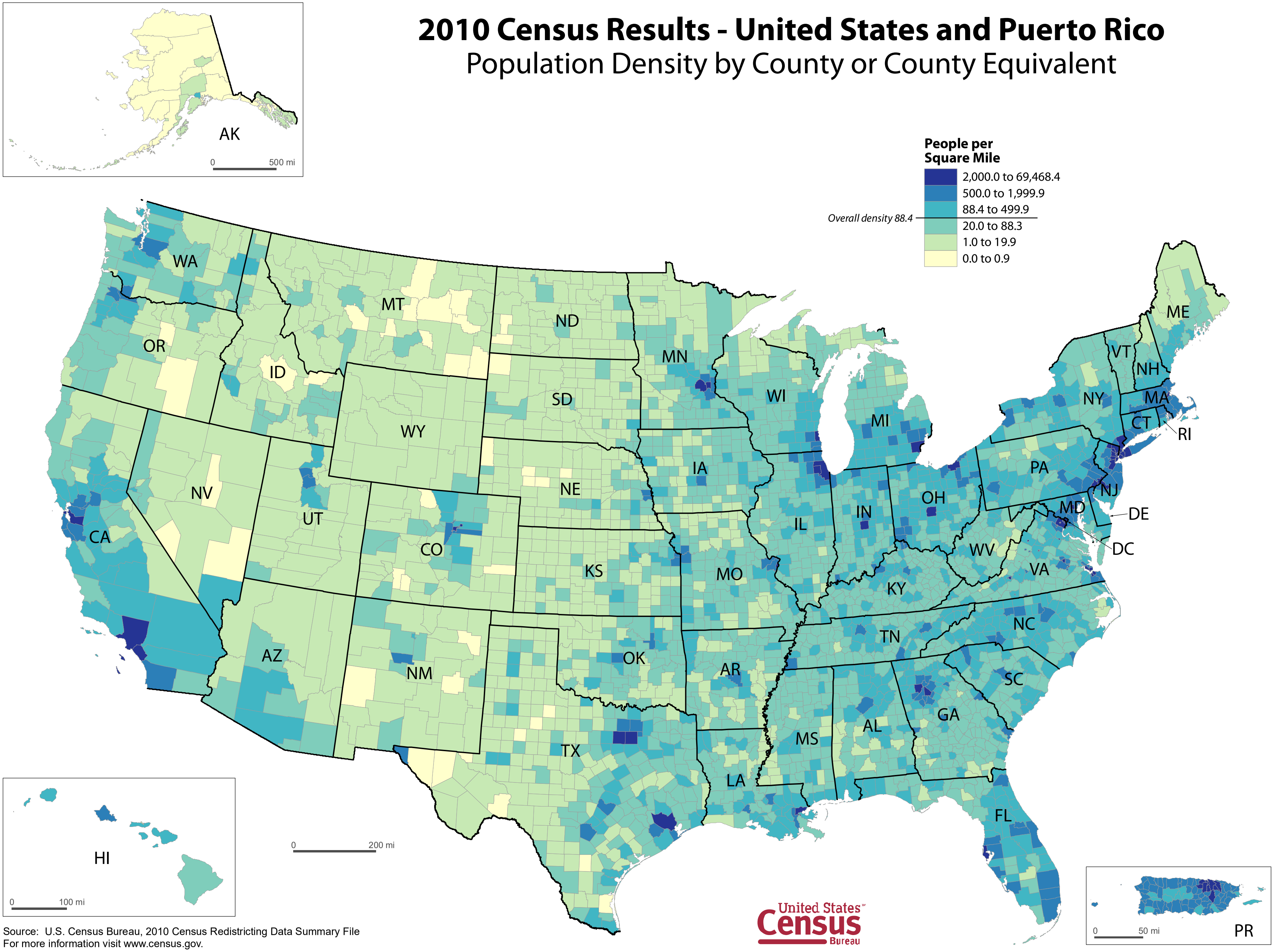
10 APPENDICES

Appendix A. U.S. Census Bureau Population Density Map

(Source: United States Census Bureau)

2010 Census Results - United States and Puerto Rico

Population Density by County or County Equivalent



Source: U.S. Census Bureau, 2010 Census Redistricting Data Summary File
For more information visit www.census.gov.

United States Census Bureau

Appendix B. Manufacturer Monitoring Equipment Information

Appendix B.1 GE EPM 4600 Multi-feed Power and Energy Metering System

(Reference source for Multilin™ EPM 4600 is GE Energy Connections. Reprint permission granted by General Electric.)

Multilin™ EPM 4600 Metering System

Chapter 2: EPM 4600 Metering System Overview and Specifications

The EPM 4600 unit is a multi-port, high-density power and energy metering system, designed to be used in high-density metering environments such as data centers, commercial high-rise complexes, high-density power distribution panels, and branch circuits.

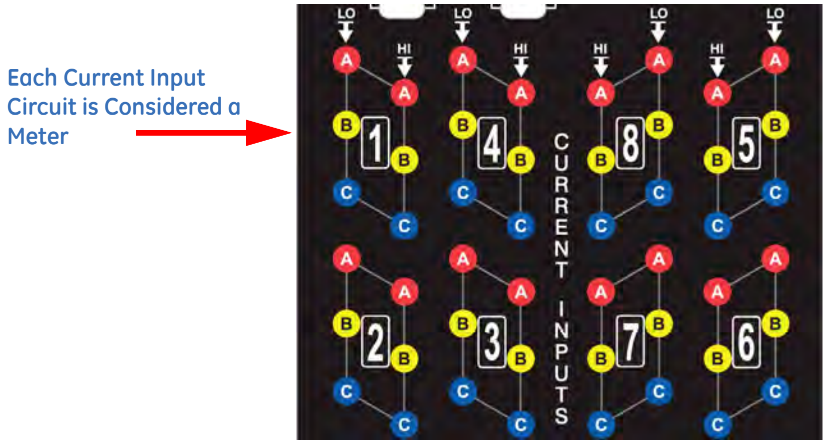
FIGURE 2.1: EPM 4600 Metering System

The EPM 4600 metering system provides 8 three phase or 24 single phase meters served by one central processing unit, which delivers the measured data in multiple formats via RS485 serial communication, USB port communication, RJ45 Ethernet, or 802.11 WiFi Ethernet options. The EPM 4600 metering system also has data logging and load profiling capability to provide historical data analysis.

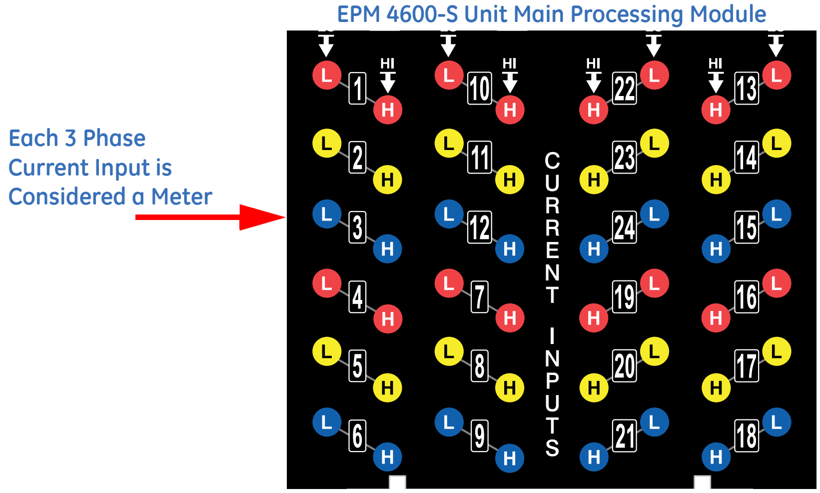
The EPM 4600 unit can be ordered as either an EPM 4600-T for three phase systems or as an EPM 4600-S for single phase systems. The EPM 4600 unit is designed to be a cost-effective instrument for high density metering. It is important to note that for this design to function properly, all loads must be powered from a common voltage (or three phase voltage) set.

The EPM 4600 metering system was designed using the following concept:

EPM 4600-T Unit Main Processing Module



EPM 4600-S Unit Main Processing Module



The EPM 4600 metering system offers up to 32 MegaBytes of non-volatile memory for per-circuit Energy usage trending. The EPM 4600 unit provides you with up to 5 logs: two historical logs, a log of limit alarms, a log of I/O changes, and a sequence of events log.

The EPM 4600 metering system is designed with advanced measurement capabilities, allowing it to achieve high performance accuracy. It is rated as a 0.5% Class accuracy metering device, meeting ANSI C12.20 and IEC 62053-22 0.5% classes.

Optional Display

The EPM 4600 unit offers an optional touch-screen color LED display. The display is available in two sizes: 3.5” (DIS3500) and 5.7” (DIS5700). The display lets you view readings from all of the meters on the EPM 4600 unit. See “Using the Optional Display” on page 10-1 for DIS3500/DIS5700 display details.

Voltage and Current Inputs

Universal Voltage Inputs

Voltage inputs allow measurement up to Nominal 480VAC (Phase to Reference) and 600VAC (Phase to Phase). This insures proper safety when wiring directly to high voltage systems. The EPM 4600 unit will perform to specification on 69 Volt, 120 Volt, 230 Volt, 277 Volt, and 347 Volt power systems.

Higher voltages require the use of potential transformers (PTs). The EPM 4600 unit is programmable to any PT ratio needed.

Current Inputs

The EPM 4600 unit can be ordered with either a 10 Amp or a 2 Amp secondary for current measurements. Depending on the EPM 4600 metering system model, there are either 8 three phase current inputs, or 24 single phase current inputs. The current inputs are only to be connected to external current transformers that are approved or certified.

The 10 Amp or 2 Amp secondary is an ordering option and as such it cannot be changed in the field. The 10 Amp secondary model (10A) allows the unit to over-range to 10 Amps per current circuit. The 2 Amp secondary model (02A) allows the unit to overrange to 2 Amps per current circuit.

Ordering Information

Table 2–2: EPM 4600 Meter Order Codes

	PL4600	–	*	–	*	–	*	–	*	–	*	Description
Base Unit	**PL4600**		|		|		|		|		|	
Feed Configuration			**T**		|		|		|		|	Three Phase
			S		|		|		|		|	Single Phase
Frequency					**5**		|		|		|	50 Hz AC frequency system
					6		|		|		|	60 Hz AC frequency system
Current Inputs							**10A**		|		|	Up to 10A Current
							02A		|		|	Up to 2A Current
Software									**A**		|	Transducer
									B		|	Basic Logging-2MB Memory
									C		|	Advanced Logging-32MB Memory
Communications											**S**	Serial (RS485) Modbus
											W	WiFi, RJ45 100BaseT Ethernet

Example:

PL4600-T-6-10A-B-S

EPM 4600 metering system with three phase circuit configuration, 60 Hz Frequency, 10 Amp Secondary, B Software option, and Serial (RS485) Modbus communication.

NOTE on Frequency: It is important to specify the frequency to insure the highest possible calibration accuracy from the factory.

Table 2–3: EPM 4600 Display Order Codes

	PL4600	–	*	Description
Displays	**PL4600**	-	**DIS3500**	3.5" Touch Screen Display with Installation Kit
			DIS5700	5.7" Touch Screen Display with Installation Kit

Software option

The EPM 4600 metering system is equipped with a Software option, which is a virtual firmware-based switch that lets you enable features through software communication. The Software option allows feature upgrades after installation without removal from service.

Available Software option upgrades are as follows:

- Software option A: Transducer
- Software option B: Basic logging with 2 MegaBytes* memory
- Software option C: Advanced logging with 32 MegaBytes* memory

* The table below shows the number of days of logging available with B and C, for the EPM 4600-T and EPM 4600-S circuit configurations, based on a 15 minute logging interval. Note that both EPM 4600-T and EPM 4600-S units have Log 1; Log 2 is used for EPM 4600-T units, only, and Log 3 is used for EPM 4600-S units, only.

Model	Wiring	Log 1 B	Log 2/3 B	Log 1 C	Log 2/3 C
EPM 4600-T	Three Phase/ 8 circuits	68 days	105 days	3617 days	2872 days
EPM 4600-S	Single Phase/24 circuits	136 days	47 days	7235 days	1247 days

Obtaining a Software option:

Contact GE Digital Energy's inside sales staff at sales@gedigitalenergy.com and provide the following information:

1. Serial number(s) of the EPM 4600 unit(s) you are upgrading. Use the number(s), with leading zeros, shown in the GE Communicator Device Status screen (from the GE Communicator Main screen, click **Tools>Device Status**).
2. Desired Software option.
3. Credit card or Purchase Order number. GE Digital Energy will issue a Software option encrypted key.

Enabling the Software option:

1. Open GE Communicator software.
2. Power up your EPM 4600 unit.
3. Connect to the EPM 4600 unit through GE Communicator software (see "Communicating with the Meter" on page 5-1).
4. Click **Tools>Change Software option** from the Title Bar. A screen opens, requesting the encrypted key.
5. Enter the Software option key provided by GE Digital Energy.
6. Click the **OK** button. The Software option is enabled and the EPM 4600 unit resets.

Measured Values

The EPM 4600 metering system provides the following measured values, all in real time instantaneous. As the following tables show, some values are also available in average, maximum and minimum.

Table 2.1: Single Phase Circuit Configuration

Measured Values	Instantaneous	Avg	Max	Min
Voltage L-N	X		X	X
Current	X	X	X	X
WATT	X	X	X	X
VAR	X	X	X	X
VA	X	X	X	X
PF	X	X	X	X
+Watt-Hour	X			
-Watt-Hour	X			
Watt-Hour Net	X			
+VAR-Hour	X			
-VAR-Hour	X			
VAR-Hour Net	X			
VA-Hour	X			
Frequency	X		X	X
Current Angle	X			

Table 2.2: Three Phase Circuit Configuration

Measured Values	Instantaneous	Avg	Max	Min
Voltage L-N	X		X	X
Voltage L-L	X		X	X
Current per Phase	X	X	X	X
Current Neutral (see NOTE, below)	X	X	X	X
WATT (A,B,C,Tot.)	X	X	X	X
VAR (A,B,C,Tot.)	X	X	X	X
VA (A,B,C,Tot.)	X	X	X	X
PF (A,B,C,Tot.)	X	X	X	X
+Watt-Hour (A,B,C,Tot.)	X			
-Watt-Hour (A,B,C,Tot.)	X			
Watt-Hour Net	X			
+VAR-Hour (A,B,C,Tot.)	X			
-VAR-Hour (A,B,C,Tot.)	X			
VAR-Hour Net (A,B,C,Tot.)	X			
VA-Hour (A,B,C,Tot.)	X			
Frequency	X		X	X
Voltage Angles	X			
Current Angles	X			

NOTE

Neutral current is calculated only when the voltages are connected; if voltages are not connected, the neutral current will not be calculated.

Utility Peak Demand

The EPM 4600 metering system provides user-configured Block (Fixed) window or Rolling window Demand modes. This feature lets you set up a customized Demand profile. Block window Demand mode records the average demand for time intervals you define (usually 5, 15 or 30 minutes). Rolling window Demand mode functions like multiple, overlapping Block windows. You define the subintervals at which an average of Demand is calculated. An example of Rolling window Demand mode would be a 15-minute Demand block using 5-minute subintervals, thus providing a new Demand reading every 5 minutes, based on the last 15 minutes.

Utility Demand features can be used to calculate Watt, VAR, VA and PF readings. Voltage provides an instantaneous Max and Min reading which displays the highest surge and lowest sag seen by the meters. All other parameters offer Max and Min capability over the user-selectable averaging period.

Specifications

Power Supply

Range:	Universal, 90-300VAC @50/60Hz or 150VDC
Power Consumption:	18VA, 12W, Maximum

Voltage Inputs (Measurement Category III)

(For Accuracy specifications, see “Accuracy” on page 2-12.)

Range:	Universal, Auto-ranging up to 576VAC L-N, 721VAC L-L
Supported hookups:	EPM 4600-T: 3 Element Wye
	EPM 4600-S: Single Phase, 2 wire, 3 wire
Input Impedance:	4.2M Ohm/Phase
Burden:	0.09VA/Phase Max at 600 Volts; 0.014VA at 120 Volts
Pickup Voltage:	20VAC
Connection:	7 Pin 0.400” Pluggable Terminal Block
	AWG#12 -26/ (0.08 -2.5) mm2
Fault Withstand:	Meets IEEE C37.90.1
Reading:	Programmable Full Scale to any PT ratio

Current Inputs

(For Accuracy specifications, see “Accuracy” on page 2-12.)

Class 10:	5A Nominal, 10A Maximum
Class 2:	1A Nominal, 2A Maximum
Burden:	0.005VA Per Input Max at 11 Amps
Pickup Current:	0.1% of Nominal Class 10: 5mA Class 2: 1mA
Current Input Terminals:	8-32 Threaded Studs
Reading:	Programmable Full Scale to any CT ratio
Continuous Current Withstand:	20 Amps
Maximum Voltage across Current Inputs:	1VAC

Maximum Voltage from Current Inputs to Ground: 50VAC

NOTE

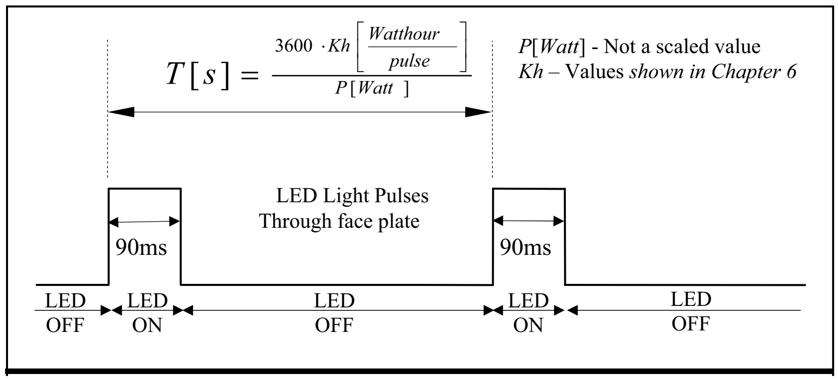
For detailed electrical specifications for the optional display see "DIS3500/DIS5700 Specifications" on page 10-3

Wh Pulses

Red LED light pulses through top cover (see "Performing Watt-Hour Accuracy Testing" on page 6-2 for Kh values):

Peak Spectral wavelength: 574nm

Output timing:



See **"Performing Watt-Hour Accuracy Testing" on page 6-2** for Kh values.

Isolation

All Inputs and Outputs are galvanically isolated to 2500 VAC

Environmental Rating with and without Optional Display DIS3500/DIS5700

Storage:	(-20 to +70)^{o} C/(-4 to +158)^{o} F
Storage with Display:	(-20 to +60)^{o} C/(-4 to +140)^{o} F
Operating:	(-20 to +60)^{o} C/(-4 to +140)^{o} F
Operating with Display:	(0 to +50)^{o} C/(+32 to +122)^{o} F
Humidity:	to 95% RH Non-condensing
Humidity with Display:	to 85% RH Non-condensing; Wet bulb temperature 39°C/ 102.2° F or less

Measurement Methods

Voltage, current:	True RMS
Power:	Sampling at over 400 samples per cycle on each channel simultaneously

Update Rate

All parameters:	Every 60 cycles (e.g., 1 s @ 60 Hz)

Communication

Standard:

1. RS485 port (Com 1)
2. USB port (Com 2)
3. RS485/Display port (Com 3)

4. Energy pulse output LED for meter testing: there are 8 pulses, one for each of the three phase loads of the EPM 4600-T; for the EPM 4600-S, the test pulses are shared, with one pulse for every three loads (see "Using the Metering System's Watt-Hour Test Pulses" on page 6-1 for more details and instructions for using the Test pulses).

Optional:

Ethernet/WiFi port (Com 1): 802.11b Wireless or RJ45 Connection 10/100BaseT Ethernet

Com Specifications

RS485 Ports (Com 1 and Com3):

RS485 Transceiver; meets or exceeds EIA/TIA-485 Standard

Type:	Two-wire, half duplex
Min. input impedance:	96kΩ
Max. output current:	±60mA
Protocol:	Modbus RTU, Modbus ASCII
Com port baud rates:	9600 to 57600 bps
Device address:	001-247
Data format:	8 Bit

WiFi/Ethernet Port (optional Com 1):

Wireless security:	64 or 128 bit WEP; WPA; or WPA2
Protocol:	Modbus TCP
Device address:	001-247

USB Port (Com 2):

Protocol:	Modbus ASCII
Com port baud rate:	57600 bps
Device address:	1

Com Specifications for Optional Displays DIS3500/DIS5700

Serial Interface COM1:

Asynchronous Transmission: RS232C / RS422 / RS485

Data Length:	7 or 8 bits
Stop Bit:	1 or 2 bits
Parity:	None, odd or even
Data Transmission Speed:	2,400 to 115.200 kbps, 187,500 bps
Connector:	D-Sub 9-pin (plug)

Ethernet Interface:

Ethernet (LAN):	IEEE802.3i/ IEEE802.3u, 10BASE-T/100BASE-TX
Connector:	D-Sub 9-pin (plug)

LED:

Green, lit:	Data transmission is available
Green, blinking:	Data transmission is occurring

Relay Output/Digital Input Board Specifications at 25° C

Relay outputs:

Number of outputs: 2

Contact type:	Changeover (SPDT)
Relay type:	Mechanically latching
Switching voltage:	AC 150V / DC 30V
Switching power:	750VA / 150W
Switching current:	5A
Switching rate max.:	10/s
Mechanical life:	5 x 10^7 switching operations
Electrical life:	10^5 switching operations at rated current
Breakdown voltage:	AC 1000V between open contacts
Isolation:	AC 3000V / 5000V surge system to contacts
Reset/power down state:	No change - last state is retained

Inputs:

Number of inputs:	4
Sensing type:	Wet or dry contact status detection
Wetting voltage:	DC (1-24)V, internally generated
Input current:	2.5mA – constant current regulated
Minimum input voltage:	0V (input shorted to common)
Maximum input voltage:	DC 150V (diode protected against polarity reversal)
Filtering:	De-bouncing with 50ms delay time
Detection scan rate:	100ms
Isolation:	AC 2500V system to inputs
External Connection:	AWG 12-26/(0.129 - 3.31)mm^2 11 pin, 0.200" pluggable terminal block

Mechanical Parameters

Dimensions:	7.6(L) x 11.28(W) x 4.36(H) in / 19.3(L) x 28.65(W) x 11.07(H) cm
Weight:	7 pounds (3.18kg)

Compliance

- UL Listing: UL61010-1, CAN/CSA C22.2 No. 61010-1, UL file number E250818
- IEC 62053-22 (0.5% Class)
- ANSI C12.20 (0.5% Accuracy)
- ANSI (IEEE) C37.90.1 Surge Withstand
- ANSI C62.41 (Burst)
- EN61000-6-2 Immunity for Industrial Environments
- EN61000-6-4 Emission Standards for Industrial Environments
- EN61326 EMC Requirements

Accuracy

(For full Range specifications see "Specifications" on page 2-8.)

EPM 4600 metering system Clock accuracy:

±3.5ppm max. (±0.3024 second/day) over the rated temperature range

For 23 °C, three phase or single phase 3 wire connected balanced load:

Parameter	Accuracy	Accuracy Input Range
Voltage L-N [V]	0.3% of reading*	(69 to 480)V
Voltage L-L [V]	0.5% of reading	(120 to 600)V
Current Phase [A]	0.3% of reading	(0.15 to 5)A
Current Neutral (calculated) [A]	2.0% of Full Scale	(0.15 to 5)A @ (45 to 65)Hz
Active Power Total [W]	0.5% of reading*	(0.15 to 5)A @ (69 to 480)V @ +/- (0.5 to 1) lag/ lead PF
Active Energy Total [Wh]	0.5% of reading*	(0.15 to 5)A @ (69 to 480)V @ +/- (0.5 to 1) lag/ lead PF
Reactive Power Total [VAR]	1.0% of reading*	(0.15 to 5)A @ (69 to 480)V @ +/- (0 to 0.8) lag/ lead PF
Reactive Energy Total [VARh]	1.0% of reading*	(0.15 to 5)A @ (69 to 480)V @ +/- (0 to 0.8) lag/ lead PF
Apparent Power Total [VA]	1.0% of reading*	(0.15 to 5)A @ (69 to 480)V @ +/- (0.5 to 1) lag/ lead PF
Apparent Energy Total [VAh]	1.0% of reading*	(0.15 to 5)A @ (69 to 480)V @ +/- (0.5 to 1) lag/ lead PF
Power Factor	1.0% of reading*	(0.15 to 5)A @ (69 to 480)V @ +/- (0.5 to 1) lag/ lead PF
Frequency	+/- 0.01Hz	(45 to 65)Hz

* For unbalanced voltage inputs where at least one crosses the 150V auto-scale threshold (for example, 120V/120V/208V system), degrade accuracy by additional 0.4%.

The EPM 4600 metering system's accuracy meets the IEC62053-22 and ANSI C12.20 Accuracy Standards for 0.5% Class Energy meters.

Appendix B.2 Honeywell E-Mon Class 3400 Smart Meter

(Unfortunately, permission has been delayed for reprinting the specification sheet for the Class 3400 Smart Meter, a product of E-Mon D-Mon: Energy Monitoring Products & Systems, Honeywell Corporation. Since the publication of this report cannot be delayed, the report will be published without it.)

The specification sheet for the Class 3400 Smart Meter, as well as other documents for the Class 3400 Smart Meter and other E-Mon meters, can be downloaded from:

http://www.emon.com/en/downloads

A summary of the specification sheet for the Class 3400 Smart Meter can be found on the following two pages.

Class 3400 Smart Meter

Advanced kWh/Demand Meters with Communication

4-line by 20-character backlit LCD display for

- kWh
- Real-time kW load and kW demand with peak data and time
- Power factor, current, and voltage per phase

Onboard optional set-up for

- IP address
- Meter date and time
- Load control settings (optional expanded feature package)
- ID codes for EZ7, Modbus, and BACnet

Onboard installation diagnostics and verification

Split-core current sensors (0-2V output)

Built-in RS-485 communications

- Supports up to 52 Class 3200, 3400, or 5000 meters per channel
- Cables in daisy chain or star configuration, 3-conductor, 18-22 AWG, up to 4,000 feet total per channel

Built-in communication

- RS-485
- Ethernet
- Pulse output
- Optional telephone modem

Protocols

- EZ7
- Modbus RTU or TCP/IP
- BACnet MS/TP or IP
- LonWorks FT-10

Records KWh and kVARh delivered, and kWh and kVARh received in the first four channels

- Data stored in 15-minute intervals for 72 days (or 5-minute intervals for 24 days)
- Data stored in first-in, first-out format

Compatible with E-Mon Energy software using EZ7 protocol for automatic meter reading, billing, and profiling of energy data

Meter appropriate for use on three-phase, 3-wire (delta) or three-phase, 4-wire (wye) circuits

Enclosure

- Standard - Outdoor NEMA 4X polycarbonate enclosure with padlocking hasp and mounting flanges for indoor/outdoor installation (stand alone)
- Optional – Industrial grade JIC steel enclosure with padlocking hasp and mounting flanges for indoor installation (stand alone)

UL/CUL listed. Certified to ANSI C12.20 national accuracy standards

Meters available for three-phase 120/208-240V, 277/480V, and 347/600V systems

Meter ampacity sizes: 100A, 200A, 400A, 800A, 1600A, 3200A

Appendix B.3 Onset Data Loggers for Real Power or Phase RMS Currents

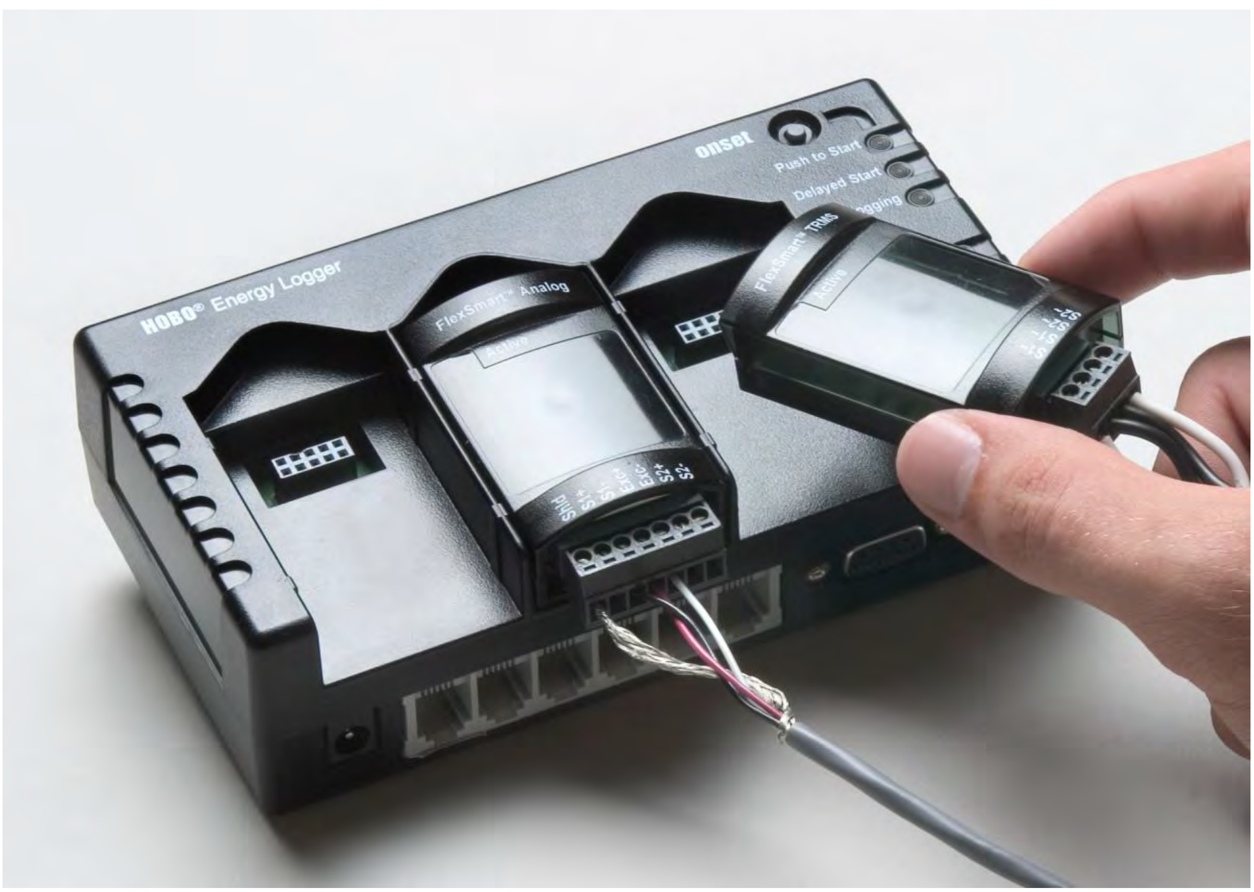
Reference source for the following devices is Onset Corporation / www.onsetcomp.com:

- HOBO Energy Logger
- FlexSmart TRMS Module
- HOBO® State Data Logger (UX90-001x)

Reprint permission granted by Onset Computer Corporation.

Reference source for the WattNode Pulse is WattNode BACnet energy meter manufactured by Continental Control Systems, LLC. Reprint permission granted by Continental Control Systems, LLC.

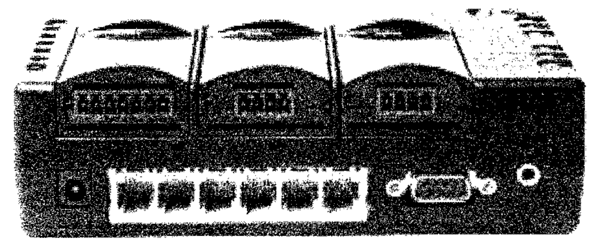

FlexSmart™ Analog
Active
FlexSmart™ TRMS
Active
FlexSmart™ TRMS
Active
onset
Push to Start
Delayed Start
Logging
Memory Low
Battery Low
Sensor Fail


onset
Push to Start
Delayed Start
HOBO® Energy Logger
FlexSmart™ Analog
Active
Shld
S1+
S1-
Exc+
S2+
S2-
FlexSmart™ TRMS
Active

HOBO® Energy Logger

Multi-channel energy data logging system

The HOBO Energy Logger multi-channel data logger is a modular, reconfigurable data logging system for energy and industrial monitoring applications.



The 15-channel system enables energy and facility management professionals to quickly and easily solve a broad range of monitoring applications without having to purchase a toolbox full of data loggers.

Supported Measurements: Temperature, Relative Humidity, Dew Point, 4-20mA, AC Current, AC Voltage, Air Velocity, Amp Hour, Carbon Dioxide, Compressed Air Flow, DC Current, DC Voltage, Differential Pressure, Gauge Pressure, Kilowatt Hours, Kilowatts, Power Factor, Pulse Input, Volatile Organic Compound, Volt-Amp Reactive, Volt-Amp Reactive Hour, Volt-Amps, Water Flow, Watt Hours, Watts, Wind

Key Advantages:

- Records up to 15 channels
- Provides 12v excitation for third-party sensors
- Pre-configured Smart Sensors for fast setup
- Signal conditioning modules retain configurations until you change them, providing plug-and-play convenience for commonly used sensors
- Flexible power options include battery operation or AC power adapter
- Works with Onset's E50B2 Power & Energy Meter to measure Power Factor, Reactive Power, Watt Hours, and more

Minimum System Requirements:


Software


Interface Cable*


Sensor

*USB to Serial interface cable, part #CABLE-PC-3.5

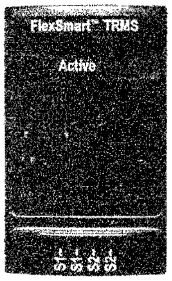
Part number	H22-001
Memory	512K nonvolatile flash data storage
Operating Range	-20° to 50°C (-4° to 122°F) with alkaline batteries -40° to 60°C (-40° to 140°F) with lithium batteries
Sensor Inputs	6 RJ-12 Smart Sensor jacks plus 3 FlexSmart module slots
Communication	RS-232 via 3.5 mm serial port*
Logging Interval	1 second to 18 hours, user-specified interval
Sensor Excitation	12 V DC at 200 mA total, with user-programmable warm up time on a per-channel basis
Battery Life	1 year typical
Battery Type	8 standard AA alkaline batteries (included)
External Power	Supports optional 13.6 V DC regulated AC Wall Adapter Connector
Time Accuracy	0 to 2 seconds for the first data point and ± 5 seconds per week at 25°C (77°F)
Dimensions	15.6 cm x 8.4 cm x 4.6 cm (6.13 in x 3.31 in x 1.81 in)
CE Compliant	Yes

*USB to Serial interface cable, part #CABLE-PC-3.5


FlexSmart™ TRMS
Active
S1~ S1~ S2~ S2~

FlexSmart™ TRMS Module

(Part No: S-FS-TRMSA & S-FS-TRMSA-D)



Quick Start Guide

Inside this package:

- FlexSmart TRMS Module
- Detachable screw terminal connector
- Imprintable label
- This guide

Note: Refer to the documentation provided with the Onset HOBO® H22 or U30 series data logger and HOBOware® Pro software for additional information on using and configuring the FlexSmart TRMS Module.

Introduction

Thank you for purchasing an Onset FlexSmart TRMS Module. With proper care, it will give you years of accurate and reliable measurements.

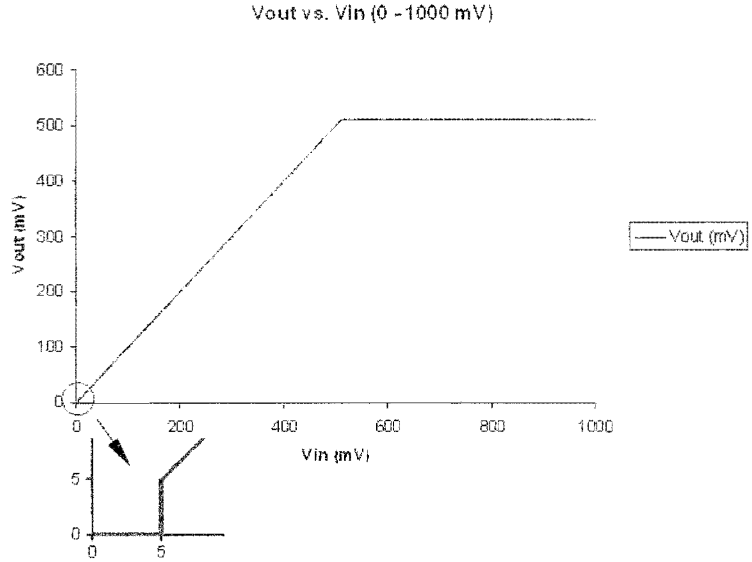
The S-FS-TRMSA and S-FS-TRMSA-D are easy-to-configure, True-RMS input measurement modules. The S-FS-TRMSA is compatible with Onset's HOBO H22 series data loggers. The S-FS-TRMSA-D is compatible with both the HOBO U30 and H22 series loggers. The "-D" variant has a modular connector for connecting to an available smart-sensor port. Both 2-channel modules have an input range of 512 millivolts RMS full-scale. Thus, they are fully compatible with industry-standard voltage and current transformers (PT and CT) which output 333 millivolts RMS full-scale.

The modules feature extremely low-power operation, resulting in long battery life for unattended data logging applications.

Specifications

Input Channels	Two, AC-coupled
Field Wiring	Two-wire via screw terminals on detachable connector, 16-24 AWG Replacement detachable connectors: Part of spares kit, Onset part no: A-FS-TRMSA-4P-1
Input Range	5 to 512 mVRMS
Minimum Input Voltage	5mVRMS; Input voltages < 5mV will be clipped to zero (see graph below)
Maximum Input Voltage	+/- 1V referred to AC- terminals (pins 2 and 4)
Input Frequency	50/60 Hz
Accuracy	+/- 0.3% of reading +/- 0.5% of FSR
ADC Resolution	15 bits
AC Waveform	< 4 Crest Factor
Power Requirements	+3.3V @ 3mA active, 6µA sleep
Transfer Function	$VRMS = \sqrt{\frac{1}{T}\bullet\int_0^T \left[V(t)^2\right]dt}$
Measurement Averaging Option	Yes
CE	The CE Marking identifies this product as complying with all relevant directives in the European Union (EU).

Minimum Input Voltage Graph



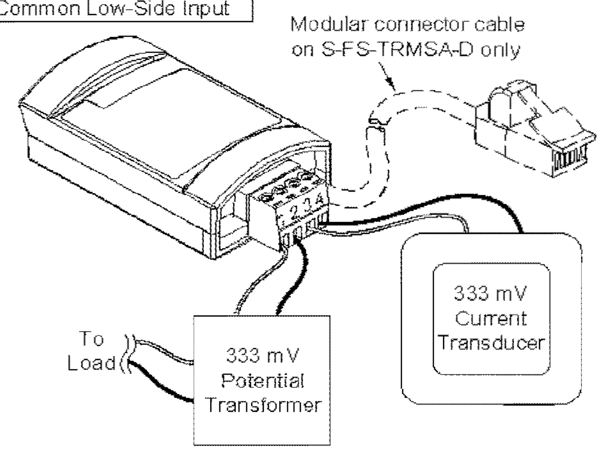
Module Connections

Potential Transformers (PT) and Current Transducers (CT) are connected to the module via a four-pin Phoenix-style detachable screw terminal connector. Once the PTs and/or CTs are connected, the module can then be configured using HOBOware Pro software (with the module installed on the HOBO H22 or U30 series data logger).

The diagram at below illustrates *typical* connections for a PT and CT. For module connection instructions specific to PTs and CTs purchased from Onset, refer to the documentation provided with each PT and CT.

Note: For three-phase monitoring, each of the three modules should be wired so that similar parameters are connected to corresponding pin numbers. For example, voltage inputs pins 1 and 2 on each module; current inputs pins 3 and 4 on each module.

Pin #	Function
1	Channel 1 High-Side Input
2	Common Low-Side Input
3	Channel 2 High-Side Input
4	Common Low-Side Input



Measurement Averaging

This sensor supports measurement averaging. When measurement averaging is enabled, data is sampled more frequently than it is logged. The multiple samples are then averaged together and the average value is stored as the data for the interval. For example, if the logging interval is set at 10 minutes and the sampling interval is set at 1 minute, each recorded data point will be the average of 10 measurements. Measurement averaging is useful for reducing noise in the data.

HOBO® State Data Logger (UX90-001x) Manual

The HOBO State/Pulse/Event/Runtime data logger records state changes, electronic pulses and mechanical or electrical contact closures from external sensing devices. Using HOBOware®, you can easily configure the internal magnetic reed switch or the external sensor to monitor and record data in a wide variety of applications, such as energy consumption, mechanical equipment operation, and water and gas flow. This compact data logger also has a built-in LCD screen to monitor logging status, battery use, and memory consumption. There are two models of the HOBO state logger: the UX90-001 has 128 KB of memory while the UX90-001M has 512 KB.

HOBO State Data Logger

Models: UX90-001
UX90-001M

Included Items:

- 2.5 mm input cable
- Command™ strip
- Double-sided tape
- Hook & loop strap
- Magnet with 2 screws

Required Items:

- HOBOware 3.3 or later
- USB cable (included with software)

Accessories:

- Wattnode kWh transducers
- Power & Energy Meter (T-VER-E50B2)
- Water Flow Meter Sensor (T-MINOL-130-NL)
- U-Shuttle (U-DT-1)

Specifications

Internal Sensor

Maximum State, Event, Runtime Frequency	1 Hz
Preferred Switch State	No magnet present (normally open)

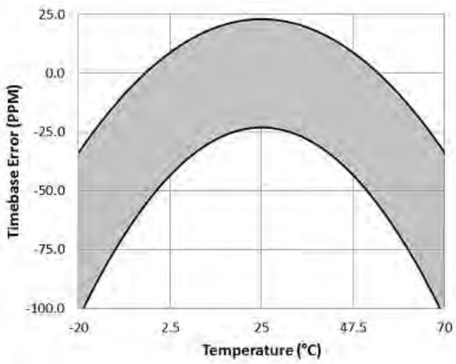
External Input

External Contact Input	Electronic solid state switch closure or logic driven voltage output
Range	0 to 3 V DC (USB powered), 0 to 2.5 V DC (battery powered)
Maximum Pulse Frequency	50 Hz
Maximum State, Event, Runtime Frequency	1 Hz
Pulse, Event Lockout Time	0 to 1 second in 100 ms steps
Solid State Switch Closure	Input Low: < 10 KΩ; Input High: > 500 KΩ
Internal Weak Pull-Up	100 KΩ
Input Impedance	Solid state switch closure: 100 KΩ pull up

Logger

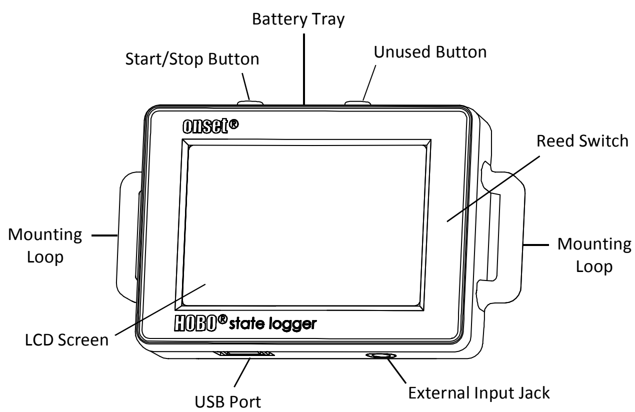
Resolution	Pulse: 1 pulse, Runtime: 1 second, State and Event: 1 State or Event
Logging Rate	1 second to 18 hours, 12 minutes, 15 seconds
Memory Modes	Wrap when full or stop when full
Start Modes	Immediate, push button, date & time, or next interval
Stop Modes	When memory full, push button, or date & time
Time Accuracy	±1 minute per month at 25°C (77°F) (see Plot A)
Power Source	One 3V CR2032 lithium battery and USB cable
Battery Life	1 year, typical with logging intervals greater than 1 minute and normally open contacts
Memory	UX90-001: 128 KB (84,650 measurements, maximum) UX90-001M: 512 KB (346,795 measurements, maximum)
Download Type	USB 2.0 interface
Full Memory Download Time	10 seconds for 128 KB; 30 seconds for 512 KB
Logger Operating Range	Logging: -20° to 70°C (-4° to 158°F); 0 to 95% RH (non-condensing) Launch/Readout: 0° to 50°C (32° to 122°F) per USB specification
LCD	LCD is visible from: 0° to 50°C (32° to 122°F); the LCD may react slowly or go blank in temperatures outside this range
Size	3.66 x 5.94 x 1.52 cm (1.44 x 2.34 x 0.6 in.)
Weight	23 g (0.81 oz)
Environmental Rating	IP50
CE	The CE Marking identifies this product as complying with all relevant directives in the European Union (EU).

Specifications (continued)



Plot A: Time Accuracy

Logger Components and Operation



Start/Stop Button: Press this button for 3 seconds to start or stop logging data. This requires configuring the logger in HOBOware with a push button start or stop (see *Setting up the Logger*). You can also press this button for 1 second to record an internal event (see *Recording Internal Logger Events*) or to turn the LCD screen on if the option to turn off the LCD has been enabled (see *Setting up the Logger*). Note that the other button on the top of the logger is not functional for this model.

Battery Tray: Remove the battery tray (not visible in the diagram) on the top of the logger to access the logger battery (see *Battery Information*).

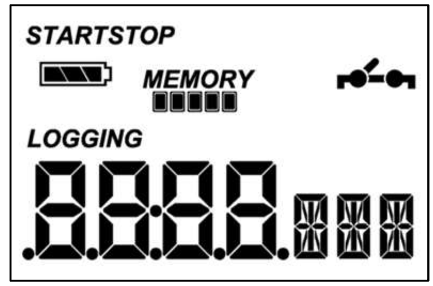
Reed Switch: The internal reed switch (not visible in the diagram) inside the logger housing allows for monitoring when windows and doors are open or closed (see *Using the Magnet*).

Mounting Loops: Use the two mounting loops to mount the logger with the hook-and-loop strap (see *Mounting the Logger*).

External Input Jack: Use this jack to attach the 2.5 mm input cable to an external sensing device (see *Using the Input Cable*).

USB Port: Use this port to connect the logger to the computer or the HOBO U-Shuttle via USB cable (see *Setting up the Logger* and *Reading Out the Logger*).

LCD Screen: This logger is equipped with an LCD screen that displays details about the current status. This example shows all symbols illuminated on the LCD screen followed by definitions of each symbol in the following table.



LCD Symbol	Description
START	The logger is waiting to be launched. Press and hold the Start/Stop button for 3 seconds to launch the logger.
STOP	The logger has been launched with a push button stop enabled; press and hold the Start/Stop button for 3 seconds to stop the logger. **Note**: If you also launched the logger with a push button start, this symbol will not appear on the display for 5 minutes.
	The battery indicator shows the approximate battery power remaining.
 MEMORY	If the logger has been configured to stop logging when memory fills, the memory bar indicates the approximate space remaining in the logger to record data. In this example, the logger memory is almost full.
 MEMORY	If the logger has been configured to never stop logging (wrapping enabled), then a single block will blink starting at the left and moving right over time. Each block represents a segment of memory where the data is being recorded. In this example, the middle block is blinking.
	The switch is open or off.
	The switch is closed or on.
	The logger is configured to record pulse or event data.
LOGGING	The logger is currently logging.
05.38 M-S	**Time display when logger is logging:** This shows the total amount of time the switch has been closed or on since logging began, ranging from seconds to days. This example indicates the switch has been closed or on for a total of 5 minutes and 38 seconds. The logger must be launched with the LCD set to show "Time" for this symbol to display. **Time display when logger is stopped:** This indicates the logger has been configured to start logging on a particular date/time. The display will count down to the start date/time until logging begins. In this example, 5 minutes and 38 seconds remain until logging will begin.
24 %	This shows the percentage of time the switch has been closed or on since logging began. This example indicates the switch has been closed or on for a total of 24% of the time since logging began. The logger must be launched with the LCD set to show "%" for this symbol to display.
StoP	The logger has been stopped.

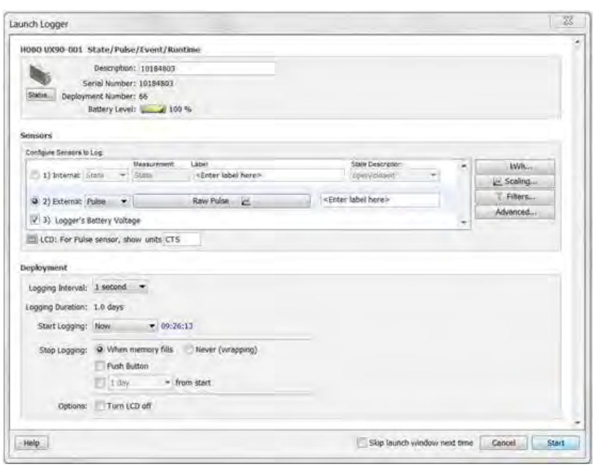
Notes:

- You can disable the LCD screen when logging. Select “Turn LCD Off” when setting up the logger as described in the next section. When this option is enabled, you can still temporarily view the LCD screen by pushing the Start/Stop button for 1 second. The LCD will then remain on for 10 minutes.
- When the logger has stopped logging, the LCD will remain on until the logger is offloaded to a computer or HOBO U-Shuttle (unless launched with the “Turn LCD Off” option). Once the logger has been offloaded and disconnected from the computer, the LCD will turn off automatically after 2 hours. The LCD will turn back on the next time the logger is connected to the computer.
- If the pulse count exceeds 9,999 or -999, a second decimal point will be illuminated on the LCD to indicate the count has surpassed the 4-digit display.

Setting up the Logger

Use HOBOware to set up the logger, including selecting the start and stop logging options, configuring the sensors, and entering scaling factors as necessary. It may be helpful to set up the logger to start at a specific date/time or with a push button stop and then bring it to the location where you will mount it to connect any external devices and test the connections before logging begins.

1. **Connect the logger and open the Launch Logger window**. To connect the logger to a computer, plug the small end of the USB cable into the side of the logger and the large end into a USB port on the computer. Click the Launch icon on the HOBOware toolbar or select Launch from the Device menu.



Important: USB 2.0 specifications do not guarantee operation outside the range of 0°C (32°F) to 50°C (122°F).

2. **Configure the sensor.** Choose either the internal or external sensor. Enter the name and select the state description as necessary or select the sensor type. Type a label for the sensor if desired.

   The internal sensor can be configured to log:

   - **State.** This records how long an event lasts by storing the date and time when the state or switch changes (logic state high to low or low to high). The logger checks every second for a state change, but will only record a time-stamped value when the state change occurs. One state change to the next represents the event duration.
   - **Runtime.** The logger checks the state of the switch once every second. At the end of each logging interval, the logger records how many seconds the line was in the logic low state.

   The external channel can be configured to log state or runtime as described above or the following:

   - **Pulse.** This records the number of pulse signals per logging interval (the logger records a pulse signal when the input transitions to the logic low). There are built-in scaling factors you can select for supported devices and sensors, or you can set your own scaling when you select raw pulse counts. Click the Advanced button to adjust the maximum pulse frequency and lockout time as needed (see *Setting the Maximum Pulse Frequency and Lockout Time* for more details). **Note:** Setting maximum pulse frequency to 50 Hz will reduce battery life.
   - **Event.** This records the date and time when a connected relay switch or logic low transition occurs (the logger records an event when the input transitions to the logic low). This is useful if you need to know when a switch closes, but the duration of the closure is not important. Click the Advanced button to adjust the lockout time to debounce switches as needed.

3. **Configure optional filters as necessary.** Click the Filters button to create additional filtered data series based on the sensor configuration. Any filtered series will be automatically available upon reading out the logger.

4. **Set the units to display on the LCD screen.** For State and Runtime sensors, select either Time or %. For external sensors, you can either use the default units or enter your own units up to three characters.

5. **If the logger is configured to record pulse or runtime, choose a logging interval from 1 second to a maximum of 18 hours, 12 minutes, and 15 seconds.**

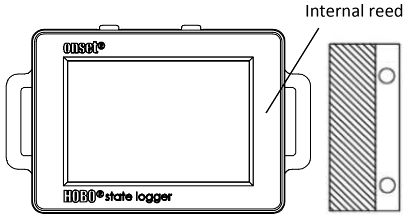
6. **Choose when to start logging:**
   - **Now.** Logging begins immediately.
   - **At Interval.** Logging will begin at the next even interval (available when logging pulse or runtime).
   - **On Date/Time.** Logging will begin at a date and time you specify.
   - **Push Button.** Logging will begin once you press the Start/Stop logging button for 3 seconds.

7. **Choose when to stop logging:**
   - **When Memory Fills.** Logging will end once the logger memory is full.
   - **Never (Wrapping).** The logger will continue recording data indefinitely, with newest data overwriting the oldest.
   - **Push Button.** Logging will end once you press the Start/Stop logging button for 3 seconds. Note that if you also choose Push Button to start logging, then you will not be able to stop logging until 5 minutes after logging begins.
   - **Specific Stop Time.** Logging will end at a date and time you specify.

8. **Choose whether to keep the LCD on or off.** By default, the LCD will always remain on while logging. If you select the "Turn LCD off" checkbox, the LCD will not show the current readings, status, or other information while the logger is logging. You will, however, be able to temporarily turn the LCD screen on by pressing the Start/Stop button for 1 second if you select this option.
9. **Click the Start button to launch the logger.** Disconnect the logger from the computer and deploy it using the mounting materials (see *Mounting the Logger*). After logging begins, you can read out the logger at any time (see *Reading Out the Logger* for details).

Using the Magnet (Internal Sensor)

The logger contains an internal reed switch that can be used with the included magnet as the input to the logger. This configuration can be used to determine when a door or window is open or closed. The magnet must be oriented as shown below, positioned to the right side of the logger when the LCD screen is facing up.



Using the Input Cable (External Sensor)

The 2.5 mm input cable included with the logger can be used to measure contact closures and allows the logger to be mounted remotely from the contacts. Connect the contacts to the black and white wires, and plug the other end of the cable into the external input jack on the bottom of the logger. Do not connect the contacts to any other devices or cables.

If the external sensor was configured to record raw pulse counts or events in HOBOware, there is also an option to specify lockout time. This can prevent false readings from mechanical contact closure bouncing. For more details on setting lockout time, see the HOBOware Help.

Determining Logging Duration Data

The logger's storage capacity and logging duration depends on the interval between state changes and events. The longer the interval between state changes, the more memory is needed to store each data point.

The following table shows how memory capacity is affected by the amount of time between events:

Time Between Events	Approximate Total Data Points	Approximate Logging Duration (1 Year Battery Life)	Logger Part Number
1 to 15 seconds	84,650	23.51 hours to 14.7 days	UX90-001
	346,795	4.01 to 60.21 days	UX90-001M
16	63,488	11.76 to 187.38 days	UX90-001
seconds to 4.25 minutes	260,096	48.17 days to 2.1 years	UX90-001M
4.26 to 68.25 minutes	50,790	150.49 days to 6.6 years	UX90-001
	208,077	1.69 years to 2.7 decades	UX90-001M
68.26 minutes to 18.2 hours	42,325	5.5 years to 8.8 decades	UX90-001
	173,397	2.25 to 36.03 decades	UX90-001M

Notes:

- Typical battery life is 1 year when state or event changes are at 1 minute or greater intervals.
- The logger can record battery voltage data in an additional channel. This is disabled by default. Recording battery voltage reduces storage capacity and is generally not used except for troubleshooting.

Setting Maximum Pulse Frequency and Lockout Time

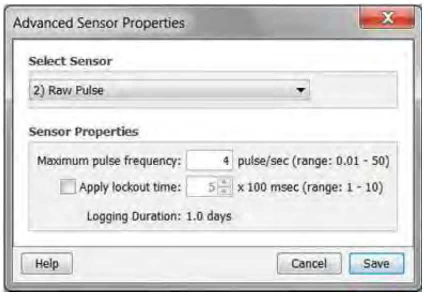
When recording raw pulse counts, the logger dynamically adjusts its memory use from 4 to 32 bits instead of a typical fixed width. This results in the ability to store more data using less space, which in turn extends logging duration. The default pulse rate is 4 Hz; the maximum pulse frequency is 50 Hz. Decreasing the rate will increase logging duration. The following table shows examples of how pulse rate and logging interval affect logging duration.

Logging Interval	Pulse Rate (Hz)	Number Bits Required	Approx. Total Data Points	Approx. Logging Duration	Logger Part Number
1 min	4	8	126,976	88 days	UX90-001
			520,192	361 days	UX90-001M
1 min	50	12	84,650	58 days	UX90-001
			346,795	240 days	UX90-001M

You can change the maximum pulse frequency in HOBOware. In addition, you can also set a lockout time for raw pulse and event channels to prevent false readings from mechanical sensors as their relay state changes. To change the maximum pulse frequency or lockout time:

1. Click the Advanced button from the Launch Logger window in HOBOware.
2. Select the sensor that corresponds with the pulse channel you wish to configure.
3. Set the maximum pulse frequency (on raw pulse channels only) keeping in mind that the larger the pulse frequency, the shorter the logging duration will be.
4. Click the "Apply lockout time" checkbox if you wish to specify a time period when pulses will be ignored (only available for raw pulse channels and event channels). Select the lockout time value from 1 to 10. On sensors with both

pulse frequency and lockout time settings, lockout time will affect the maximum pulse frequency: the higher the lockout time, the lower the maximum pulse frequency will be. **Note:** When lockout time is enabled, you can specify a value from 1 to 10 (with a default of 5), which is then multiplied by 100 milliseconds for a range of 0.1 to 1 second. The available range for the maximum pulse frequency is automatically recalculated based on the lockout time. For example, if the lockout time is set to 2, the maximum pulse frequency range changes to 0.01 to 5 Hz.



5. Click Save. Note that the selections will not take effect in the logger until you launch it.

Reading Out the Logger

There are two options for reading out the logger: connect it to the computer with a USB cable and read out it with HOBOware, or connect it to a HOBO U-Shuttle (U-DT-1, firmware version 1.15m030 or higher) and then offload the data files from the U-Shuttle to HOBOware. Refer to the HOBOware Help for more details.

Recording Internal Logger Events

The logger records the following internal events (different from state/event changes) to help track logger operation and status:

Internal Event Name	Definition
Host Connected	The logger was connected to the computer.
Started	The Start/Stop button was pressed to begin logging.
Stopped	The logger received a command to stop recording data (from HOBOware or by pushing the Start/Stop button).
Button Up/Button Down	The Start/Stop button was pressed for 1 second.
Safe Shutdown	The battery level dropped below 2.5 V; the logger performs a safe shutdown.

Mounting the Logger

There are several ways to mount the logger using the materials included:

- Attach the Command strip to the back of the logger to mount it a wall or other flat surface.
- Use the double-sided tape to affix the logger to a surface.
- Insert the hook-and-loop strap through the mounting loops on both sides of the logger to mount it to a curved surface, such as a pipe or tubing.

Protecting the Logger

The logger is designed for indoor use and can be permanently damaged by corrosion if it gets wet. Protect it from condensation. If the message FAIL CLK appears on the LCD screen, there was a failure with the internal logger clock possibly due to condensation. Remove the battery immediately and dry the circuit board.

Note: Static electricity may cause the logger to stop logging. The logger has been tested to 8 KV, but avoid electrostatic discharge by grounding yourself to protect the logger. For more information, search for "static discharge" in the FAQ section on onsetcomp.com.

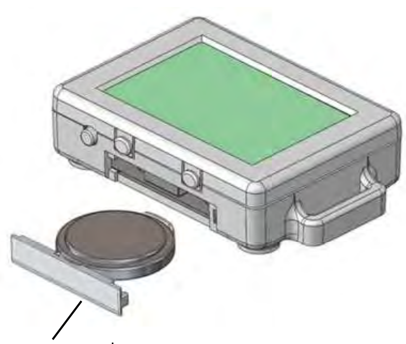
Battery Information

The logger is installed with a 3V CR2032 battery (HRB-TEMP). Expected battery life varies based on the ambient temperature where the logger is deployed, the logging interval, the rate of state changes and/or events, the frequency of offloading to the computer, and battery performance. A new battery typically lasts 1 year with logging intervals greater than 1 minute and when the input signals are normally open or in the high logic state. Deployments in extremely cold or hot temperatures, logging intervals faster than 1 minute, or continuously closed contacts may reduce battery life. Estimates are not guaranteed due to uncertainties in initial battery conditions and operating environment.

The logger can also be powered by the USB cable when the remaining battery voltage is too low for it to continue logging. Connect the logger to the computer, click the Readout button on the toolbar, and save the data as prompted. Replace the battery before launching the logger again.

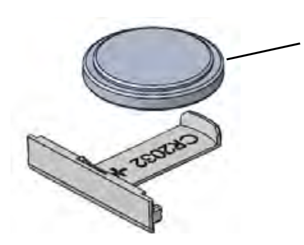
To replace the battery:

1. Holding the logger with the LCD screen facing up, pull the battery tray out of the logger housing.



Battery tray removed from logger

2. Remove the old battery from the tray.
3. Place the new battery in the tray with the positive side facing down.



CR2032 battery being placed in the tray, positive side facing down

4. With the LCD screen still facing up, slide the tray back into the logger. The LCD should display “HOBO” briefly after correctly installing the battery.

WARNING: Do not cut open, incinerate, heat above 85°C (185°F), or recharge the lithium battery. The battery may explode if the logger is exposed to extreme heat or conditions that could damage or destroy the battery case. Do not dispose of the logger or battery in fire. Do not expose the contents of the battery to water. Dispose of the battery according to local regulations for lithium batteries.

HOBOware provides the option of recording the current battery voltage at each logging interval, which is disabled by default. Recording battery life at each logging interval takes up memory and therefore reduces logging duration. It is recommended you only record battery voltage for diagnostic purposes.


Continental Control Systems LLC
WATTNODE® BACNET
A–
B+
C
X
MS/TP
Com
WNC-3Y-208-BN
120V~ 50-60Hz 3W
SN 117096
Ver 1.13
2013-05-15
N
ΦA CT 0.333V~
Status
ΦB CT 0.333V~
Status
ΦC CT 0.333V~
Status
Φ-N 120V~
Φ-Φ 240V~
240V CAT III
ΦA
ΦB
ΦC
1
0
Watthour Meter
US LISTED 3KNN
Boulder, CO USA

Overview

Congratulations on your purchase of the WattNode® BACnet® watt/watt-hour transducer (meter). The WattNode meter offers precision energy and power measurements in a compact package. It enables you to make power and energy measurements within existing electric service panels avoiding the costly installation of subpanels and associated wiring. It is designed for use in demand side management (DSM), sub-metering, and energy monitoring applications. The WattNode meter communicates on an EIA RS-485 two-wire bus using the BACnet protocol. Models are available for single-phase, three-phase wye, and three-phase delta configurations for voltages from 120 Vac to 600 Vac at 50 and 60 Hz.

Measurements

The WattNode BACnet meter measures the following:

- True RMS Power - Watts (Phase A, Phase B, Phase C, Sum)
- Reactive Power - VARs (Phase A, Phase B, Phase C, Sum)
- Power Factor (Phase A, Phase B, Phase C, Average)
- True RMS Energy - Watthours (Phase A, Phase B, Phase C, Sum)
- Reactive Energy - VAR-hours (Sum)
- AC Frequency
- RMS Voltage (Phase A, Phase B, Phase C)
- RMS Current (Phase A, Phase B, Phase C)
- Demand and Peak Demand

One WattNode BACnet meter can measure up to three different "single-phase two-wire with neutral" branch circuits from the same service by separately monitoring the phase A, B, and C values. If necessary, you can use different CTs on the different circuits.

Communication

The WattNode meter uses a half-duplex EIA RS-485 interface for communication. The standard baud rates are 9,600, 19,200, 38,400, and 76,800 baud. The meter uses the industry standard BACnet MS/TP communication protocol, allowing up to 64 devices per RS-485 subnet.

Diagnostic LEDs

The meter includes three power diagnostic LEDs—one per phase. During normal operation, these LEDs flash on and off, with the speed of flashing roughly proportional to the power on each phase. The LEDs flash green for positive power and red for negative power. Other conditions are signaled with different LED patterns. See **Installation LED Diagnostics (p. 22)** for details.

The BACnet WattNode meter includes a communication LED that lights green, yellow, or red to diagnose the RS-485 network. See **BACnet Communication Diagnostics (p. 27)** for details.

Options

The WattNode BACnet meter can be ordered with options. For more details and documentation, see article WattNode BACnet - Options on our website.

General Options

- ***Option CT=xxx*** - Pre-assign xxx as the ***CtAmpsA, B, and C*** values.
- ***Option CT=xxx/yyy/zzz*** - Pre-assign xxx to ***CtAmpsA***, yyy to ***CtAmpsB***, and zzz to ***CtAmpsC***.

Current Transformers

The WattNode meter may use split-core (opening), solid-core (toroidal), and flexible Rogowski current transformers (CTs), with a full-scale voltage output of 333.33 mVac and opening widths ranging from 0.3 in (7.6 mm) up to 12 in (305 mm) or Rogowski lengths up to 48 in (1220 mm). Split-core and Rogowski CTs are easier to install without disconnecting the circuit being measured. Solid-core CTs installation requires that you disconnect the circuit to install the CTs.

Additional Literature

These additional documents are available on the Continental Control Systems, LLC website or BACnet.org website.

- WattNode BACnet Object List (Excel format): WNC-BACnet-Object-List
- Continental Control Systems, LLC website
  - http://www.ccontrolsys.com/w/WattNode_BACnet - main page.
  - http://www.ccontrolsys.com/w/Category:WattNode_BACnet - support articles.
- http://www.bacnet.org
  - BACnet Standard: ASHRAE/ANSI Standard 135-2010

Front Label

This section describes the connections, information, and symbols on the front label.

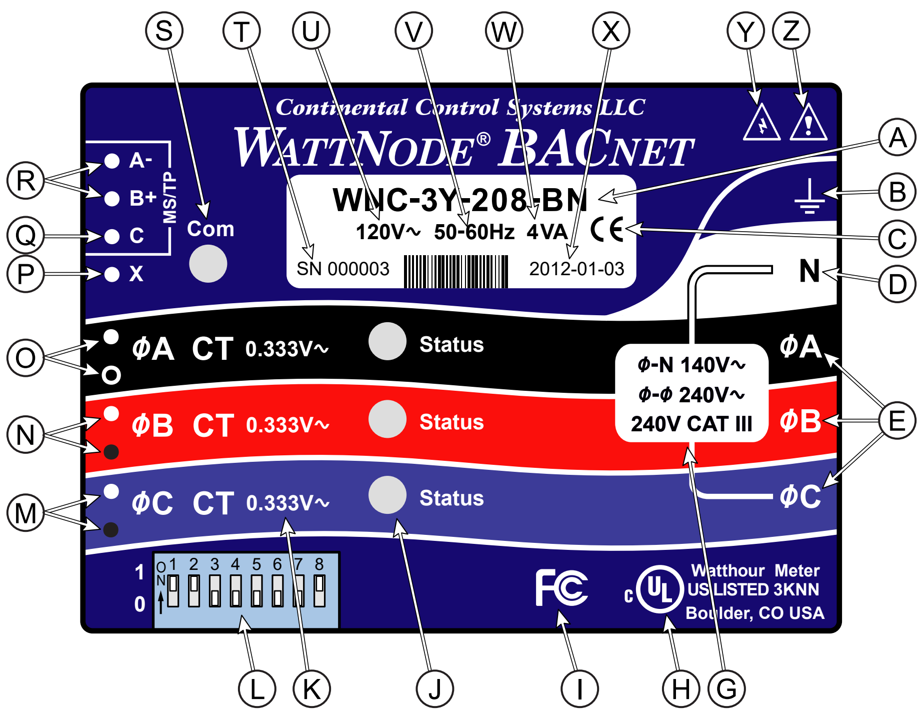


Figure 1: Front Label Diagram

A: WattNode model number. The "**WNC**" indicates a third generation WattNode meter. The "**3**" indicates a three-phase model. The "**Y**" or "**D**" indicates wye or delta models, although delta models can measure wye circuits (the difference is in the power supply). The "**208**" (or other value) indicates the nominal line-to-line voltage. Finally, the "**BN**" indicates BACnet output.

B: Functional ground. This terminal should be connected to earth ground if possible. It is not required for safety grounding, but ensures maximum meter accuracy.

C: CE Mark. This logo indicates that the meter complies with the regulations of the European Union for Product Safety and Electro-Magnetic Compatibility.

D: Neutral. This terminal "**N**" should be connected to neutral for circuits where neutral is present.

E: Line voltage inputs. These terminals connect to the **ϕA** (phase A), **ϕB** (phase B), and **ϕC** (phase C) electric mains. On wye models the meter is powered from the **ϕA** and **N** terminals. On delta models, the meter is powered from the **ϕA** and **ϕB** terminals.

G: Line voltage measurement ratings. This block lists the nominal line-to-neutral "**ϕ-N 120V~**" voltage, line-to-line "**ϕ-ϕ 240V~**" voltage, and the rated measurement voltage and category "**240V CAT III**" for this WattNode model. See the **Specifications (p. 50)** for more information about the measurement voltage and category.

H: UL Listing mark. This shows the UL and cUL (Canadian) listing mark and number "**3KNN**".

I: FCC Mark. This logo indicates that the meter complies with part 15 of the FCC rules.

J: Status LEDs. These are status LEDs used to verify and diagnose meter operation. See **Installation LED Diagnostics (p. 22)** for details.

K: Current transformer (CT) voltage rating. These markings "**0.333V~**" indicate that the meter must be used with CTs that generate a full-scale output of 0.333 Vac (333 millivolts).

L: DIP switch. This DIP switch block is used to set the BACnet MAC (network) address and baud rate. See **Setting the BACnet Address (p. 19)**.

M, N, O: Current transformer (CT) inputs. These indicate CT screw terminals. Note the white and black circles at the left edge of the label: these indicate the color of the CT wire that should be inserted into the corresponding screw terminal. The terminals marked with black circles are connected together internally.

P: Auxiliary output terminal. This screw terminal is used for the X terminal options.

Q: BACnet common terminal. This is the common or ground terminal for BACnet EIA RS-485 communication wiring. It is also the common for the X terminal options if they are installed.

R: BACnet signal terminals. These are the RS-485 A– and B+ signals (half-duplex, two-wire). There are several names for these terminals:

- **Inverting pin**: A–, A, –, TxD–, RxD–, D0, and on rare devices "B"
- **Non-inverting pin**: B+, B, +, TxD+, RxD+, D1, and on rare devices "A"

S: Communication status. This LED indicates communication status. See **BACnet Communication Diagnostics (p. 27)** for details.

T: Serial number. This is the meter serial number. The barcode contains the serial number in Code 128C format.

U: Mains supply rated voltage. This is the rated supply voltage for this model. The **V~** indicates AC voltage. For wye models, this voltage should appear between the **N** and **ϕA** terminals. For delta models, this voltage should appear between the **ϕA** and **ϕB** terminals.

V: Mains frequencies. This indicates the rated mains frequencies for the meter.

W: Maximum rated volt-amps. This is the maximum apparent power consumption (volt-amps) for this model.

X: Manufacture date. This is the date of manufacture for this WattNode meter.

Y: Caution, risk of electrical shock. This symbol indicates that there is a risk of electric shock when installing and operating the meter if the installation instructions are not followed correctly.

Z: Attention - consult Manual. This symbol indicates that there can be danger when installing and operating the meter if the installation instructions are not followed correctly.

Symbols

	Attention - Consult Installation and Operation Manual	Read, understand, and follow all instructions in this Installation and Operation Manual including all warnings, cautions, and precautions before installing and using the product.
	Caution – Risk of Electrical Shock	Potential Shock Hazard from Dangerous High Voltage.
	CE Marking	Complies with the regulations of the European Union for Product Safety and Electro-Magnetic Compatibility. ● Low Voltage Directive – EN 61010-1: 2001 ● EMC Directive – EN 61327: 1997 + A1/1998 + A2/2001

Installation

Precautions

DANGER — HAZARDOUS VOLTAGES

WARNING - These installation/servicing instructions are for use by qualified personnel only. To avoid electrical shock, do not perform any servicing other than that contained in the operating instructions unless you are qualified to do so.

Always adhere to the following checklist:

1) Only qualified personnel or **licensed electricians** should install the WattNode meter. The mains voltages of 120 Vac to 600 Vac can be lethal!
2) Follow all applicable local and national electrical and safety codes.
3) Install the meter in an electrical enclosure (panel or junction box) or in a limited access electrical room.
4) Verify that circuit voltages and currents are within the proper range for the meter model.
5) Use only UL listed or UL recognized current transformers (CTs) with built-in burden resistors, that generate 0.333 Vac (333 millivolts AC) at rated current. **Do not use current output (ratio) CTs such as 1 amp or 5 amp output CTs: they will destroy the meter and may create a shock hazard.** See **Current Transformers (p. 55)** for CT maximum ratings.
6) Ensure that the line voltage input leads to the meter are protected by fuses or circuit breakers (not needed for the neutral wire). See **Circuit Protection (p. 18)** for details.
7) Equipment must be disconnected from the HAZARDOUS LIVE voltages before access.
8) The terminal block screws are **not** insulated. Do not contact metal tools to the screw terminals if the circuit is energized!
9) Do not place more than one line voltage wire in a screw terminal; use wire nuts instead. You may use more than one CT wire or communication interface wire per screw terminal.
10) Before applying power, check that all the wires are securely installed by tugging on each wire.
11) Do not install the meter where it may be exposed to temperatures below –30°C or above 55°C, excessive moisture, dust, salt spray, or other contamination. The meter requires an environment no worse than pollution degree 2 (normally only non-conductive pollution; occasionally, a temporary conductivity caused by condensation must be expected).
12) Do not drill mounting holes using the meter as a guide; the drill chuck can damage the screw terminals and metal shavings can fall into the connectors, causing an arc risk.
13) If the meter is installed incorrectly, the safety protections may be impaired.

Appendix B.4 GE ASPMETER Metering Panelboard

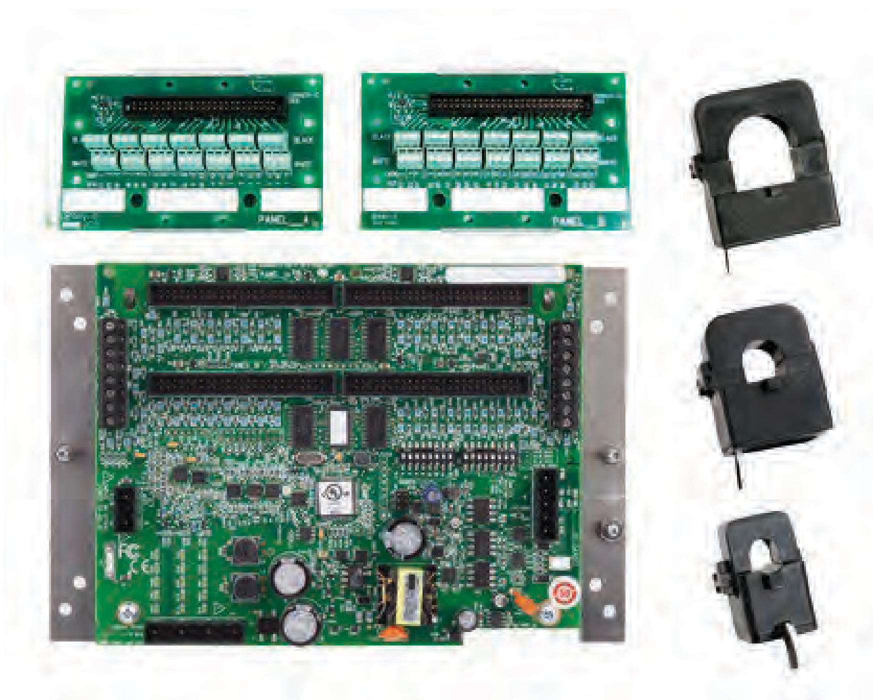
(Reference source for DEH-40700 ASPMETER Panelboard Monitoring System is GE Energy Connections. Reprint permission granted by General Electric.)

GE
Industrial Solutions

DEH-40700 Installation Instructions

ASPMETER Panelboard Monitoring System

Split Core



Safety

FCC PART 15 INFORMATION NOTE: This equipment has been tested by the manufacturer and found to comply with the limits for a class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a residential environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. This device complies with part 15 of the FCC Rules.

Operation is subject to the following two conditions:
(1) This device may not cause harmful interference, and
(2) This device must accept any interference received, including interference that may cause undesired operation.

Modifications to this product without the express authorization of the manufacturer nullify this statement.

A qualified person is one who has skills and knowledge related to the construction and operation of this electrical equipment and the installation, and has received safety training to recognize and avoid the hazards involved.

NEC2011 Article 100: No responsibility is assumed by manufacturer for any consequences arising out of the use of this material.

Control system design must consider the potential failure modes of control paths and, for certain critical control functions, provide a means to achieve a safe state during and after a path failure. Examples of critical control functions are emergency stop and over-travel stop.

	This symbol indicates an electrical shock hazard exists.
	Documentation must be consulted where this symbol is used on the product.

DANGER: Hazard of Electric Shock, Explosion or Arc Flash
Failure to follow these instructions will result in death or serious injury.

- Follow safe electrical work practices. See NFPA 70E in the USA, or applicable local codes.
- This equipment must only be installed and serviced by qualified electrical personnel.
- Read, understand and follow the instructions before installing this product.
- Turn off all power supplying equipment before working on or inside the equipment.
- Use a properly rated voltage sensing device to confirm power is off. DO NOT DEPEND ON THIS PRODUCT FOR VOLTAGE INDICATION
- Only install this product on insulated conductors.

NOTICE:

- This product is not intended for life or safety applications.
- Do not install this product in hazardous or classified locations.
- The installer is responsible for conformance to all applicable codes
- Mount this product inside a suitable fire and electrical enclosure.

WARNING: Loss of Control
Failure to follow these instructions may cause injury, death or equipment damage.

- Assure that the system will reach a safe state during and after a control path failure.
- Separate or redundant control paths must be provided for critical control functions.
- Test the effect of transmission delays or failures of communication links.
- Each implementation of equipment using communication links must be individually and thoroughly tested for proper operation before placing it in service.

For troubleshooting or service related questions, contact GE at 1-800-GE-1-STOP (1-800-431-7867).

Save These Instructions

Specifications

Inputs	
Input Power	90-277 VAC, 50/60 Hz
Accuracy	
Power/Energy	IEC 62053-21 Class 1, ANSI C12.1-2008
Voltage	±0.5% of reading 90-277 V line-to-neutral
Operation	
Sampling Frequency	2560 Hz
Update Rate	1.8 seconds (both panels)
Overload Capability	22 kAIC
Outputs	
Type	Modbus RTU™
Connection	DIP switch-selectable 2-wire or 4-wire, RS-485
Address	DIP switch-selectable address 1 to 247 (in pairs of 2)[1]
Baud Rate	DIP switch-selectable 9600, 19200, 38400
Parity	DIP switch-selectable NONE, ODD, EVEN
Communication Format	8-data-bits, 1-start-bit, 1-stop-bit
Termination	5-position depluggable connector (TX+ TX- SHIELD TX+/RX+ TX-/RX-)
Terminal Block Torque	4.4 to 5.3 in-lb (0.5 to 0.6 N-m)
Mechanical	
Ribbon Cable Support	4 ft. (0.9m) flat ribbon cable ships standard; up to 20 ft. (6m) available
Operating Conditions	
Operating Temp Range	0° to 60°C (32° to 140°F); <95% RH, non-condensing
Storage Temp Range	-40° to 70°C (-40° to 158°F)
Altitude of Operation	3000m
Compliance	
Agency Approvals	UL508 open type device, EN61010-1
Installation Category	Cat III, pollution degree 2

[1] See Configuration Section for details.

Notes:
- If ASPMETER products are used in installations with circuits higher than the product ratings, the circuits must be kept segregated per UL508A Sec. 17.5.
- 277/480VAC Wye connected (center grounded) power systems operate within the 300VAC line to neutral safety rating of the ASPMETER series, and the operational voltage limit (single-phase connection) as the line to neutral voltage is 277VAC in such power systems. Corner-grounded delta 480VAC systems would not qualify, as the actual line to earth voltage is 480VAC on each leg, exceeding the ASPMETER ratings.
- ASPMETER internal circuitry (cables and CTs) are not circuits as defined by UL508A, as they do not extend beyond the ASPMETER itself without further safety/fire isolation.

Product Overview

The ASPMETER Panelboard Monitoring System is designed to measure the current, voltage, and energy consumption of up to 92 circuits (84 branch circuits, 2 3-phase mains, 2 neutrals) on a single board. One ASPMETER can monitor up to two panels.

The ASPMETER consists of a data acquisition board and up to 84 split-core current sensors (50A, 100A, or 200A), with eight auxiliary inputs. Each conductor passes through a current sensor and terminates at the breaker. Each sensor transmits the current data to the data acquisition board. Data is transmitted using an RS-485 Modbus protocol. Each data acquisition board requires two addresses, one for each set of 42 current sensors and four auxiliary inputs. Data is updated roughly every two seconds. As a circuit approaches the user-defined threshold, the ASPMETER activates the alarm indicators.

The ASPMETER-A measures both current and power for the mains and branch circuits. The ASPMETER-B measures both current and power for the mains, and current only in each circuit. The ASPMETER-C measures current only for the mains and branch circuits.

Product Identification

ASPMETER ☐ ☐

Description

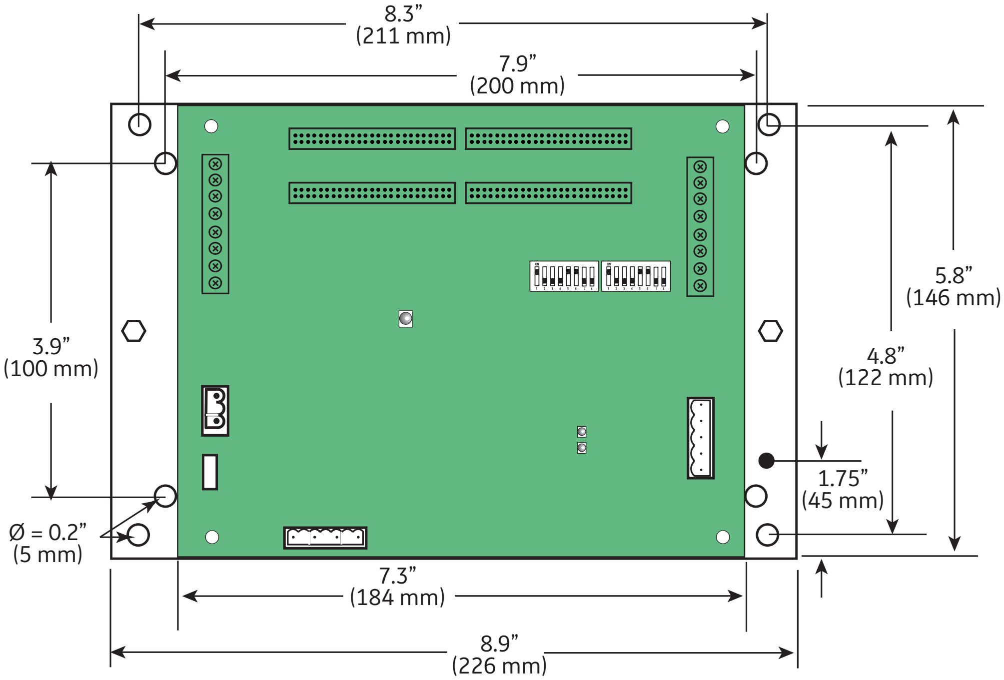
A = Advanced board
B = Intermediate board
C = Basic board

# of CTs

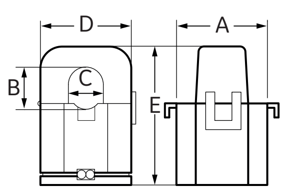
002 = 2 adapter boards, no CTs, no cables
004 = 4 adapter boards, no CTs, no cables
42 = 2 adapter boards, (42) 50A CTs, (2) 4 ft. round ribbon cables
84 = 4 adapter boards, (84) 50A CTs, (4) 4 ft. round ribbon cables

Dimensions

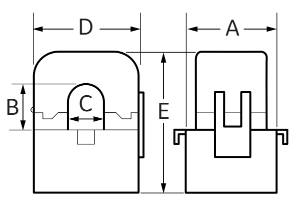
Circuit Board and Mounting Bracket



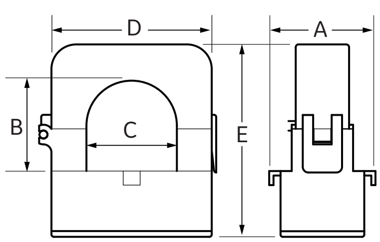
Current Sensors



ASPCT0 50 Amp
A = 1.0" (26 mm)
B = 0.5" (11 mm)
C = 0.4" (10 mm)
D = 0.9" (23 mm)
E = 1.6" (40 mm)

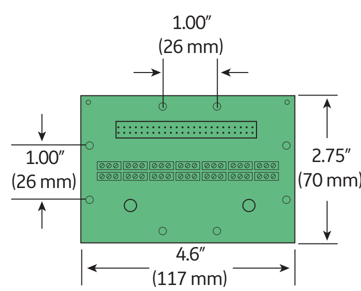


ASPCT1 100 Amp
A = 1.5" (37.5 mm)
B = 0.6" (16 mm)
C = 0.6" (16 mm)
D = 1.85" (47 mm)
E = 2.1" (53 mm)

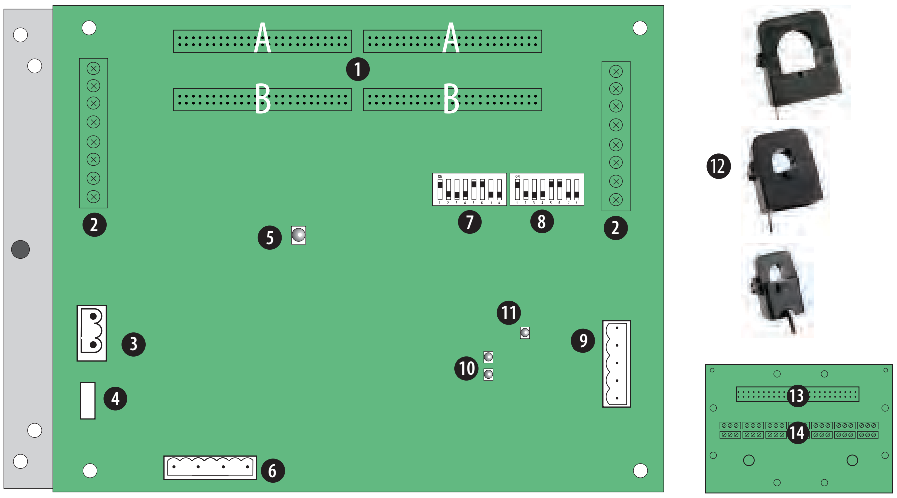


ASPCT3 200 Amp
A = 1.5" (39 mm)
B = 1.25" (32 mm)
C = 1.25" (32 mm)
D = 2.5" (64 mm)
E = 2.8” (71 mm)

Adapter Board



Product Diagrams



1. **50-Pin Ribbon Cable Connectors:** Ribbon cables attach here for easy connection of adapter boards to the data acquisition board. The two connectors on the left are for panelboard 1; the two on the right are for panelboard 2.

   NOTE: Connect Adapter Boards A and B to the correct ribbon cable connectors for each panel. The top connector is for Adapter Board A, and the bottom connector is for Adapter Board B.

   NOTE: Ribbon Cable is not included with all ASPMETER models. For ribbon cable options, see Recommended Accessories on page 14.

2. **Auxiliary Inputs:** These 0.333 VAC inputs are used for monitoring the main breaker or other high amperage source. Inputs on the left are for panelboard 1; inputs on the right are for panelboard 2.

3. **Control (Mains) Power Connection:** Easy 2-wire 90-277 VAC 50/60 Hz connection.

4. **Control Power Fuse:** 600 VAC, 500 mA time lag, factory-replaceable.

5. **Alive LED:** Red/green/amber LEDs. Blink codes are on page 5.

6. **Voltage Taps:** 1, 2, or 3 phase plus neutral connections. For voltage sensing and power calculations (no voltage taps on the ASPMETER-C). Voltage taps are shared by both panels.

7. **Communications Address DIP Switches:** Each Modbus device must have a unique address. Switches are binary weighted. Left-most switch has a value of 1; right-most switch has a value of 128.

   NOTE: Switches set the address for panel 1; panel 2 is automatically set to (Panel 1 address + 1).
   See Configuration section for details.

8. **Communications Settings DIP Switch:** Configures baud rate, parity, 2/4 wire communications.

9. **RS-485 Connection:** Used for Modbus serial communications. The Universal plug accommodates 2 or 4 wire connections.

10. **RS-485 LEDs:** The RX LED (closest to DIP switches) indicates the RS-485 is receiving information; the TX LED (farthest from DIP switches) indicates transmission of information.

11. **Power LED:** Indicates power to main board .

12. **Branch Current Sensors:** Each split-core current sensor is capable of monitoring conductors rated up to a maximum of 50, 100, or 200 amps. Up to 84 sensors can be purchased with the ASPMETER (see Recommended Accessories on page 14). One of each style is pictured here.

13. **Ribbon Cable Connectors**

14. **CT Terminal Connectors**

Data Output

Monitoring at Mains	ASPMETER-A	ASPMETER-B	ASPMETER-C
Current per phase	✓	✓	✓
Max. current per phase	✓	✓	✓
Current demand per phase	✓	✓	✓
Max. current demand per phase	✓	✓	✓
Energy (kWh) per phase	✓	✓	
Real Power (kW) per phase	✓	✓	
Apparent Power (kVA)	✓	✓	
Power factor total *	✓	✓	
Power factor per phase	✓	✓	
Voltage - L-L and average of 3 phases	✓	✓	
Voltage - L-N and average of 3 phases	✓	✓	
Voltage - L-N and per phase	✓	✓	
Frequency (phase A)	✓	✓	
Monitoring at Branch Circuit			
Current	✓	✓	✓
Max. current	✓	✓	✓
Current demand	✓	✓	✓
Max. current demand	✓	✓	✓
Real power (kW)	✓		
Real power (kW) demand	✓		
Real power (kW) demand max.	✓		
Energy (kWh) per circuit	✓		
Power factor	✓		
Apparent Power (kVA)	✓		
Modbus Alarms			
Voltage over/under	✓	✓	
Current over/under	✓	✓	✓

* Based on a 3-phase breaker rotation.

Blink Code for Status LED

Color and Pattern	Status Description
Green, once per second	Normal operation
Amber, once per second	Volts or Amps clipping
Amber, twice per second	Invalid firmware image
Red, solid or blink	Diagnostic event detected

Split-Core CT Accuracy

Description	Split-Core CT		
	50A	100A	200A
Voltage rating	300 VAC	300 VAC (CE), 600 VAC (UL)	300 VAC (CE), 600 VAC (UL)
Accuracy	±1%	±0.5%	±1%
Temperature	0° to 60°C		
Agency	UL508 recognized, EN61010-1		

Commissioning

1. Install according to instructions in Mechanical Installation.
2. Provide control power to panel.
3. Configure installation mode using Modbus Register 6.
4. Configure CT scaling.
5. Configure alarms.
6. Configure demand.

Download the free Configuration Tool “NetConfig” from www.veris.com/modbus_downloads.aspx to commission the E3x for operation.

Wiring

Power must be disconnected and locked out before making any wiring connections.

Connect 2-wire or 4-wire Modbus RS-485 daisy chain network (Figures 1 and 2).

Figure 1.

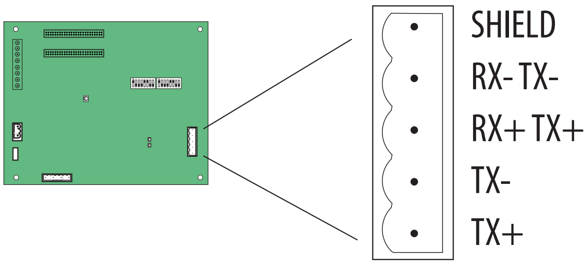
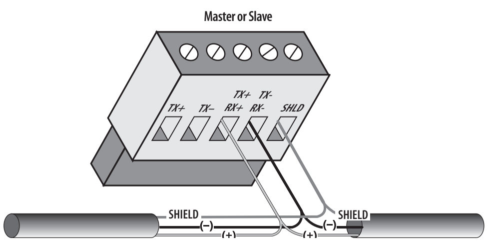
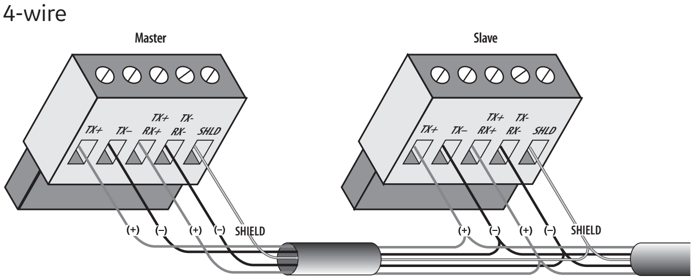


Figure 2.

2-wire



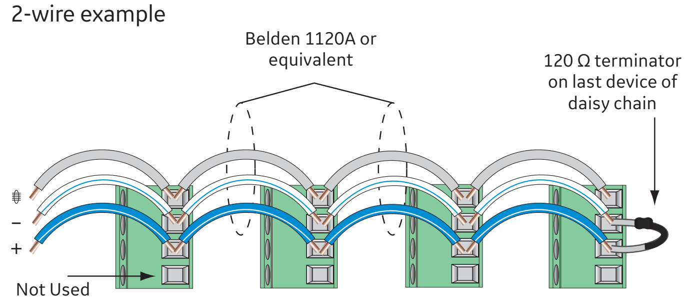
4-wire



1. Mechanically secure the RS-485 cable where it enters the electrical panel.
2. Connect all RS-485 devices in a daisy-chain fashion, and properly terminate the chain (Figure 3).

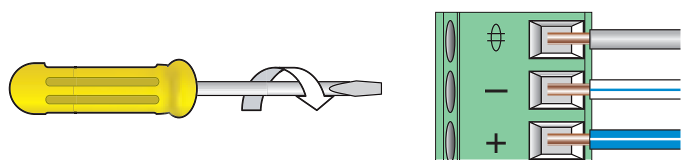
Figure 3.

2-wire example



3. Shield the RS-485 cable using twisted-pair wire, such as Belden 1120A. The cable must be voltage-rated for the installation.
4. When tightening terminals, ensure that the correct torque is applied: 0.5 to 0.6 N·m (0.37 to 0.44 ft·lb) for connectors on main board, 0.22 to 0.26 N·m (0.16 to 0.19 ft·lb) for connectors on adapter boards (Figure 4).

Figure 4.



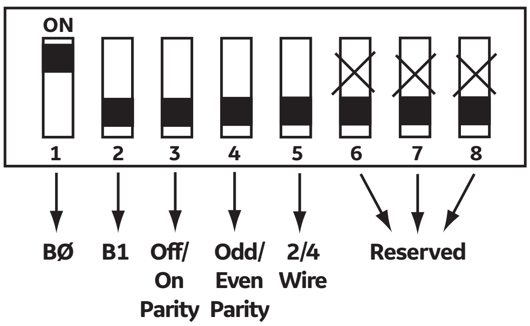
WARNING: After wiring the RS-485 cable, remove all scraps of wire or foil shield from the electrical panel. Wire scraps coming into contact with high voltage conductors could be DANGEROUS!

Configuration

1. **Communications Configuration:** Communications parameters for the ASPMETER series are field selectable for your convenience. Please see the Product Diagrams section (page 5) for selector location. The following parameters are configurable:

   • Baud Rate: 9600, 19200, 38400
   • Parity On or Off
   • Parity: odd or even
   • Wiring: two or four

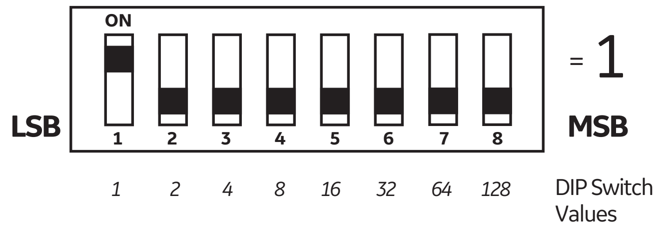
Example: 2-wire 19200 Baud, no parity (default only)



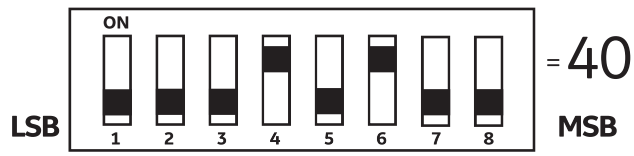
1	2	3	4	5	6	7	8	
Off	Off				X	X	X	**9600**
On	Off				X	X	X	**19200**
Off	On				X	X	X	**38400**
On	On				X	X	X	**Reserved**
		Off	Off		X	X	X	**No Parity**
		On	Off		X	X	X	**Odd Parity**
		Off	On		X	X	X	**No Parity**
		On	On		X	X	X	**Even Parity**
				On	X	X	X	**4-wire RS-485**
				Off	X	X	X	**2-wire RS-485**

2. **Address Configuration:** Each Modbus device on a single network must have a unique address. Set the switch block to assign a unique address before the device is connected to the Modbus RS-485 network. If an address is selected which conflicts with another device, neither device will be able to communicate.

3. The ASPMETER uses two logical addresses. Panel 1 uses the base address as set on the DIP switches, and Panel 2 uses this base address + 1. Address the ASPMETER as any whole number between and including 1-246. Each unit is equipped with a set of 8 DIP switches for addressing. See below.



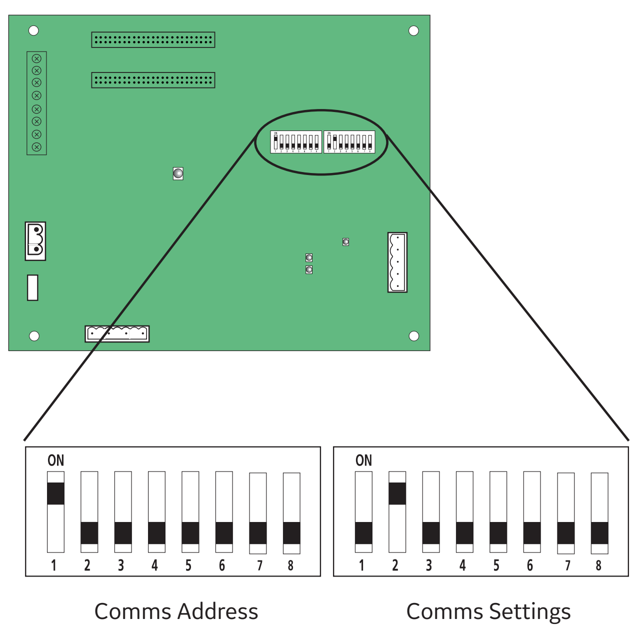
4. T o determine an address, simply add the values of any switch that is on. For example:



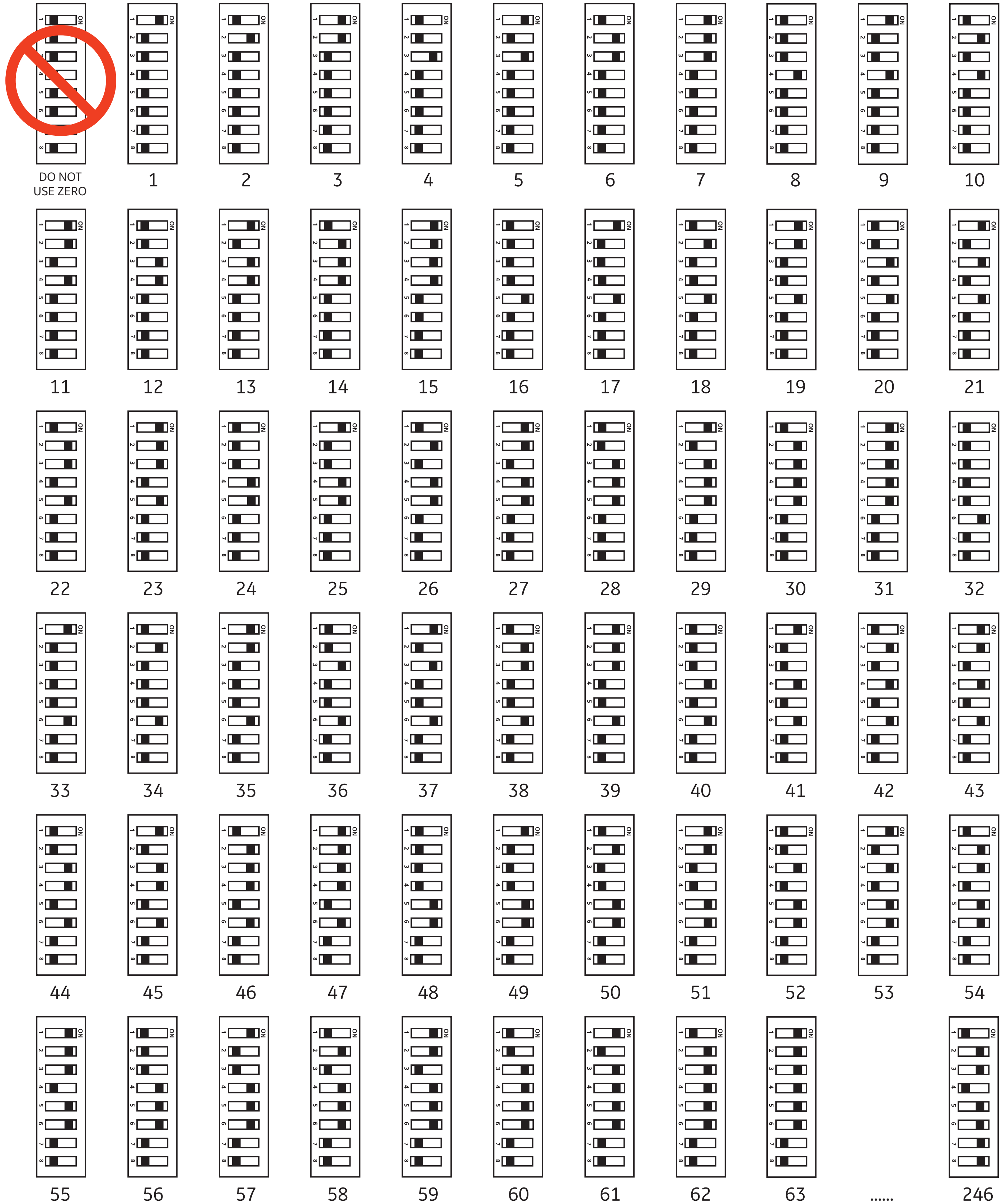
Switch number 4 has an ON Value of 8 and switch number 6 has an ON Value of 32. (8 + 32 = 40). Therefore, the address for Panel 1 is 40 and the address for Panel 2 is 41. See the Address Setup section (page 9) for a pictorial listing of the first 63 switch positions.

Default DIP Switch Settings

The ASPMETER includes two DIP switches, as shown below. Switches are shown in their default positions.



Address Setup



Mechanical Installation

	Observe precautions for handling static sensitive devices to avoid damage to the circuitry that is not covered under the factory warranty.

	Disconnect power to the electrical panel and lock it out.

1. Install the acquisition board mounting bracket in the panel using screws and bolts provided. Panels can be oriented side-by-side (Figure 5A) or vertically (Figure 5B). A grounding connection is located on the mounting bracket, near the lower right corner. Use this stud to ground the bracket when mounting on a non-conductive surface.

Figure 5A.
Side-by-side

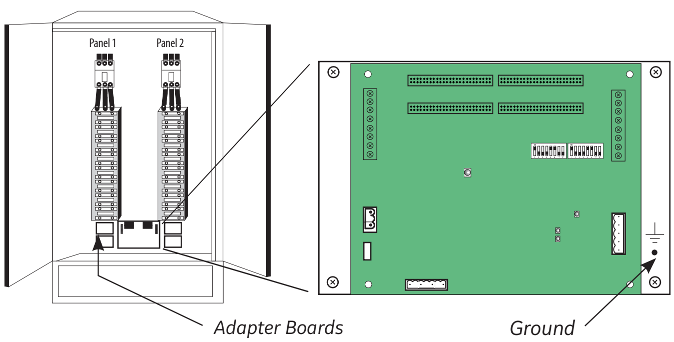
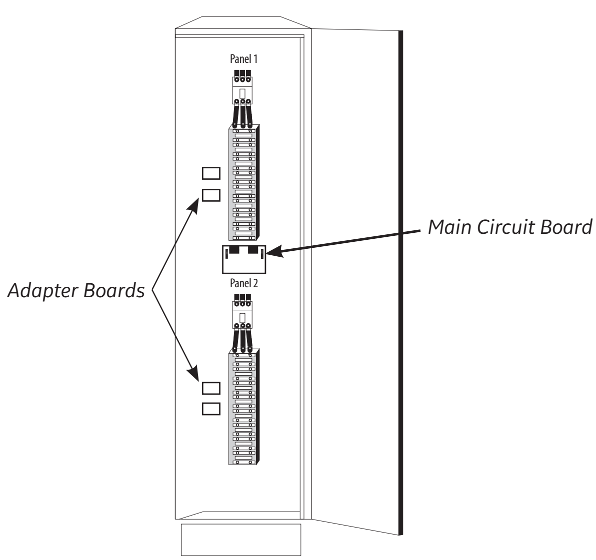
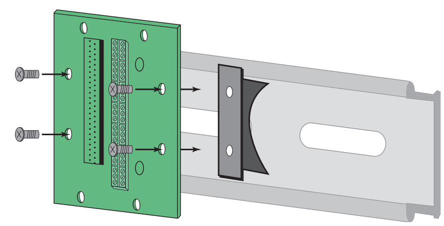


Figure 5B.
Vertically



2. Mount the adapter boards to either DIN rail or SNAPTRACK.
   — **DIN Rail:** Use the supplied screws to secure the plastic DIN clip to the adapter board. Affix the clip to the DIN rail (Figure 6).
   — **SNAPTRACK:** Secure the SNAPTRACK to the mounting surface. Click the adapter board into place (Figure 7).

Figure 6.
DIN Option – Vertical Mount



DIN Option – Horizontal Mount

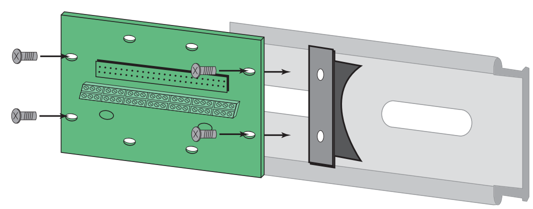
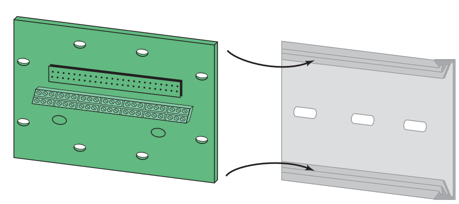


Figure 7.
SNAPTRACK



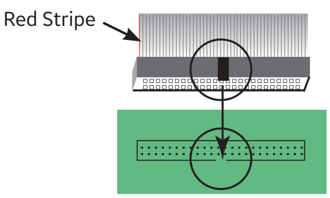
3. Connect adapter boards to the main board using ribbon cable (Figure 8). Ribbon cables are keyed to ensure proper installation.

   Orient cables so that the red stripe is on the left.

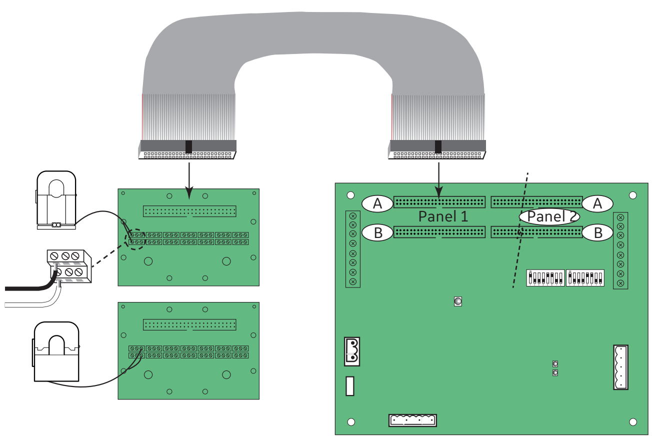
   NOTE: Flat and round ribbon cable are available. See Recommended Accessories.

4. Connect current sensors to the terminals on the adapter boards (Figure 8).

Figure 8.



Align ribbon cable key with connector keyhole. Orient ribbon cable so that the red stripe is on the left side of the connector.

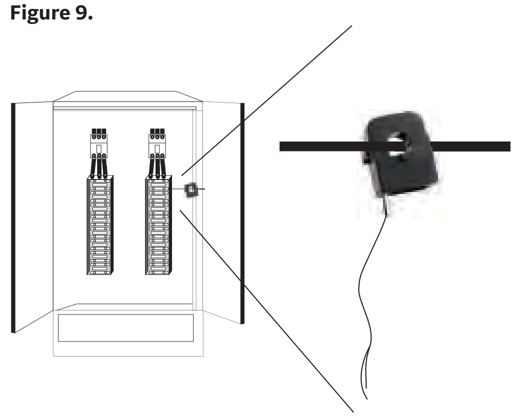


If the signed power factor feature is NOT enabled, then the current sensor orientation does not affect meter behavior. If this feature IS enabled, orient the current sensors so that the arrow points toward the load for proper operation.

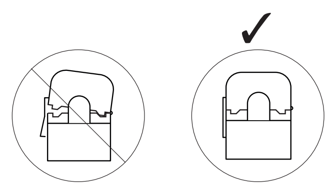
5. Install the current sensors onto the conductors to be monitored (Figure 9). Sensors can be mounted facing either direction; orientation does not affect meter accuracy.

   NOTE: Clean split-core contacts before closing. The hinge can detach, allowing the base and the top to separate for easier cleaning and installation

Figure 9.



The 50 A CT accepts a maximum #2 AWG (0.384" O.D.) wire with THHN insulation. The 100A CT accepts a maximum 3/0 AWG (0.584" O.D.) wire with THHN insulation. The 200A CT accepts a maximum of 350 MCM wire with THHN insulation. Use this gauge wire or smaller for each circuit.



Close CTs until the clasp clicks into place to ensure that contact surfaces are firmly seated.

6. Plastic cable ties are included with the product for strain relief. Insert the strain relief device into one of the available holes on the adapter board (Figure 10A). Gather all current sensor wires connected to that adapter board and secure the cable tie around them (Figure 10B).

Figure 10A.

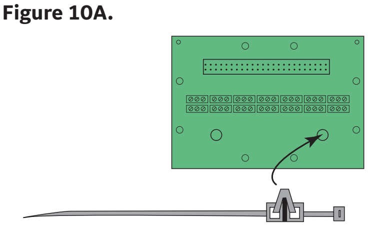
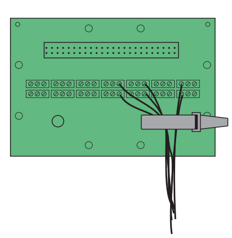
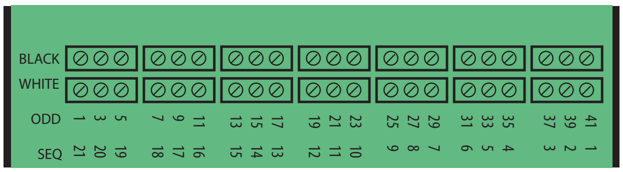


Figure 10B.



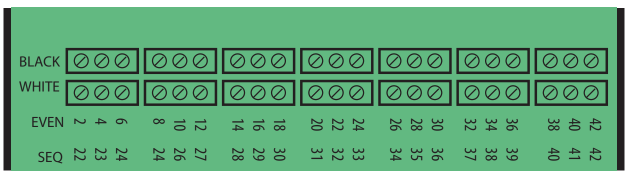
7. The adapter boards are silk screened with two rows of numbers. For applications that require odd/even branch circuit numbering, use the row designated ODD or EVEN. For applications that require sequential numbering, use the number row marked SEQ (Figures 11 and 12).

Figure 11.



Numbering – Adapter Board A:

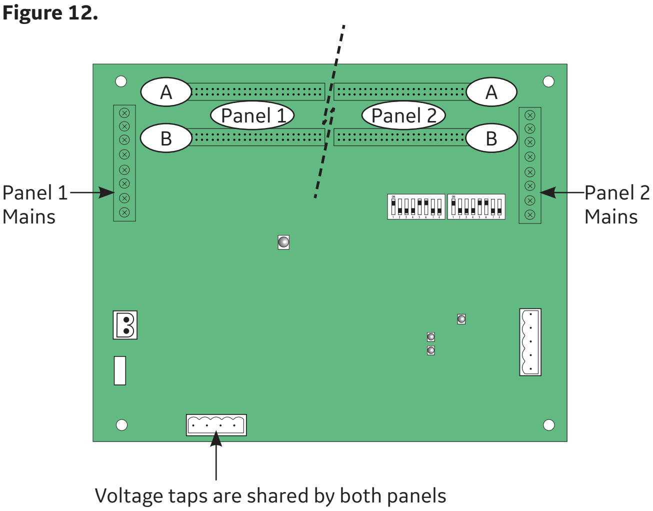
ODD	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41
SEQ	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1



Numbering – Adapter Board B:

EVEN	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42
SEQ	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42

Figure 12.



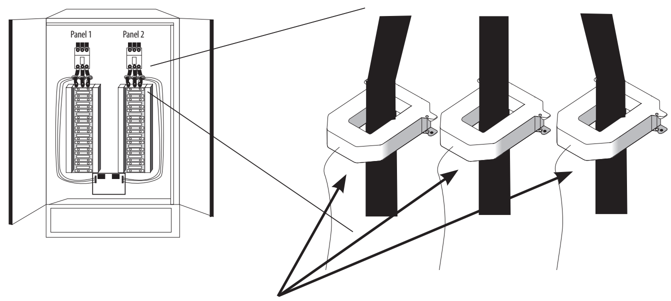
Panel 1 uses base Modbus address as set by DIP switches.
Panel 2 uses base + 1 Modbus address as set by DIP switches.

8. Configure communication and addressing parameters using DIP switches. The ASPMETER requires two addresses, one for each set of 42 current sensors and four auxiliary inputs. See the Configuration section for more information.

9. Wire RS-485 communications (see diagrams in Wiring section).

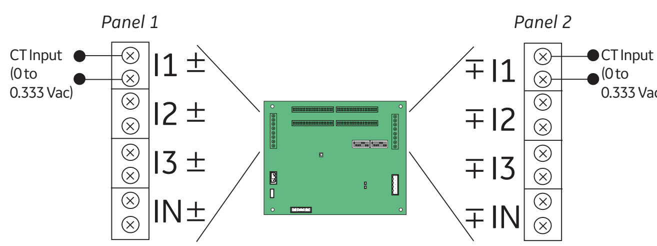
10. Connect 0.333VAC current transducers (CTs) to the main conductors by snapping CTs around lines, observing local codes regarding bending radius (optional; Figures 13 and 14).

Figure 13.



Recommended CT: AMP1 Series available in 100A max. to 2000A max. Contact your local GE sales rep for recommended CTs amperages or if higher amperages are required.

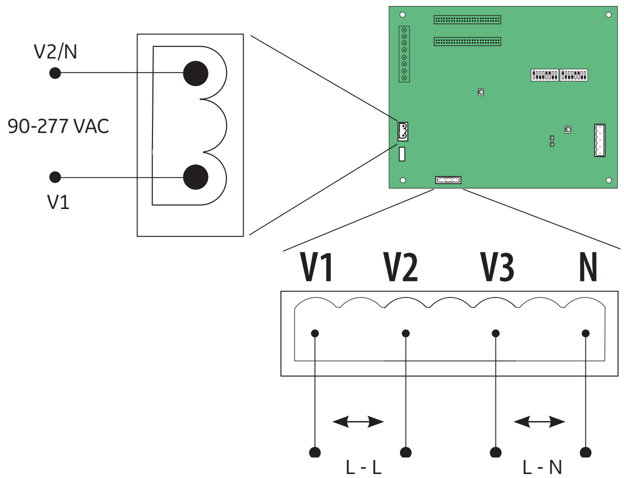
Figure 14.



Set up Modbus registers 115-118 for CT scaling.
Use base + 1 address for Panel 2 setup.
NOTE: (+) represents black, (-) represents white

11. Connect 2-wire 90-277VAC power to main power terminals. Observe polarity. For the ASPMETER-A and ASPMETER-B, connect voltage lines to the voltage taps (Figure 15). Equip voltage lines with fuses.

Figure 15.



Line to Line (L-L) Voltage: 150 to 480 VAC
Line to Neutral (L-N) voltage: 90 to 277 VAC

Recommended Accessories

Catalog Number	Description
ASPCT0	Six-pack 50 A CT, 6 ft. (1.8 m) lead
ASPCT1	Six-pack 100 A CT, 6 ft. (1.8 m) lead
ASPCT2	Single 200A CT, 6ft (1.8m) lead

Troubleshooting

Problem	Solution
Product is not communicating over Modbus daisy chain	• Check the unit Modbus address to ensure that each device on the daisy chain has a unique address. • Check Parity. • Check the communications wiring. • Check that the daisy chain is properly terminated.
RX LED is solid	• Check for reversed polarity on Modbus comms. • Check for sufficient biasing on the Modbus bus. Modbus physical specification calls for 450-650 Ω biasing. This is usually provided by the master.
The main board has a fast flashing amber light	• Verify ribbon cable connectors are inserted in the correct orientation. • If cables are correct, reset main board to re-initialize product.
The main board has a slow flashing amber light	• One or more channels is clipping. This can be caused by a signal greater than 100 A or 277 V L-N, or by a signal with high THD near the gain stage switching points (1.5 A and 10 A).
The main board has a flashing green light	• Everything is wired properly and the main board has power.
The main board is a flashing or solid red light	• Light may be red briefly while device powers up. • If light is red for more the 60 sec. device has encountered a diagnostic event. Contact technical support.
Split-core product is reading zero for some values	• Device was unable to read split-core adapter boards on power up. Verify adapter boards are connected. • Verify ribbon cable connectors are inserted in the correct orientation. • Reset main board to re-initialize product.
Power factor reading is not as expected	• Verify voltage taps are connected in appropriate phase rotation. • Verify phase rotation of breakers (firmware rev. 1.012 or higher allows for custom rotation if needed).
Current reading is not as expected, or reading is on different CT number than expected	• Verify ribbon cable is fully seated and in the correct orientation.
Current is reading zero, even when small currents are still flowing through circuit	• The product cuts off at 50 mA, and will set the reporting register to 0 mA for currents near or below this range.
Configuration Tool “NetConfig” returns Modbus error on read/write	• Verify using the latest release of Configuration Tool “NetConfig” as older versions may not support all features in current product firmware. Latest version is available on the website http://www.veris.com/modbus_downloads.aspx

For troubleshooting or service related questions, contact GE at 1-800-GE-1-STOP (1-800-431-7867).

Imagination at work

GE
41 Woodford Avenue
Plainville, CT 06062
www.geindustrial.com

DEH-40700 0516

Public Input No. 44-NFPA 70-2017 [Definition: Calculated Load]

Calculated Load

(see 220.40)

? **Noncontinuous Loads**

Receptacle Load *(see 220.44)*

80 receptacles at 180 VA	14,400 VA
10,000 VA at ~~100%~~ 100%25	10,000 VA
14,400 VA − 10,000 VA = 4400 at ~~50%~~ 50%25	2,200 VA
Subtotal	12,200 VA

? **Continuous Loads**

General Lighting*

3000 ft ^{2} at 3 VA/ft ^{2}	9,000 VA
Show Window Lighting Load	
30 ft at 200 VA/ft *[see 220.14(G)]*	6,000 VA
Outside Sign Circuit *[see 220.14(F)]*	1,200 VA
Subtotal	16,200 VA
Subtotal of the Continuous load X 125%25	20,250 VA
Subtotal from noncontinuous	12,200 VA
Total noncontinuous loads + continuous loads =	~~28,400 VA~~ 32,450 VA

*In the example, the actual connected lighting load (8500 VA) is less than the load from Table 220.12, so the minimum lighting load from Table 220.12 is used in the calculation. Had the actual lighting load been greater than the value calculated from Table 220.12, the actual connected lighting load would have been used.

Statement of Problem and Substantiation for Public Input

The NEC requires a sizing calculation to be the combined sum of the continuous and noncontinuous load, and 215.2 requires that the continuous load be sized at 125% of the load rating.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 45-NFPA 70-2017 [Section No. 220.40]	Public Input 45 seeks to add that a sizing calculation of a service or feeder takes into account the continuous load at 125%

Submitter Information Verification

Submitter Full Name: Brian Baughman

Organization: Generac Power Systems Inc

Street Address:

City:

State:

Zip:

Submittal Date: Tue Jan 24 16:20:38 EST 2017

Public Input No. 3888-NFPA 70-2017 [Definition: Example D3 Store Building]

Example D3 Store, Mercantile or Business Building

A store, mercantile or business building, 50 ft by 60 ft, or 3000 ft^2, has 30 ft of show window. There are a total of 80 duplex receptacles. The service is 120/240 V, single phase 3-wire service. Actual connected lighting load is 8500 VA.

Calculated Load

(see 220.40)

Noncontinuous Loads	-	
Receptacle Load *(see 220.44)*	-	
80 receptacles at 180 VA		14,400 VA
10,000 VA at 100%		10,000 VA
14,400 VA - 10,000 VA = 4400 at 50%		2,200 VA
	Subtotal	12,200 VA
Continuous Loads		-
General Lighting*		-
3000 ft^2 at 3 VA/ft^2		9,000 VA
Show Window Lighting Load		-
30 ft at 200 VA/ft *[see 220.14(G)]*		6,000 VA
Outside Sign Circuit *[see 220.14(F)]*		1,200 VA
	Subtotal	16,200 VA
	Subtotal from noncontinuous	12,200 VA
	Total noncontinuous loads + continuous loads =	28,400 VA

*In the example, the actual connected lighting load (8500 VA) is less than the load from Table 220.12, so the minimum lighting load from Table 220.12 is used in the calculation. Had the actual lighting load been greater than the value calculated from Table 220.12, the actual connected lighting load would have been used.

Minimum Number of Branch Circuits Required

General Lighting: Branch circuits need only be installed to supply the actual connected load *[see 210.11(B)].*

8500 VA × 1.25 = 10,625 VA

10,625 VA ÷ 240 V = 44 A for 3-wire, 120/240 V

The lighting load would be permitted to be served by 2-wire or 3-wire, 15- or 20-A circuits with combined capacity equal to 44 A or greater for 3-wire circuits or 88 A or greater for 2-wire circuits. The feeder capacity as well as the number of branch-circuit positions available for lighting circuits in the panelboard must reflect the full calculated load of 9000 VA × 1.25 = 11,250 VA.

Show Window

6000 VA × 1.25 = 7500 VA

7500 VA ÷ 240 V = 31 A for 3-wire, 120/240 V

The show window lighting is permitted to be served by 2-wire or 3-wire circuits with a capacity equal to 31 A or greater for 3-wire circuits or 62 A or greater for 2-wire circuits.

Receptacles required by 210.62 are assumed to be included in the receptacle load above if these receptacles do not supply the show window lighting load.

Receptacles

Receptacle Load: 14,400 VA ÷ 240 V = 60 A for 3-wire, 120/240 V

The receptacle load would be permitted to be served by 2-wire or 3-wire circuits with a capacity equal to 60 A or greater for 3-wire circuits or 120 A or greater for 2-wire circuits.

Minimum Size Feeder (or Service) Overcurrent Protection

(see 215.3 or 230.90)

Subtotal noncontinuous loads		12,200 VA
Subtotal continuous load at 125% (16,200 VA × 1.25)		20,250 VA
	Total	32,450 VA

32,450 VA ÷ 240 V = 135 A

The next higher standard size is 150 A *(see 240.6).*

Minimum Size Feeders (or Service Conductors) Required

[see 215.2, 230.42(A)]

For 120/240 V, 3-wire system,

32,450 VA ÷ 240 V = 135 A

Service or feeder conductor is 1/0 Cu in accordance with 215.3 and Table 310.15(B)(16) (with 75°C terminations).

Statement of Problem and Substantiation for Public Input

The committee may want to revisit the word “store” in the title of this example. For the benefit of the committee here is a list of occupancies that appear in the 2012 International Building Code that seem to align with what is intuitively understood as a store building:

BUSINESS GROUP B 304.1 Business Group B. Business Group B occupancy includes, among others, the use of a building or structure, or a portion thereof, for office, professional or service-type transactions, including storage of records and accounts. Business occupancies shall include, but not be limited to, the following: Airport traffic control towers Ambulatory care facilities Animal hospitals, kennels and pounds Banks Barber and beauty shops Car wash Civic administration Clinic, outpatient Dry cleaning and laundries: pick-up and delivery stations and self-service Educational occupancies for students above the 12th grade Electronic data processing Laboratories: testing and research Motor vehicle showrooms, Post offices Print shops Professional services (architects, attorneys, dentists, physicians, engineers, etc.) Radio and television stations Telephone exchanges Training and skill development not within a school or academic program

SECTION 309 MERCANTILE GROUP M 309.1 Mercantile Group M. Mercantile Group M occupancy includes, among others, the use of a building or structure or a portion thereof, for the display and sale of merchandise and involves stocks of goods, wares or merchandise incidental to such purposes and accessible to the public. Mercantile occupancies shall include, but not be limited to, the following: Department stores Drug stores Markets Motor fuel-dispensing facilities Retail or wholesale stores Sales rooms

Anywhere it is possible to harmonize the NEC with the dominant building code in the US, the opportunity should be taken -- especially the "easy shots" like this. Note that this proposal is a modification of the public input from the 2017 revision cycle.

Submitter Information Verification

Submitter Full Name: Michael Anthony

Organization: Standards Michigan

Street Address:

City:

State:

Zip:

Submittal Date: Thu Sep 07 07:53:55 EDT 2017

Public Input No. 1297-NFPA 70-2017 [Definition: Feeder Neutral Conductor]

Feeder Neutral Conductor

(see 220.61)

Because 210.11(B) does not apply to these buildings, the load cannot be assumed to be evenly distributed across phases. Therefore the maximum imbalance must be assumed to be the full lighting load in this case, or 11,600 VA. (11,600 VA / 277V = 42 amperes.) The ability of the neutral to return fault current *[see 250.32(B) Exception(2)]* is not a factor in this calculation.

Because the neutral runs between the main switchboard and the building panelboard, likely terminating on a busbar at both locations, and not on overcurrent devices, the effects of continuous loading can be disregarded in evaluating its terminations *[see 215.2(A)(1) Exception No. 2]*. That calculation is (11,600 VA ÷ 277V) = 42 amperes, to be evaluated under the 75°C column of Table 310.15(B)(16). The minimum size of the neutral might seem to be 8 AWG, but that size would not be sufficient to be depended upon in the event of a line-to-neutral ~~short circuit~~ fault *[see 215.2(A)(1), second paragraph]*. Therefore, since the minimum size equipment grounding conductor for a 150 ampere circuit, as covered in Table 250.122, is 6 AWG, that is the minimum neutral size required for this feeder.

Statement of Problem and Substantiation for Public Input

The Fault Current Working Group was formed to support the Correlating Committee’s Usability Task Group. Members of the Fault Current Working Group included Scott Blizard, Jim Dollard, Carl Fredericks, Jeff Hidaka, Chris Jensen, Alan Manche, and Vince Saporita. The goal of the Fault Current Working Group was to analyze the usage of the terms “short-circuit” and “fault” throughout the NEC, and submit Public Inputs, as appropriate, to improve clarity, consistency, and usability.

While “short-circuit” and “fault” have been used interchangeably throughout the NEC (and the whole electrical industry), there are subtle differences between the two. This has resulted in confusion and a lack of consistency. Thus, numerous related Public Inputs have been submitted by the Working Group.

The definition of “Fault Current, Available (Available Fault Current)” is taken from SR8 of NFPA70E-2018. The definition (“The largest amount of current capable of being delivered at a point on the system during a short-circuit condition”) clarifies that “available fault current” is the highest short-circuit current that can flow at a particular point in the electrical system. The Informational Note, also taken from SR8 of NFPA70E-2018, (“A short-circuit can occur during abnormal conditions such as a fault between circuit conductors or a ground fault. See Figure 100.0”) provides an example of the relationship between “short-circuit” and “fault”. Figure 100.0, also from SR8 of NFPA70E-2018, helps explain the difference between “available fault current”, “short-circuit current rating”, and “interrupting rating”.

“Available short-circuit current” and “short-circuit current” are changed to “available fault current” for improved consistency.

“Maximum” is deleted in front of “maximum available fault current” (and “maximum available short-circuit current”) because the new definition of “available fault current” clearly includes the maximum (largest). The only exceptions, which remain unchanged, are in 250.4(A)(5) and 250.4(B)(3), where the word “maximum” is still appropriate and is necessary for a complete understanding of the requirement.

Equipment and component fault current ratings, short-circuit ratings, and short-circuit withstand ratings are changed to “short-circuit current ratings”, in agreement with equipment and component listing standards. The only exceptions, which remain unchanged, are for switch “fault closing ratings”, also to be in agreement with existing equipment and component listing standards.

Finally, “Short-circuit current calculation” is replaced with “available fault current calculation”, improving consistency.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 1246-NFPA 70-2017 [Definition: Coordination, Selective (Selective Coordination...]	PI from Fault Current Working Group
Public Input No. 1247-NFPA 70-2017 [New Definition after Definition: Externally Operable.]	PI from Fault Current Working Group
Public Input No. 1248-NFPA 70-2017 [New Definition after Definition: Externally Operable.]	PI from Fault Current Working Group
Public Input No. 1249-NFPA 70-2017 [Section No. 110.24(A)]	PI from Fault Current Working Group
Public Input No. 1250-NFPA 70-2017 [Section No. 110.24(B)]	PI from Fault Current Working Group
Public Input No. 1251-NFPA 70-2017 [Section No. 225.52(B)]	PI from Fault Current Working Group
Public Input No. 1252-NFPA 70-2017 [Section No. 230.82]	PI from Fault Current Working Group
Public Input No. 1253-NFPA 70-2017 [Section No. 230.205(B)]	PI from Fault Current Working Group
Public Input No. 1254-NFPA 70-2017 [Section No. 368.258]	PI from Fault Current Working Group
Public Input No. 1255-NFPA 70-2017 [Section No. 430.99]	PI from Fault Current Working Group
Public Input No. 1256-NFPA 70-2017 [Section No. 445.11]	PI from Fault Current Working Group
Public Input No. 1257-NFPA 70-2017 [Section No. 480.7(D)]	PI from Fault Current Working Group
Public Input No. 1258-NFPA 70-2017 [Section No. 490.21(A)(4)]	PI from Fault Current Working Group
Public Input No. 1259-NFPA 70-2017 [Section No. 490.21(B)(2)]	PI from Fault Current Working Group
Public Input No. 1260-NFPA 70-2017 [Section No. 490.21(C)(3)]	PI from Fault Current Working Group
Public Input No. 1263-NFPA 70-2017 [Section No. 490.21(D)(2)]	PI from Fault Current Working Group
Public Input No. 1264-NFPA 70-2017 [Section No. 490.21(D)(4)]	PI from Fault Current Working Group
Public Input No. 1265-NFPA 70-2017 [Section No. 490.21(E) [Excluding any Sub-Sections]]	PI from Fault Current Working Group
Public Input No. 1266-NFPA 70-2017 [Section No. 440.10(B)]	PI from Fault Current Working Group
Public Input No. 1267-NFPA 70-2017 [Section No. 505.7(F)]	PI from Fault Current Working Group
Public Input No. 1271-NFPA 70-2017 [Section No. 545.13]	PI from Fault Current Working Group
Public Input No. 1272-NFPA 70-2017 [Section No. 550.15(K)]	PI from Fault Current Working Group

Public Input No. 1273-NFPA 70-2017 [Section No. 551.47(O)]	PI from Fault Current Working Group
Public Input No. 1274-NFPA 70-2017 [Section No. 552.48(N)]	PI from Fault Current Working Group
Public Input No. 1275-NFPA 70-2017 [Section No. 620.16(B)]	PI from Fault Current Working Group
Public Input No. 1276-NFPA 70-2017 [Section No. 620.51(D)(2)]	PI from Fault Current Working Group
Public Input No. 1277-NFPA 70-2017 [Sections 670.5(1), 670.5(2)]	PI from Fault Current Working Group
Public Input No. 1281-NFPA 70-2017 [Section No. 690.8(A)(1)]	PI from Fault Current Working Group
Public Input No. 1282-NFPA 70-2017 [Section No. 690.8(D)]	PI from Fault Current Working Group
Public Input No. 1283-NFPA 70-2017 [Section No. 690.9(A)]	PI from Fault Current Working Group
Public Input No. 1284-NFPA 70-2017 [Section No. 690.13(E)]	PI from Fault Current Working Group
Public Input No. 1285-NFPA 70-2017 [Section No. 690.15(B)]	PI from Fault Current Working Group
Public Input No. 1286-NFPA 70-2017 [Section No. 690.32]	PI from Fault Current Working Group
Public Input No. 1287-NFPA 70-2017 [Section No. 695.6(I)]	PI from Fault Current Working Group
Public Input No. 1288-NFPA 70-2017 [Section No. 700.4(A)]	PI from Fault Current Working Group
Public Input No. 1289-NFPA 70-2017 [Section No. 701.4]	PI from Fault Current Working Group
Public Input No. 1290-NFPA 70-2017 [Section No. 702.4(A)]	PI from Fault Current Working Group
Public Input No. 1291-NFPA 70-2017 [Section No. 705.22]	PI from Fault Current Working Group
Public Input No. 1292-NFPA 70-2017 [Section No. 705.31]	PI from Fault Current Working Group
Public Input No. 1293-NFPA 70-2017 [Section No. 705.65(A)]	PI from Fault Current Working Group
Public Input No. 1294-NFPA 70-2017 [Section No. 706.7(D)]	PI from Fault Current Working Group
Public Input No. 1295-NFPA 70-2017 [Section No. 712.65]	PI from Fault Current Working Group
Public Input No. 1296-NFPA 70-2017 [Section No. 712.72]	PI from Fault Current Working Group

Submitter Information Verification

Submitter Full Name: Vincent Saporita
Organization: Eatons Bussmann Business
Affilliation: Eatons Bussmann Business

Street Address:

City:

State:

Zip:

Submittal Date: Mon Jul 24 20:59:36 EDT 2017

Copyright Assignment

RESEARCH FOUNDATION

RESEARCH FOR THE NFPA MISSION

Evaluation of Electrical Feeder and Branch Circuit Loading: Phase I

FINAL REPORT BY:

Tammy Gammon, Ph.D., P.E.

Georgia USA

January 2017

1 Batterymarch Park, Quincy, MA 02169-7417, USA
Email: foundation@nfpa.org   Web: nfpa.org/foundation

This page intentionally blank

FOREWORD

Interest has been growing in recent years to investigate and clarify the degree to which the feeder and branch circuit load design requirements in NFPA 70, *National Electrical Code®* (NEC®) need to be adjusted based on the increasing pace of technological innovation along the entire span of the electrical power chain.

There are multiple factors driving this issue and supporting the need to address this topic. For example, today's Energy Codes are driving down the electrical load presented by end use equipment and thus load growth assumptions that justify "spare capacity" should be re-examined. In addition, larger than necessary transformers that supply power to feeder and branch circuits expose unnecessary flash hazard to electricians working on live equipment.

This report summarizes a Phase I effort to develop a data collection plan to provide statistically significant load data for a variety of occupancy and loading types to provide a technical basis for considering revisions to the feeder and branch circuit design requirements in the National Electrical Code®. This initial effort has an emphasis on general commercial (office) occupancies, and the deliverables provide a review of the literature, and clarify the key elements of a data collection plan in support of a potential second phase (not included in the scope of this effort).

This page intentionally blank

ACKNOWLEDGEMENTS

The Fire Protection Research Foundation expresses gratitude to the report author Tammy Gammon, Ph.D., P.E. located in Georgia USA.

The Research Foundation appreciates the guidance provided by the Project Technical Panelists, the funding provided by the project sponsors, and all others that contributed to this research effort. Special thanks are expressed to the following Panel members: Robert Arno, Harris Corp. & IEEE Fellow; Mark Earley, NFPA; Mark Hilbert, IAEI & CMP-2 Chair; Brian Liebel, Illuminating Engineering Society of North America; and Mark Lien, Illuminating Engineering Society of N.A. (Alt to B Liebel). Thanks are also extended to the following Sponsors: Michael Berthelsen, University of Minnesota; Brett Garrett, The Ohio State University (alternate for Bob Wajnryb); Lou Galante, University of Iowa; Jeff Gambrall, University of Iowa (Alternate to Lou Galante); Dean Hansen, University of Texas Austin; Kane Howard, Michigan State University; Michael Hughes, Michigan Association of Physical Plant Administrators; Jim Jackson, University of Nebraska (alternate for Brian Meyers); Paul Kempf, University of Notre Dame; Brian Meyers, University of Nebraska; Bob Wajnryb, The Ohio State University; and Bob Yanniello, Eaton Corporation. Gratitude is likewise expressed to three liaisons that supported this effort: Mike Anthony, University of Michigan; Jim Harvey, University of Michigan; and Richard Robben, Ann Arbor, MI.

About the Fire Protection Research Foundation

The Fire Protection Research Foundation plans, manages, and communicates research on a broad range of fire safety issues in collaboration with scientists and laboratories around the world. The Foundation is an affiliate of NFPA.

About the National Fire Protection Association (NFPA)

Founded in 1896, NFPA is a global, nonprofit organization devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards. The association delivers information and knowledge through more than 300 consensus codes and standards, research, training, education, outreach and advocacy; and by partnering with others who share an interest in furthering the NFPA mission.

All NFPA codes and standards can be viewed online for free.

NFPA's membership totals more than 60,000 individuals around the world.

Keywords: electrical feeder, branch circuit, loading, transformer, NEC, National Electrical Code, NFPA 70

Report number: FRPF-2016-32

PROJECT TECHNICAL PANEL

Robert Arno, Harris Corp. & IEEE Fellow (NY)

Mark Earley, NFPA (MA)

Mark Hilbert, IAEI & CMP-2 Chair (NH)

Brian Liebel, Illuminating Engineering Society of North America (NY)

Mark Lien, Illuminating Engineering Society of N.A. (NY) (Alt to B Liebel)

PROJECT SPONSORS

Eaton Corporation, Bob Yanniello
Michigan Association of Physical Plant Administrators, Michael Hughes
Michigan State University, Kane Howard
The Ohio State University, Bob Wajnryb and Brett Garrett (alternate)
University of Iowa, Lou Galante and Jeff Gambrall (alternate)
University of Minnesota, Michael Berthelsen
University of Nebraska, Brian Meyers and Jim Jackson (alternate)
University of Notre Dame, Paul Kempf
University of Texas Austin, Dean Hansen

PROJECT LIAISONS

Mike Anthony, University of Michigan (MI)
Jim Harvey, University of Michigan (MI)
Richard Robben, Ann Arbor, MI

This page intentionally blank

Fire Protection Research Foundation Project

Review of Literature and Data Collection Plan
Evaluation of Electrical Feeder and Branch Circuit Loading: Phase 1

Submitted by

Tammy Gammon, Ph.D., P.E.

January 2017

Project Technical Panel

Mark Hilbert, IAEI and NEC Code-Making Panel 2 Chair
Robert Arno, Harris Corporation
Mark Earley, NFPA
Brian Liebel, IES

Project Sponsors

University of Minnesota
The Ohio State University
University of Iowa
University of Texas – Austin
Michigan State University
Michigan Association of Physical Plant Administrators
University of Nebraska
University of Notre Dame
Eaton Corporation

EXECUTIVE SUMMARY

The purpose of this Phase I project is to conduct a literature review and to develop a data collection plan for an ambitious Phase II study on the evaluation of electrical feeder and branch circuit loading. The intent of this research is to evaluate electrical feeder and branch circuit loading given present National Electrical Code requirements, electrical safety, energy conservation, and reduction of capital investment.

This research project focuses on commercial buildings. Report Sections 1 through 7 cover a review of related work and published data. Specifically, electricity usage and commercial building demographics are reviewed in Sections 1 and 2 to provide insight into the number of feeders and branch circuits installed in the United States and the amount of electricity supplied by them. Furthermore, Section 2 on commercial buildings and Section 3 on end-use loads have been included because the characteristics of the commercial buildings determine the electrical loads and the design of the electrical feeders and branch circuits supplying those loads. Section 4 addresses some of the factors which shape end-use equipment decisions and includes energy consumption projections for commercial buildings to the year 2040.

Commercial building energy conservation codes are covered in Section 5 with a focus on lighting and power requirements in ASHRAE 90.1. In Section 6, the following engineering practices are discussed: one utility, traditional building electrical system design, and design in federal buildings. The NEC's minimum lighting power requirements are also compared with ASRHAE 90.1 and other guidelines in Section 6.

Section 7 addresses transformer efficiency and electrical safety issues as a function of transformer loading. Section 7 contains the author's analysis regarding concern that lightly loaded transformers (supplying lightly loaded feeders) are associated with additional energy losses and increased arc flash hazards.

The data collection plan is presented in Section 8. Although included as the final section of this report, Section 8 has been written to serve as a document which can stand alone, independent of the other report sections.

TABLE OF CONTENTS

1 Electricity Usage in the United States 1
1.1 Electric Utility Customers and Consumption........ 1
1.2 Seasonal Influences and Climate........ 2
2 Commercial Buildings 5
2.1 General Demographics for All Commercial Buildings [5] 5
2.2 Commercial Building Types and Specific Demographics [5]........ 8
2.3 Commercial Building Energy Usage by Geography [5]........11
2.4 Commercial Building Energy Usage by Building Type [5]........15
2.5 Electric Utility Commercial Building Loading 18
3 Building End-Use Loads and Electricity Consumption 19
3.1 End-Use Load Types and CBECS Models [5] 19
3.2 CBECS End-Use Load Consumption [5] 20
3.3 Miscellaneous Electric Loads in CDM and Elsewhere........25
3.4 Receptacle and Plug and Process Load Studies........29
3.4.1 Lawrence Berkeley National Laboratory Office Receptacle Study........29
3.4.2 University of Idaho & California PIER Studies on Receptacle Load Power........31
3.4.3 NREL Study on Plug and Process Load Power Density and Other Work 32
3.4.4 Studies on Device Power Consumption 34
3.4.5 Receptacle Load Power Densities in Real Estate and Building Design 36
4 EIA Model and Predictions for Commercial Buildings........37
4.1 NEMS Commercial Demand Module........37
4.2 EIA 2015-2040 Projections for Commercial Buildings 38
5 Commercial Building Energy Conservation Codes 38
5.1 U.S. Department of Energy (DOE) Commercial Buildings Models........38

5.2 Historical Perspective, Energy Savings, and Coverage 41

5.3 ASHRAE 90.1 – General, Power, and Lighting Requirements 42

5.4 Development of ASHRAE 90.1 Lighting Power Allowances 45

6 Engineering Practices 47

6.1 Electric Utility Demand Load and Transformer Sizing for Commercial Buildings 47

6.2 Traditional Design Practices for Electrical Systems in Buildings 49

6.2.1 Building Demand Load, Panel, and Feeder Sizing 49

6.2.2 Branch Circuit Sizing and Protection 50

6.2.3 In-House Transformers and Connecting Equipment Selection 51

6.3 NEC Lighting Requirements and Other Lighting Guidelines 51

6.3.1 NEC and NEC Comparison with ASHRAE Requirements 51

6.3.2 IEEE, IES, and Federal Lighting Recommendations 53

6.4 Federal Recommendations in Building Electrical System Design 54

6.4.1 GSA's PBS-P100, Facilities Standards for the Public Buildings Service 54

6.4.2 PBS-P100 Advanced Building Metering and Control 55

6.4.3 PBS-P100 Demand Load Calculations 55

6.4.4 PBS-P100 Treatment of Harmonics 56

7 Oversizing and "Rightsizing" Transformers 57

7.1 1999 Cadmus Transformer Loading Study [32] 57

7.2 Transformer Loading and Efficiency 58

7.3 Transformer Sizing and Arc Flash Hazards in Building Systems 64

8 Data Collection and Analysis Plan for Evaluation of Electrical Feeder and Branch Circuit Loading Project Phase II 68

8.1 Motivation for Project 68

8.2 Relevance of Project Focus 71

8.3 Selection of Study Type and Participating Study Buildings 72

8.3.1 Objective 72

8.3.2 Types of Commercial Buildings 73
8.3.3 Geographic Distribution of Study Buildings 74
8.3.4 Criteria for Building Selection 76
8.3.5 Required Building Documents and Information 80
8.4 Site Monitoring 82
8.4.1 System Monitoring Options 82
8.4.2 Monitoring Equipment 84
8.4.3 Method of Data Collection on Site and to Project Personnel 86
8.5 Data Analysis 86
8.5.1 Evaluation of Lighting Load 86
8.5.2 Evaluation of Receptacle Load 87
8.5.3 Evaluation of Other Loads 87
8.5.4 Evaluation of In-House Feeder Sizing and Transformer Loading 87
8.5.5 Evaluation of Main Feeder Size and Service Transformer Loading 88
8.5.6 General Evaluation of Power Quality 88
8.6 Deliverables 88
8.7 Budget 88
9 References 89
10 Appendices 91
Appendix A. U.S. Census Bureau Population Density Map 91
Appendix B. Manufacturer Monitoring Equipment Information 93
Appendix B.1 GE EPM 4600 Multi-feed Power and Energy Metering System 94
Appendix B.2 Honeywell E-Mon Class 3400 Smart Meter 107
Appendix B.3 Onset Data Loggers for Real Power or Phase RMS Currents 110
Appendix B.4 GE ASPMETER Metering Panelboard 128

LIST OF FIGURES

Figure 1. Numbers of U.S. Electric Utility Customers in June 2016 2

Figure 2. Annual Retail U.S. Electricity Sales from 2001 to 2015 2

Figure 3. Monthly Electricity Sales in U.S. from 2001 to 2015 4

Figure 4. IECC Climate Regions in the U.S. 4

Figure 5. Commercial Buildings – Numbers and Total Floorspace Categorized by Size............ 6

Figure 6. Commercial Buildings – Numbers and Mean Square Feet Categorized by Year 7

Figure 7. Commercial Buildings – Numbers and Mean Square Feet Categorized by Region 7

Figure 8. Commercial Building Types – Numbers, Floorspace, & Electricity Consumption........10

Figure 9. Commercial Building Types – Mean Size and Operating Hours 10

Figure 10. Percentage Employees by Commercial Building Type 11

Figure 11. Electricity Consumption in Commercial Buildings Categorized by Climate 12

Figure 12. Number of Commercial Buildings (Percentage) Categorized by Climate 12

Figure 13. Mean Annual Electric Energy and Power Intensities Categorized by Climate...........14

Figure 14. Percentage Energy Source Consumption Categorized by Geographic Region 14

Figure 15. Mean Annual Electric Energy and Power Intensities Categorized by Region............15

Figure 16. Percentage of Energy Source Consumption Categorized by Building Type.............16

Figure 17. Electric Energy Intensity Categorized by Commercial Building Type 16

Figure 18. Electric Power Intensity Categorized by Commercial Building Type 17

Figure 19. Austin Energy - Commercial Building Average Electric Power Intensity 18

Figure 20. Percentage End-Use Electricity Consumption for All Commercial Buildings 21

Figure 21. AC and Ventilation and Refrigeration Electricity Consumption by Building Type 22

Figure 22. Office Equipment/Computing, Lighting, and Cooking Consumption by Type 22

Figure 23. Refrigeration, AC and Ventilation Electric Energy Intensity by Building Type 23

Figure 24. Lighting and Office Equipment/Computing Electric Energy Intensity by Type 23

Figure 25. Refrigeration, AC and Ventilation Electric Power Intensity by Type 25

Figure 26. Plug Load Office Building Study at Lawrence Berkeley National Laboratories..........30

Figure 27. Energy & Power Intensities for DOE Reference Office Buildings in Miami................41

Figure 28. Austin Energy – VA and Power Demand Load in Commercial Buildings 48

Figure 29. Efficiency Curves for Three Eaton 45 kVA, 480Δ-208Y-V Transformers 60

Figure 30. Power Losses as Percentage of Power Supplied for Three Eaton Transformers......60

Figure 31. Power Losses: 7.5 to 45 kVA Loads Supplied by 30 to 75 kVA Transformers 61

Figure 32. Power Losses: 75 to 225 kVA Loads Supplied by 75 to 300 kVA Transformers 61

Figure 33. Efficiency as Function of Rise for 45 kVA, 480Δ-208YV, EL-4 Core Transformer.....62

Figure 34. Efficiency as Function of Rise for 45 kVA, 480Δ-208YV, EL-5 Core Transformer.....62

Figure 35. Efficiency as Function of Rise for 45 kVA, 480Δ-208YV, EL-6 Amorphous Core......62

Figure 36. Available Short-Circuit Current at Transformer Secondary in Typical Systems.........66

Figure 37. 1584-2002 Arc Current at Transformer Secondary in Typical Systems 66

Figure 38. 1584-2002 Incident Energy after 100 ms at Secondary in Typical Systems.............67

Figure 39. IECC Climate Regions in the U.S. 75

Figure 40. Monitoring Optimal Site with Load Separation 77

Figure 41. Monitoring "Good" or "Optimal" Site 78

Figure 42. Monitoring Acceptable Site...79

Figure 43. Monitoring a Site Not Meeting "Optimal," "Good," or "Acceptable" Ranking 80

LIST OF TABLES

Table 1. IECC Climate Zones [2],[3],[4] 5

Table 2. IECC Climate, Precipitation, and Temperature Descriptions [3] 5

Table 3. Estimated Mean Power Intensities (W/ft^2) for Commercial Office Buildings* 25

Table 4. Navigant MELs - Total & Unit 2011 Energy Consumption and Active Power Draw 27

Table 5. 2011 MEL Percentage Energy Consumption by Predominant Building Category 28

Table 6. Subcategory MEL Equipment used in Composite Profile (Annual Basis for 2011) 29

Table 7. Summary of Results in University of Idaho's Receptacle Load Study* 31

Table 8. New Buildings Institute Receptacle and Lighting Load Office Study [11] 32

Table 9. Plug and Process Load Power Densities of Four Government Offices 33

Table 10. Plug and Process Load Power Densities of Seven Stanford University Buildings 33

Table 11. Plug and Process Load Power Densities of Ten Office Buildings 33

Table 12. Baumann Study: Plug Load Power Densities in Different Office Space Types* 34

Table 13. Measured Power Consumption of Common Office Devices in Various States* 35

Table 14. Baumann Study - Device Nameplate and Idle and In-use Power Consumption* 36

Table 15. Commercial Demand Module Building Categories, Floorspace, and Occupancy* 38

Table 16. DOE Reference Building Models and Equivalent CBECS Building Type 39

Table 17. ASHRAE 90.1 & IECC Building Area Method Lighting Power Density Allowances 44

Table 18. ASHRAE 90.1 & IECC Lighting Power Allowances for Selected Space Types 45

Table 19. Austin Energy Demand Factors for Connected Commercial Loads 48

Table 20. Austin Energy Three-Phase Pad-mount Transformer Loading Guidelines[a,b,c] 49

Table 21. Traditional Engineering Demand Factors for Building Loads* 50

Table 22. NEC (VA/ft^2) and ASHRAE 90.1 (W/ft^2) Lighting Power Density by Occupancy 53

Table 23. Recommended Illumination Levels and Lighting Densities in PBS-P100 54

Table 24. 2014 PBS-P100 Minimum Receptacle Load Power Density 56

Table 25. 2014 PBS-P100 Additional Spare Capacity 56

Table 26. Measured Transformer Load Factor in 1999 Cadmus Study 57

Table 27. 1999 Cadmus Study – Power Factor, Total Harmonic Distortion, and K-Factor.........58

Table 28. Eaton Percentage of Transformers Manufactured in 2016 by Rise Type 63

Table 29. Eaton Percentage of Transformers Manufactured in 2016 by K-Factor Rating 64

Table 30. Three Typical 480-V Building Systems 65

Table 31. Impedance for 480Δ-208Y/120 V, 150°C Rise, 15 – 300 kVA Transformers.............66

Table 32. NEC (VA/ft^2) and ASHRAE 90.1 (W/ft^2) Lighting Power Density by Occupancy.........69

Table 33. Geographic Selection and Number of Monitoring Sites 75

Table 34. System Monitoring Options for Study Buildings 82

1 ELECTRICITY USAGE IN THE UNITED STATES

1.1 Electric Utility Customers and Consumption

This project addresses National Electrical Code Articles 210 – 230, specifically Article 220, which provides the requirements for branch-circuit, feeder, and service load calculations. The NEC has been adopted in 47 states[1] and applies to the vast majority of building electrical systems in this country. Although some entities generate part of or all their electric power on site, most electric power users in this country are customers of an electric power utility. Figure 1 reveals that electric utilities had close to 150 million customer accounts in June 2016. Over 131 million residential accounts provide power to the U.S. population, estimated at over 322 million. Electric utilities also had 18.3 million commercial and 827,000 industrial accounts in June 2016. Even though the number of commercial customers equals less than 14% of the number of residential customers, Figure 2 shows that the two sectors have purchased roughly the same amount of electricity over the past fifteen years. In 2015, the residential, commercial, and industrial sectors purchased 1.40, 1.36, and 0.96 trillion kW-hours, respectively.

The sheer number of electric utility customers and the amount of electricity sold in the United States attest to the importance of the National Electric Code (first printed in 1897) which applies to all new electrical installations where it is adopted and enforced. Since each electric utility customer must have at least one electrical service feeder, the number of service feeders must approach 150 million and the numbers of distribution feeders and branch circuits must exceed a billion.

---

[1]As of September 1, 2016, the NEC (2008, 2011, or 2014 edition) had been adopted in all states except Arizona, Missouri, and Mississippi. Source: http://www.electricalcodecoalition.org/state-adoptions.aspx, accessed September 9, 2016. The 2017 edition of NFPA 70, *The National Electrical Code* or *NEC*, was issued by the National Fire Protection Association (NFPA) in August 2016.

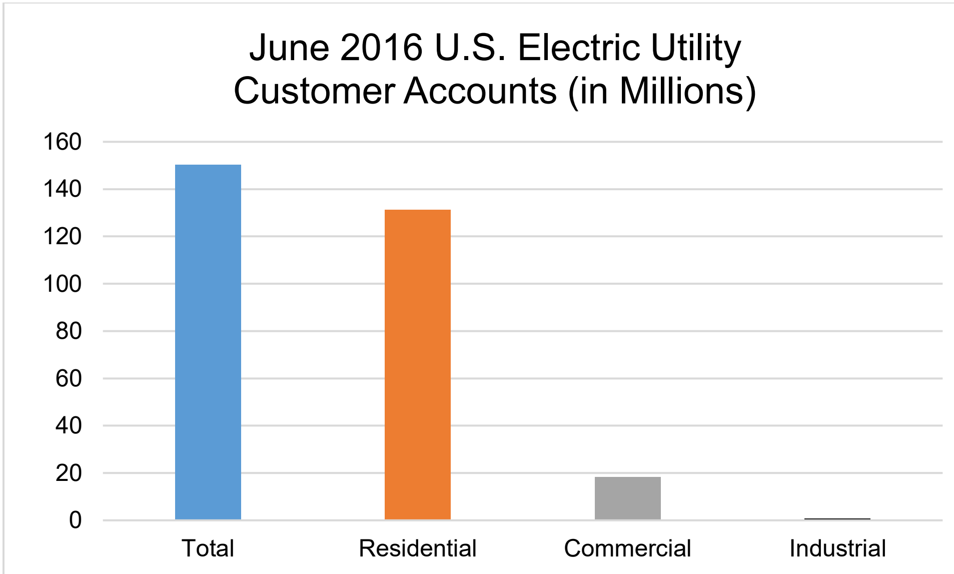


Figure 1. Numbers of U.S. Electric Utility Customers in June 2016
(Data Source: [1])

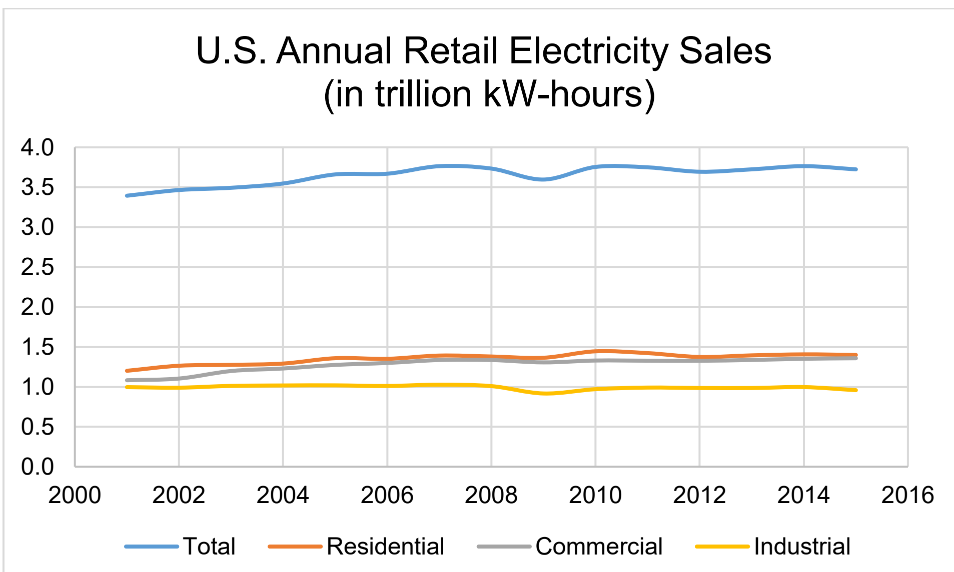


Figure 2. Annual Retail U.S. Electricity Sales from 2001 to 2015
(Data Source: [1])

1.2 Seasonal Influences and Climate

Figure 3 shows the seasonal influences of electricity purchases on commercial and residential customers. Both sectors have greater electricity demands during the summer and winter seasons. Residential customers have sharp peaks in consumption during both summer and winter months. As an aggregate group, commercial customers have a large summer peak, but the winter peak is much smaller in comparison. Individual customers that do not use electricity as the primary energy source for heating may not experience a sharp peak in electricity consumption; however, electric loads, such as lighting and receptacle (portable electric heaters if the building is not kept warm enough) may increase during winter months. In the summer, refrigeration costs may rise for cold storage warehouses and food service (grocery stores) buildings. The heat dissipated by lighting, other electrical loads, and electrical equipment may also increase the demand for air conditioning load in the summer, especially for older installations where older electrical loads and electrical equipment tend to have greater heat losses and manufactured with lower energy efficiency ratings.

Some industrial processes are greatly affected by ambient temperature and humidity; therefore, the electrical energy demanded by those processes is also dependent on the seasons.

The type of heat and the geographic location of the facility determines summer and winter electricity demand for the building. The IECC climate region map [2], developed for the U.S. Department of Energy, is included as Figure 4 and first appeared in the 2004 edition of ASHRAE 90.1. It features eight main climate zones based on temperature; the zones tend to run in east-west bands subdivided by moisture condition. [3]

Thirteen IECC climate zones are defined in Table 1. The thermal criteria for the zones are based on the number of cooling degree days over 50°F (CDD50°F) and the number of heating degree days lower than 65°F (HDD65°F). As an example, ten heating degree days is equivalent to the average outdoor temperature of 55°F for a 24-hour period[2].

In its work developing representative commercial building models for energy consumption, the Department of Energy identified three additional climate zones. The most populated city in each of these sixteen (total) zones is listed in Table 1. In the DOE modeling and simulation work, two climate regions were found for climate zone 3B and were subdivided as 3B-California coast and 3B-other for the remaining areas of the climate zone [2]. The temperature and rainfall conditions which further subdivide the climate zones are described in Table 2.

[2] Mathematically, (65°F - 55°F) x one 24-hour period = 10 heating degree days. Another example: The average temperature is 70°F for twelve hours equates to (70°F - 50°F) x ½ of a 24-hour period = 10 cooling degree days.

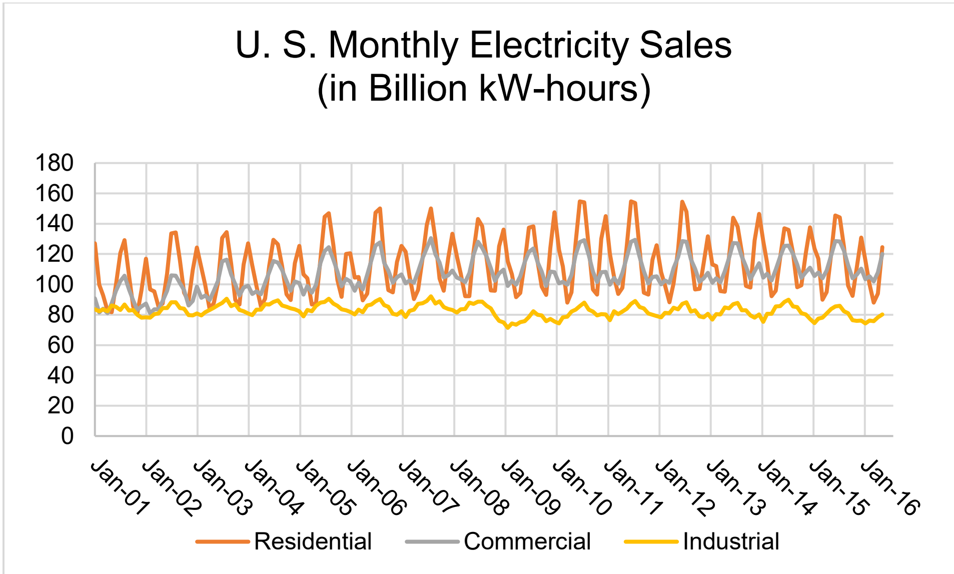


Figure 3. Monthly Electricity Sales in U.S. from 2001 to 2015
(Data Source: [1])

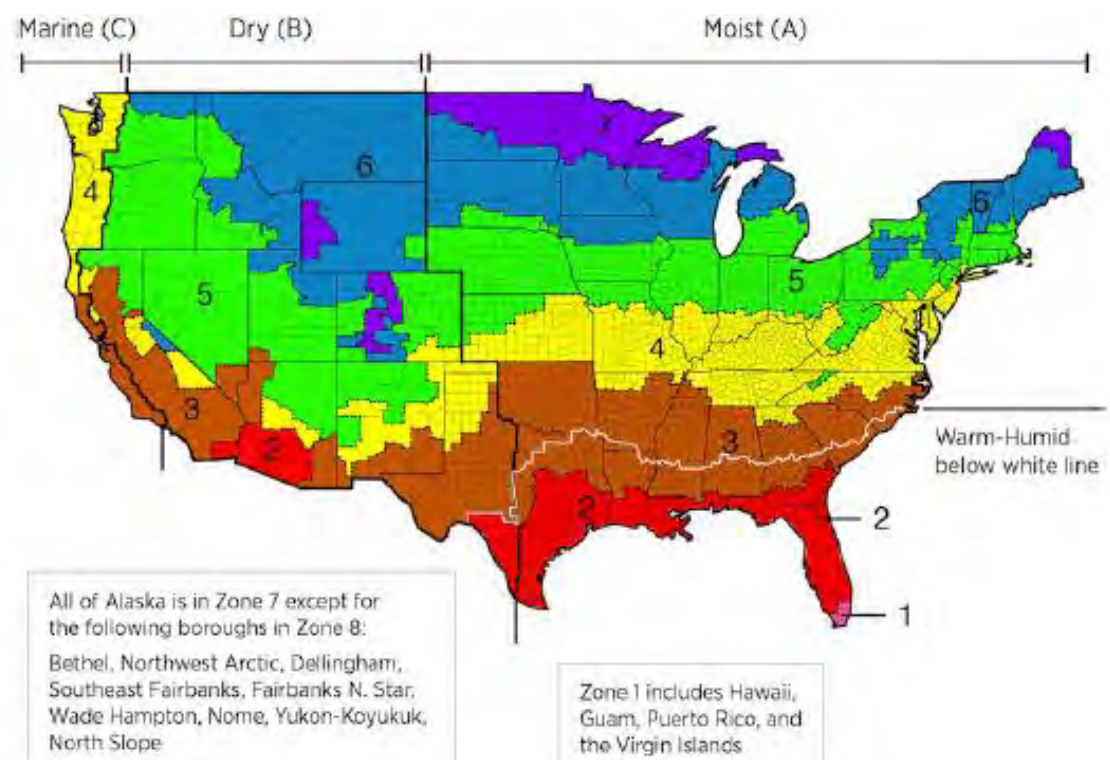


Figure 4. IECC Climate Regions in the U.S.
(Source: U.S. Department of Energy, and reference [4])

Table 1. IECC Climate Zones [2],[3],[4]

IECC	CDD50°F	HDD65°F	Temperature	Moisture	Most Populated City
1	> 9000		Hot	Humid	Miami
2A	> 6300		Hot	Humid	Houston
2B	> 6300		Hot	Dry	Phoenix
3A	> 4500	≤ 5400	Hot, Mixed	Humid	Atlanta
3B	> 4500	≤ 5400	Hot	Dry	Las Vegas (other) Los Angeles (CA coast)
3C		≤ 3600	Marine	Marine	San Francisco
4A	≤ 4500	≤ 5400	Mixed	Humid	Baltimore
4B	≤ 4500	≤ 5400	Mixed	Dry	Albuquerque
4C		> 3600, ≤ 5400	Marine	Marine	Seattle
5		> 5400	Cold		Chicago (**5A**) Denver (**5B**)
6		> 7200	Cold		Minneapolis (**6A**) Helena, MT (**6B**)
7		> 9000	Very Cold		Duluth, MN
8		> 12600	Subarctic		Fairbanks, AK

Table 2. IECC Climate, Precipitation, and Temperature Descriptions [3]

Climate Description	Precipitation, Annual (inches)	Temperature Description
Hot-Humid	> 20	During warmest six consecutive months, 67°F+ for 3000+ hours and/or 73°F+ for 1500+ hours
Hot-Dry	< 20	Monthly average > 45°F throughout year
Mixed-Humid	> 20	Monthly average < 45°F during winter months
Mixed-Dry	< 20	Monthly average < 45°F during winter months
Marine	Dry summer season Heaviest month 3+ times that of lowest	Warmest monthly mean < 72°F 27°F < Coldest monthly mean < 72°F Monthly average > 50°F at least four months

2 COMMERCIAL BUILDINGS

2.1 General Demographics for All Commercial Buildings [5]

Data collected from the Commercial Buildings Energy Consumption Survey (CBECS) provide much insight into the characteristics and energy usage of commercial buildings in the United States. A team of approximately six U.S. Energy Information Administration (EIA) employees supervises the CBECS study, which has recently been contracted out in the “tens of millions of dollars."[3] The most recent CBECS was conducted in 2013 to collect data for existing buildings and energy usage in 2012. The initial sample involved over 12,000 buildings, which was reduced to a final sample of 6,720 buildings. The final sample set was weighted to represent the total number of commercial buildings in the U.S., which the EIA estimates as approximately 5,557,000. The 2012 CBECS was based on climate zones as identified in Figure 4.

The total numbers and floor space of U.S. commercial buildings are displayed in Figure 5 based on general building size. Smaller commercial buildings (1,001 to 10,000 square feet) account for 72% of all commercial buildings, but only 19% of the total floor space. Larger commercial buildings (50,000 or more square feet) account for only 6% of all commercial office buildings, but 51% of the floor space. Figures 6 and 7 show the number of buildings and size (in mean square feet) by year of construction and region of the country. The median age of a building is 32 years ([5], Table B2). Historically speaking, it appears that as the U.S. population increases, more buildings are constructed and are larger in size. In Figure 7, the four census regions are represented by green columns and the regional subdivisions are represented by blue columns. For example, the South, which has the largest number of buildings, is subdivided into three areas: South Atlantic, East South Central, and West South Central. However, the largest commercial buildings (statistical average of floor space) are located in the Middle Atlantic area, part of the Northeast region.

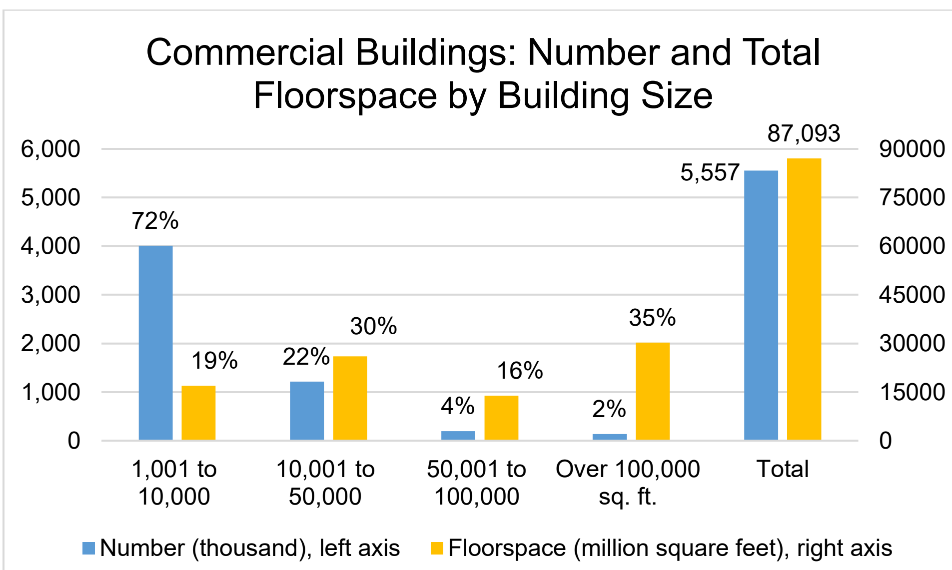


Figure 5. Commercial Buildings – Numbers and Total Floorspace Categorized by Size
(Data Source: Table B1 from [5])

[3] September 14, 2016 email from Joelle Michaels, EIA's CBECS Survey Manager.

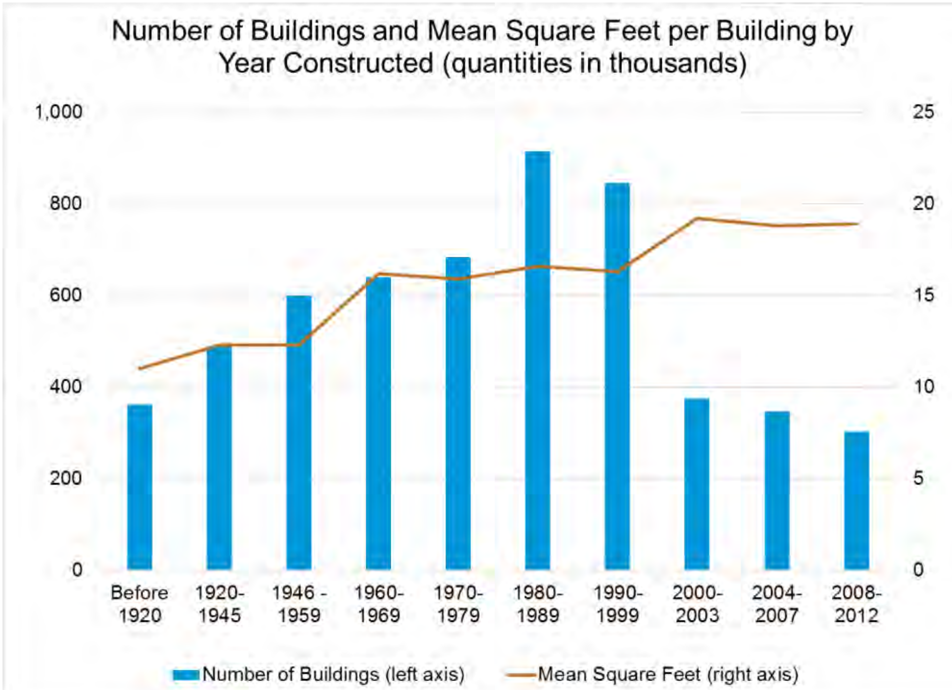


Figure 6. Commercial Buildings – Numbers and Mean Square Feet Categorized by Year
(Data Source: Table B1 from [5])

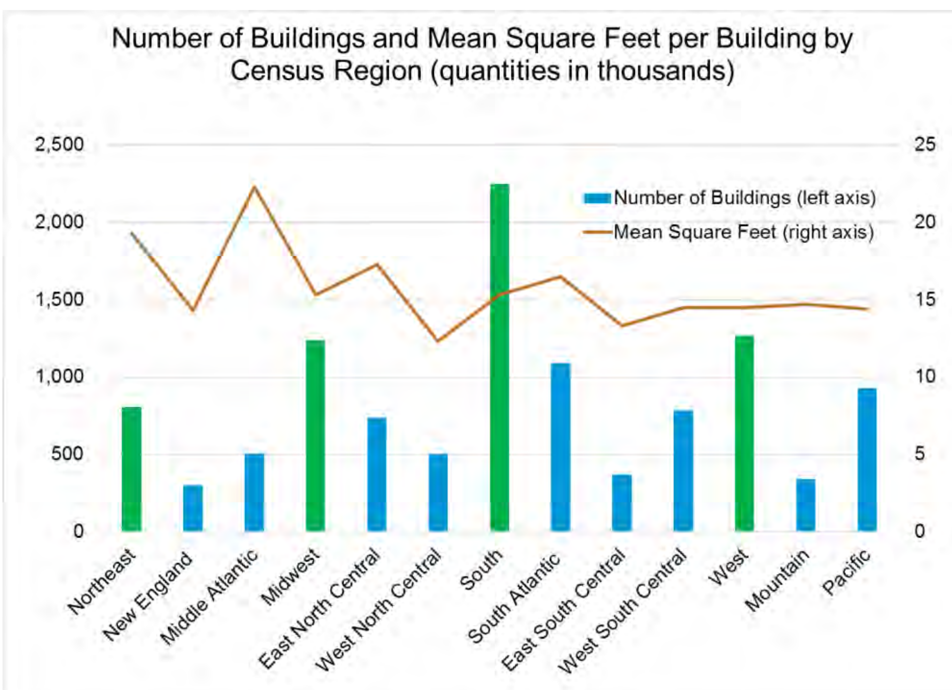


Figure 7. Commercial Buildings – Numbers and Mean Square Feet Categorized by Region
(Data Source: Table B1 in [5])

2.2 Commercial Building Types and Specific Demographics [5]

Sixteen building types have been identified by primary activity. This work will focus on five commercial building types:

- Education (e.g., K-12 schools, universities, day care, vocational training)[4]
- Healthcare, Inpatient (e.g., hospital, inpatient rehabilitation)
- Healthcare, Outpatient (e.g., medical office, outpatient rehabilitation, veterinarian)
- Lodging (e.g., hotel, dormitory, fraternity, nursing home, assisted living, shelter)
- Office (e.g., administrative, professional or government office; bank; city hall; call center)

Education buildings are used for academic or technical classroom instruction. Buildings on education campuses which are not primarily used for instruction are categorized by their primary functions; administration offices, libraries, student centers and dormitories are not identified as education buildings.

Healthcare buildings are used for patient diagnosis and treatment. If medical offices use diagnostic equipment, they are categorized as outpatient healthcare buildings; otherwise, they are categorized as office buildings.

Lodging buildings provide accommodations for short-term or long-term residents. Lodging may include simple amenities at motels or skilled nursing in nursing homes. Minimal supervision may be provided at dormitories and fraternities, while more extension supervision would be required at children's homes.

Office buildings cover a wide range of administrative, government, financial, and professional offices. They include general sales, non-profit, social service, and religious offices, as well as construction, plumbing, HVAC and other contractor offices.

Classrooms, student residence halls, offices, and even hospitals are often part of large university complexes. In fact, university complexes are communities with most, if not all, building types represented.

[4] In comments dated December 21, 2016, Mike Anthony stated, "Education facilities up to K-12 are governed by safety codes that recognize the behavioral characteristics of the occupants. Higher education facilities are governed by commercial codes. It may come as a surprise that classrooms in higher education have a 20 percent occupancy rate; and that most of the square footage in higher education is devoted to administrative activity."

The other eleven commercial building types are:

- Food Sales (e.g., grocery)
- Food Service (e.g., restaurant)
- Mercantile, Retail other than mall (e.g., liquor stores, automobile dealerships, art gallery)
- Mercantile, Enclosed and strip malls
- Public Assembly (e.g., cinema, museum, sports arena, funeral home, library, health club)
- Public Order and Safety (e.g., police station, fire station, courthouse, penitentiary)
- Religious Worship
- Service (e.g., post office, gas station, dry cleaner, repair shop, hair salon, copy/print shop)
- Warehouse and Storage
- Other (e.g., crematorium, laboratory, data center, airplane hangar)
- Vacant

As shown in Figure 8, office buildings comprise the highest percentage (19%) of the number of commercial buildings by type. Figure 8 also illustrates that the total floor space (19%) and electricity consumption (20%) of office buildings account for similarly high percentages. The building type, *Warehouse and Storage*, accounts for the second highest number of commercial buildings (13%) and total floor space (15%); however, by proportion, this building type consumes much less electricity (7%). Education buildings represent the third highest percentage of total square feet (14%) and the second highest percentage of electricity consumption (11%).

Figure 9 displays the mean size and mean operating hours per week of commercial buildings. Although inpatient healthcare occupies a small percentage of the total floor space for commercial buildings, the mean size of inpatient healthcare buildings, at 247,800 square feet, dwarfs all other building types. The second largest building type is lodging at 36,900 square feet. Inpatient healthcare (168 hours) and lodging (165 hours) typically around-the-clock (i.e., 24/7 operation). Food sales (121 hours) and public order and safety (113 hours) also have a high number of operating hours.

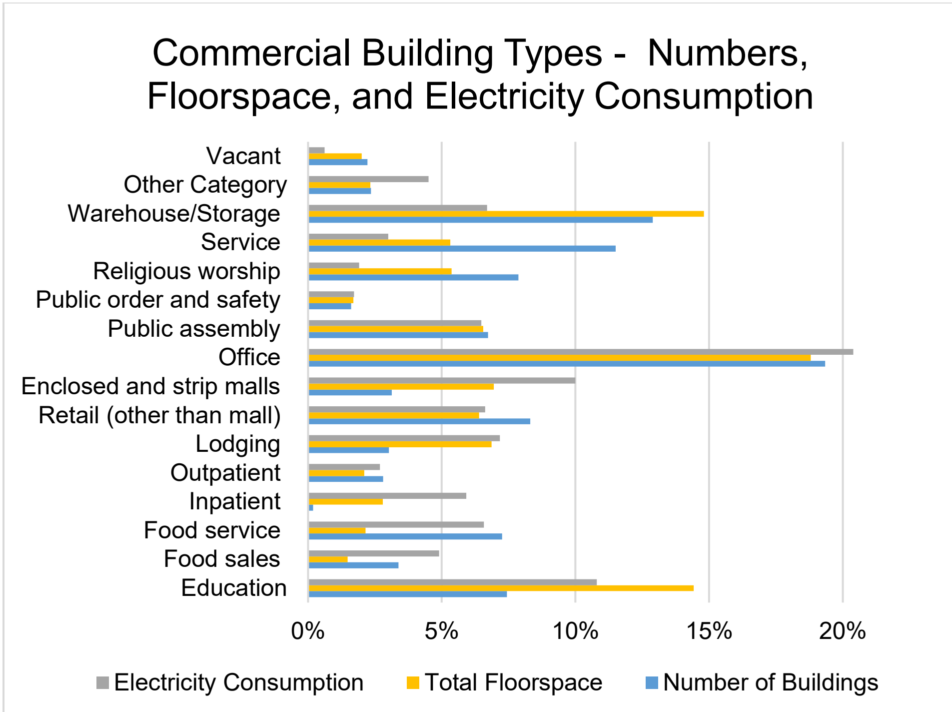


Figure 8. Commercial Building Types – Numbers, Floorspace, & Electricity Consumption
(Data Source: Table C13 in [5])

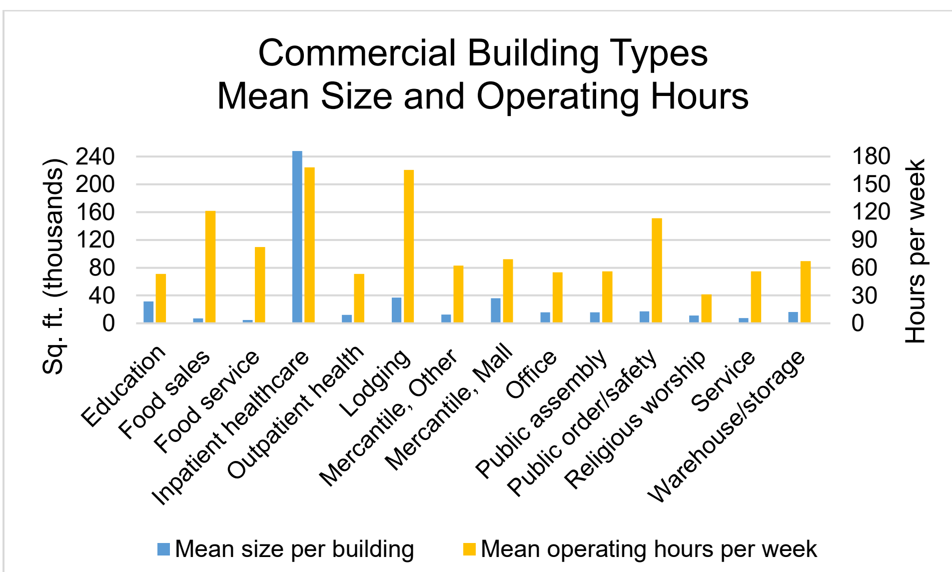


Figure 9. Commercial Building Types – Mean Size and Operating Hours
(Data Source: Table B1 in [5])

In the process of working, employees utilize electrical equipment, even if only as task lighting. Basic electrical safety in the workplace applies to all employees, not just electrical workers. Statistically speaking, as this numbers of employees increase, concern and attention to electrical safety should also increase. Therefore, a carefully designed and properly installed electrical installation is even more important when larger numbers of employees are involved. Figure 10 illustrates that education, healthcare (inpatient and outpatient), and office buildings account for 50% of the 104.9 million people working in commercial buildings. Electrical safety concerns also especially apply to lodging which provides housing for short- and long-term residents. In this research project, the commercial building category of lodging has been added to cover dormitories on university campuses, but it also addresses long-term healthcare needs provided by assisted living centers and nursing homes. Electrical safety, in the context of employee and resident safety, also covers proper operation, care, and maintenance of electrical systems and equipment. Improperly installed, operated, and maintained electrical systems and equipment could result in harmful and deadly fires.

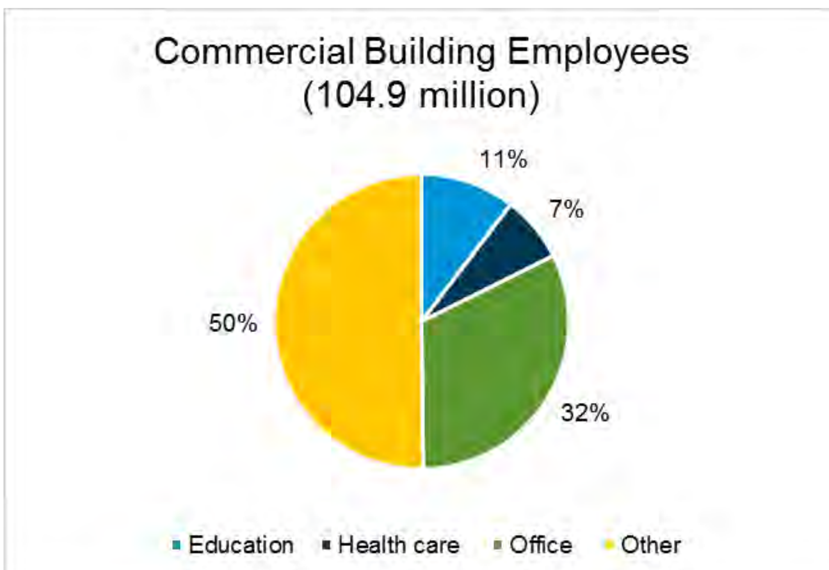


Figure 10. Percentage Employees by Commercial Building Type
(Data Source: Table B1 in [5])

2.3 Commercial Building Energy Usage by Geography [5]

As previously seen in Figure 8, the amount of electricity consumption depends on commercial building type. Figure 11 shows it also depends on climate. In hot, humid climates, the percentage of electricity consumption (18%) is notably higher than the percentage of total floor

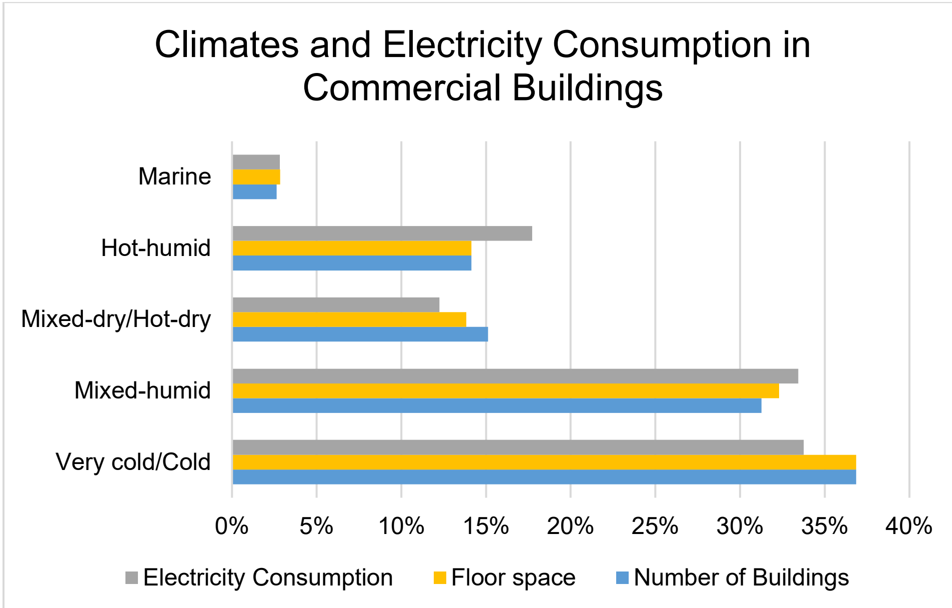


Figure 11. Electricity Consumption in Commercial Buildings Categorized by Climate
(Data Source: Table C13 in [5])

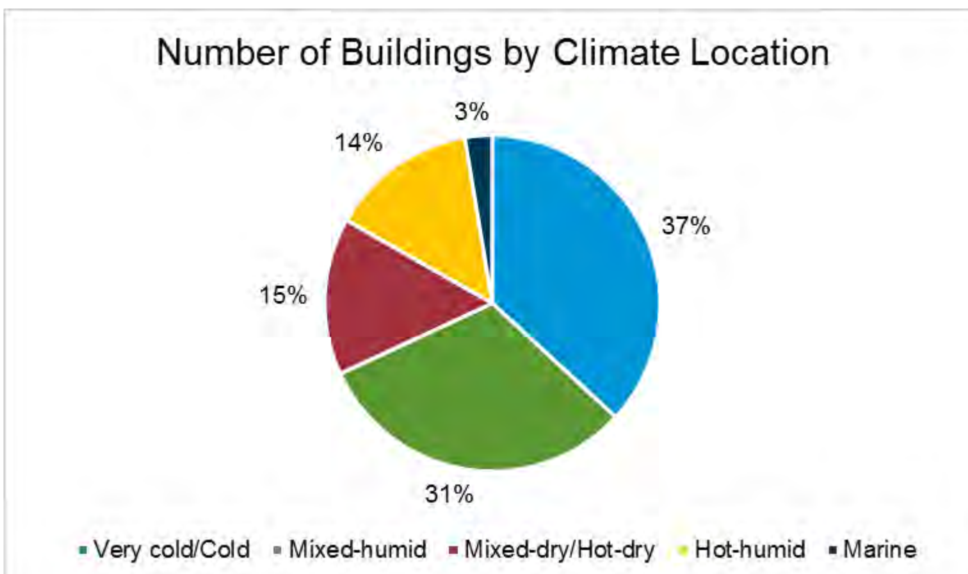


Figure 12. Number of Commercial Buildings (Percentage) Categorized by Climate
(Data Source: Table C13 in [5])

space (14%). Conversely, in cold and very cold climates, the percentage of electricity consumption (34%) is lower than the total floor space (37%). As seen in Table 1, colder climates have lower energy demands for air conditioning and have higher energy demands for heating.

The higher electricity consumption in hot, humid climates (per total floor space) in Figure 11 is likely due to the greater cooling needs in hot, humid climates; the lower electricity consumption in cold and very cold climates suggests that other energy sources, not electricity, are meeting the greater heating needs. The percentages of the total number of commercial buildings located in each climate are displayed in Figure 12. Over two-thirds of the buildings are located in mixed humid (zones 4A and part of 3A) and cold or very cold climate (zones 5, 6, and 7) zones [3].

Figure 13 shows the annual mean electric energy and power intensities for commercial buildings located in each climate. In 2012, the mean electric energy and power intensities were 14.6 kW-hour and 1.7 W per square foot for all climates represented in the study. The highest intensities were found in hot-humid climates at 18.4 kW-hours and 2.1 W per square foot. The mixed-dry and hot-dry climate region had the lowest intensities of 13.0 kW-hours and 1.5 W per square foot. The cold and very cold climate region may have been higher due to a higher electric heat load.

It must be remembered that mean power intensity differs greatly from the power intensity during peak consumption. For example, the power demand for air conditioning load is high during summer months and will peak in the afternoons especially on hot days. In climate zones with higher numbers of degree cooling days, air conditioning loads tend to have a higher power density demand. A building located in a hot climate has relatively few heating degree days; furthermore, energy for heating in any climate may be provided by another energy source, such as natural gas. A building might be designed with a high demand power density for air conditioning load with no or low electric power requirements for heating. A building in a cold climate might be designed for a low air conditioning power density but is might have no, low or high electric power requirements for heating, depending on the energy source(s) for heat.

Figure 14 shows the percentages of energy sources meeting the energy needs of commercial buildings by different census regions of the country. The South has the highest percentage of energy supplied by electricity (70%) and the lowest percentage of energy supplied by natural gas (24%). In the West, 60% of the energy is supplied by electricity, followed by 54% and 52% in the Midwest and Northeast, respectively. In contrast, the Midwest has the highest percentage of natural gas (41%), and the Northeast has the highest percentages of fuel oil (6%) and district heat (8%). In the 2012 CBECS, fuel oil is specified as distillate fuel oil, diesel, and kerosene; district heat is specified as steam or hot water from a utility or a campus central plant.

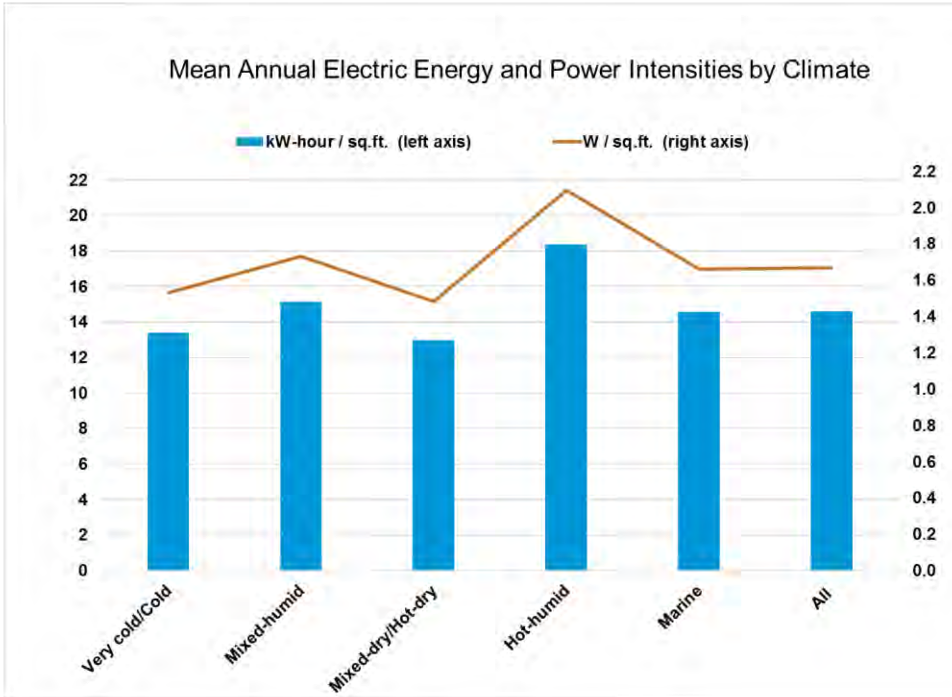


Figure 13. Mean Annual Electric Energy and Power Intensities Categorized by Climate
(Data Source: Table C13 in [5])

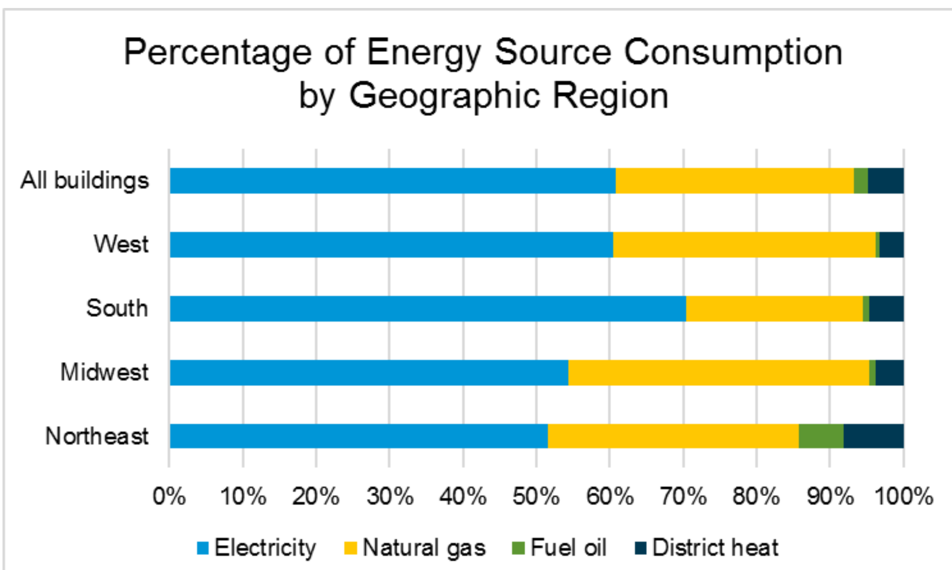


Figure 14. Percentage Energy Source Consumption Categorized by Geographic Region
(Data Source: Table C1 in [5])

Figure 15 shows that commercial buildings in the South also had the highest energy and power intensities at 16.1 kW-hours and 1.8 W per square foot in 2012. However, higher energy and power intensities do not necessarily imply that a higher percentage of the energy supplied

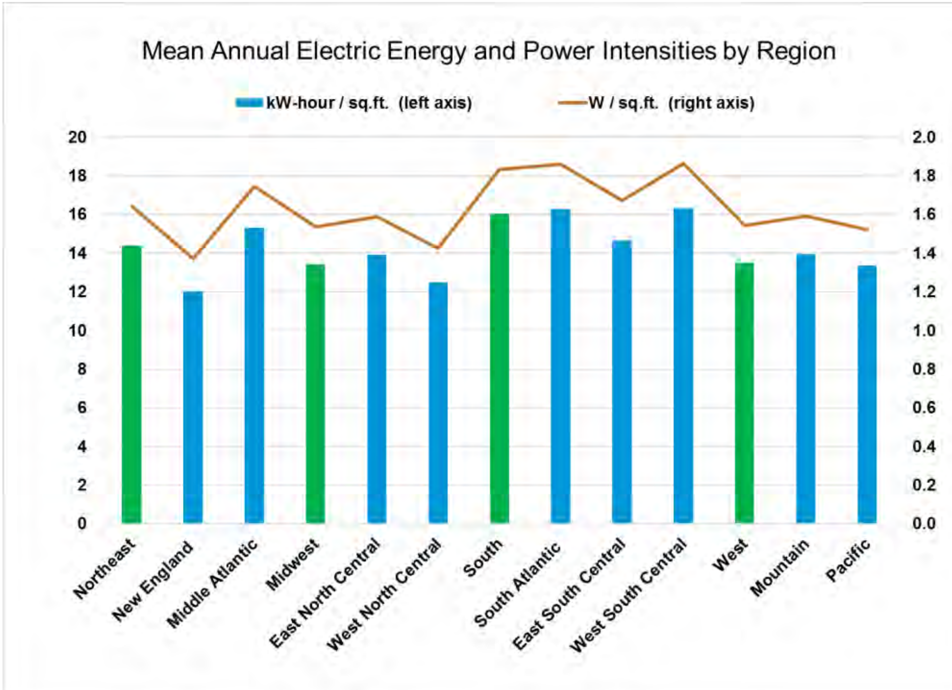


Figure 15. Mean Annual Electric Energy and Power Intensities Categorized by Region
(Data Source: Table C13 in [5])

to a building is in the form of electricity. Commercial buildings in the Northeast had the second highest electric energy and power intensities of 14.4 kW-hours and 1.6 W per square foot; in the Northeast, electricity also accounted for the lowest percentage of energy consumption by source. In Figure 15, the green columns represent the census regions and the blue columns to the right represent the subdivisions of the region.

2.4 Commercial Building Energy Usage by Building Type [5]

Figure 16 shows percentages of energy sources meeting the energy needs of commercial buildings by building type. Food sales, non-mall retail, and offices led in the highest percentage of energy needs met by electricity (79%, 77%, and 70%, respectively); not surprisingly, food sales, non-mall retail, and offices also had the lowest percentage of energy needs met by natural gas (20%, 20%, and 23%, respectively). Food sales buildings have a large refrigeration load. The highest consumers of district heat as a percentage of total energy are public assembly (13%), inpatient healthcare (11%), education (8%), office (6%), and lodging (5%).

By commercial building type, Figure 17 shows that food sales, food service, and inpatient healthcare require the most electricity per square foot of floor space. In 2012, their electric energy consumption was 48.7, 45.0, and 31.0 kW-hours per square foot, respectively. In comparison, offices consumed 15.9 kW-hours per square foot, and the electric energy intensity of all commercial building types was 18.4 kW-hours per square foot.

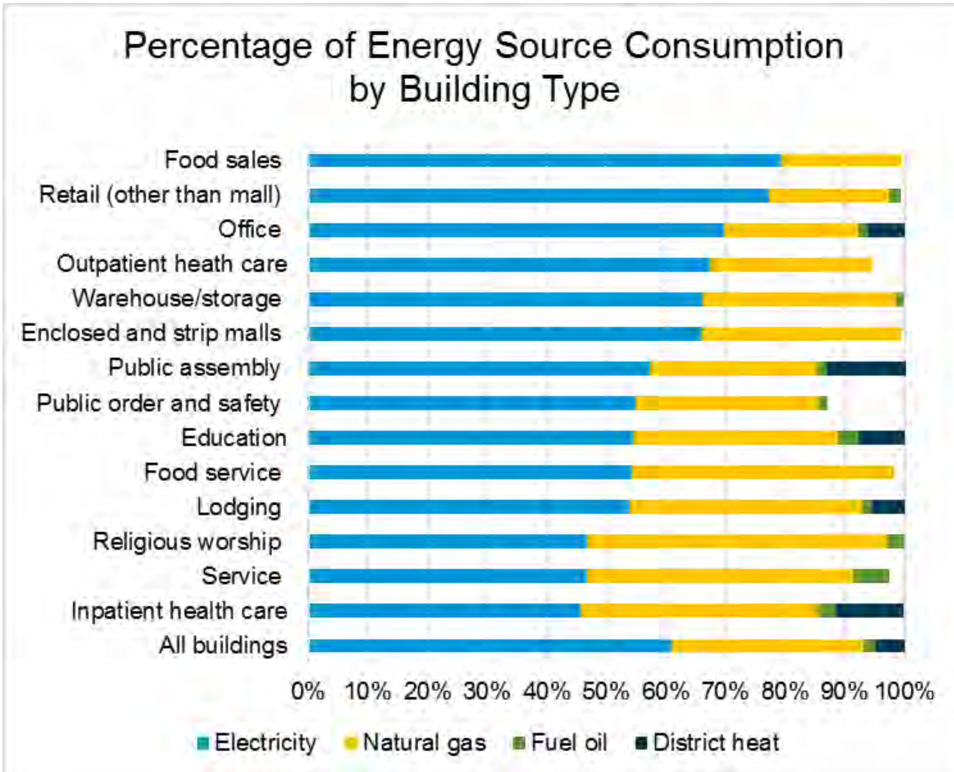


Figure 16. Percentage of Energy Source Consumption Categorized by Building Type
(Data Source: Table C1 in [5])

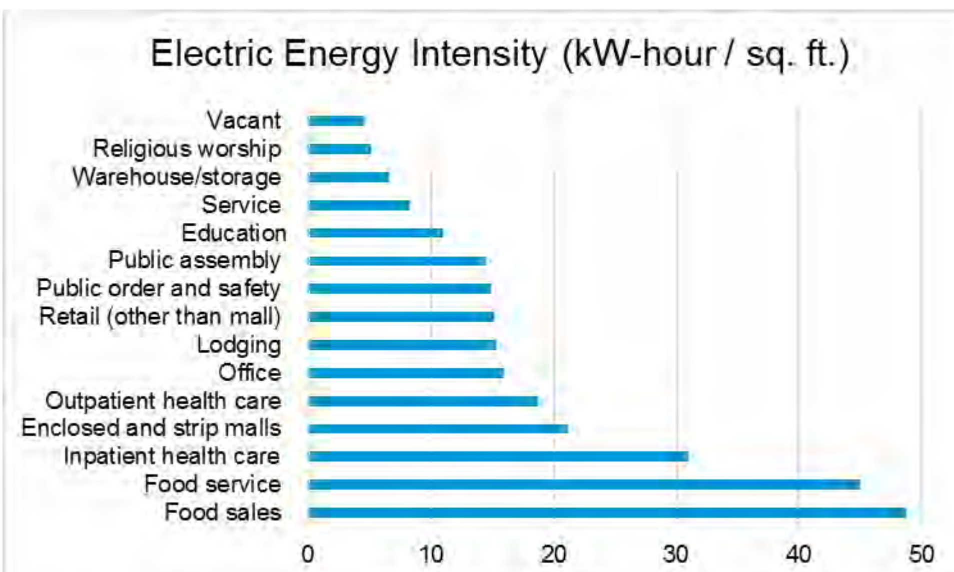


Figure 17. Electric Energy Intensity Categorized by Commercial Building Type
(Data Source: Table C13 in [5])

The mean electric power intensity for each building type in 2012 is displayed in Figure 18. As discussed earlier, the mean power intensity differs greatly from the demand power intensity; furthermore, these quantities differ from the power densities for which a building is designed. The power intensity of a building will change throughout the day to maintain thermal comfort, to adequately illuminate the spaces within the building, and to supply the electrical equipment so that employees can conduct their work activities and the building can achieve its function.

In most building types, the power intensity depends on the function of a building and the building's operating hours. The mean operating hours for the various types of commercial buildings was shown in Figure 9. Although long operating hours suggest long hours of adequate illumination and electrical equipment and device usage, long operating hours do not necessary result in high electric energy and power intensities. Figure 9 indicates that all inpatient healthcare and most lodging operate 24 hours a day, seven days a week. However, as Figure 18 shows, inpatient healthcare had a mean electric power density 3.5 W per square foot, but lodging was only 1.8 W per square foot.

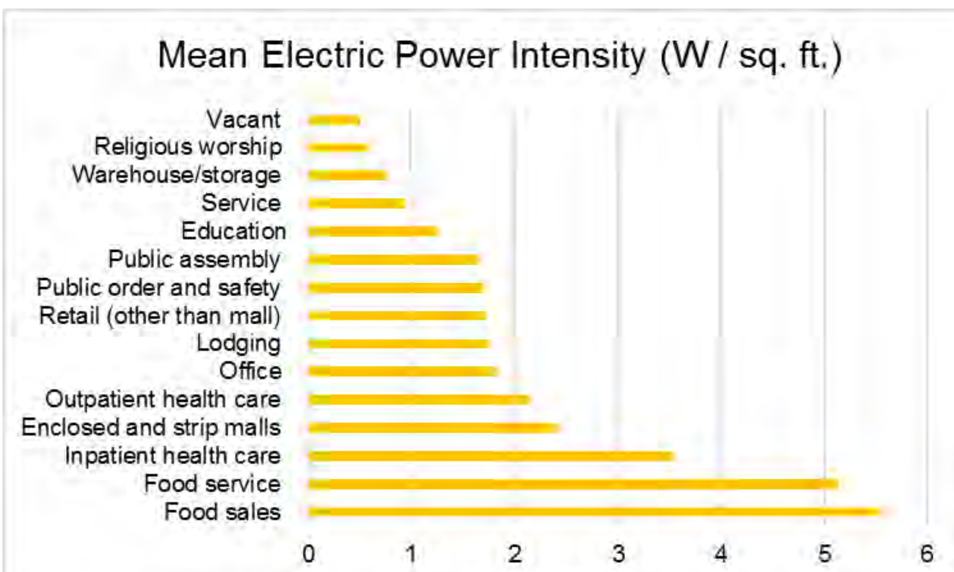


Figure 18. Electric Power Intensity Categorized by Commercial Building Type
(Data Source: Table C13 in [5], Note on terminology[5])

[5] The 2012 CBECS data and documentation classified commercial healthcare building types as "Inpatient health care" and "Outpatient health care" and the graphs in this report reflect the CBECS spelling. Various web sites delve into the correctness and usage of the terms "health care" and "healthcare." In response to a sponsor comment, the report author has used the term "healthcare" in the body of the report.

2.5 Electric Utility Commercial Building Loading

Figure 19 displays the average electric power intensity of various types of commercial buildings calculated from information released by Austin Energy in a public hearing [6]. The power intensities in Figure 19 are notably higher than those in Figure 18. One reason might be that the table produced by Austin Energy may be representative of buildings in the Austin, Texas area, a warm, humid climate with only 1,661 degree heating days in the last twelve months.[6] In Figure 19, restaurants and food stores account for the highest average loads ranging from 9.2 to 12.4 watts per square foot. Likewise, the 2012 CBECS found that food sales and food service (i.e., restaurants) had the highest mean electric power intensities, but the intensities were only 5.6 and 5.1 watts per square foot, respectively. Hospitals had the third

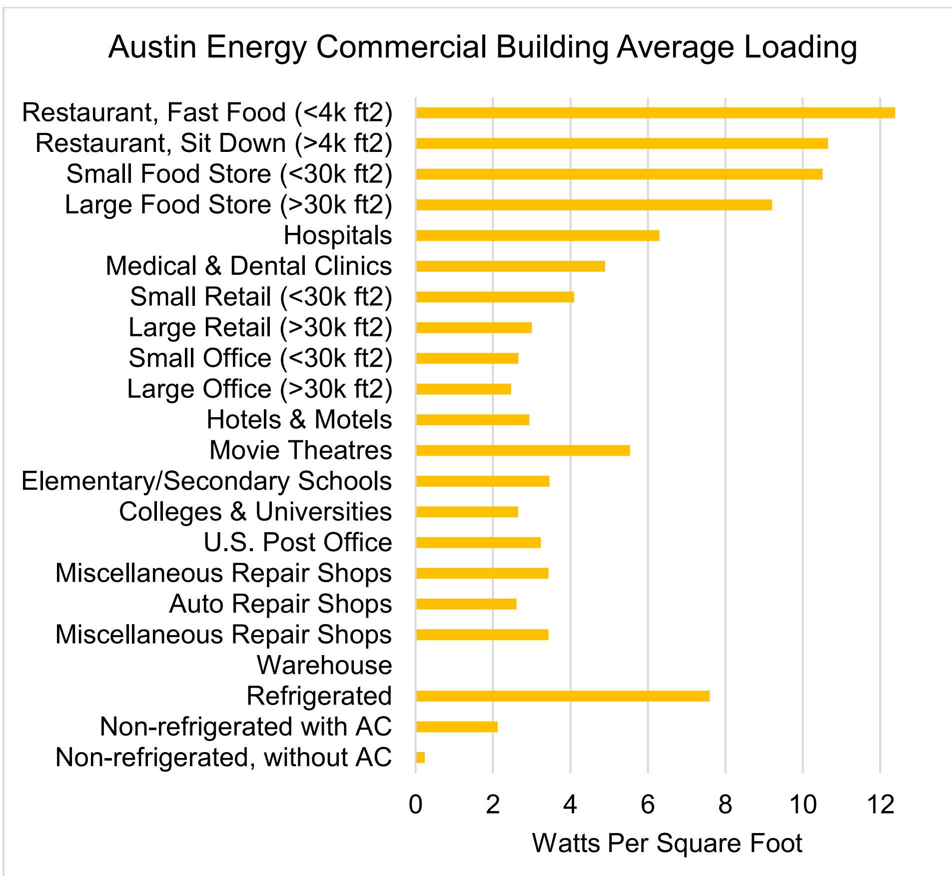


Figure 19. Austin Energy - Commercial Building Average Electric Power Intensity
(Data Source: [6])

[6]Calculated on the website www.degreedays.net using from data taken October 1, 2015 through September 30, 2016 at the Austin-Bergstrom International Airport.

highest electric power intensities in Figures 18 and 19; the 2012 CBECS was 3.5 watts per square foot, while Austin Energy was 6.3 watts per square foot. However, there was less deviation in office buildings. Austin Energy found that office building loading was 2.5 to 2.7 watts per square foot and the 2012 CBECS was 1.8 watts per square foot.

3 BUILDING END-USE LOADS AND ELECTRICITY CONSUMPTION

3.1 End-Use Load Types and CBECS Models [5]

The 2012 CBECS included estimations of the end-use consumption by energy source, including electricity.[7] The estimations were determined from end-use models based on equations and parameters found in ASHRAE, Illuminating Engineering Society of North America (IESNA), and other standard engineering handbooks. Up-to-date parameters were also taken from large-scale field studies of commercial buildings.

The engineering estimations were calibrated by cross-section regression models where the estimations were fit based on consumption per square foot. Where possible, the regression models were reconciled with a building's known energy consumption. The reconciliation ratio was applied to the modeled end-use estimates.

- Space Heating and Cooling

The models estimated the total energy needed for space heating and cooling. The amount of electric energy required to meet the heating and cooling energy needs was determined from equipment type and estimated efficiency. The calculations account for the building heat losses and gains as a function of conductance and annual heating and cooling degree days, based on the thermal properties of the roof and wall materials. The energy models also included the ventilation heat loss or gain as a function of external air volume brought into the building daily, the temperature difference between the inside and outside air, and the heat capacity of the air.

- Ventilation

  The model estimated supply and return fan energy use based on external air ventilation volumes. Variable-air-volume factors were estimated by climate zone. Static pressure differences were accounted for by system type and by floor space.

---

[7] Details released on March 12, 2016 about the CBECS end-use consumption estimates are summarized in this section. The estimation models were described on the following website: http://www.eia.gov/consumption/commercial/estimation-enduse-consumption.cfm.

- Water Heating

  Water heating was estimated based on 1) equipment type and efficiency; 2) building type and size; and 3) ground water temperature.
- Lighting

  The model estimated the electric energy required to supply interior and exterior lighting fixtures. Interior lighting calculations included: 1) the efficiency (in lumens per watt) of lamp system types used in building; 2) the recommended average illuminance levels by building type; and 3) average building operating hours.
- Cooking

  The model was based on the number and types of cooking equipment reported in the CBECS and the 2005 California Commercial End-use Survey (CEuS) sponsored by the California Energy Commission.
- Refrigeration

  The model factored in the reported number of refrigeration units but was primarily based on the CEuS intensity estimates and the building type.
- Computer and Office Equipment

  Electricity consumption for office equipment in all building types was estimated. Computer equipment included personal and laptop computers, monitors, servers, and data centers. Other office equipment included copiers, printers, fax machines, cash registers, and video displays.
- Other

  "Other" end-use equipment supplied by electricity was based on floor space and CEuS intensities for miscellaneous, process equipment, motors, and air compressors.

3.2 CBECS End-Use Load Consumption [5]

Figure 20 illustrates the end-use percentages of electricity consumption in commercial buildings. Lighting, ventilation, refrigeration, and cooling loads accounted for 64% of the electricity consumed in commercial buildings. Computing and office equipment accounted for 14% of the end-use electricity consumption.

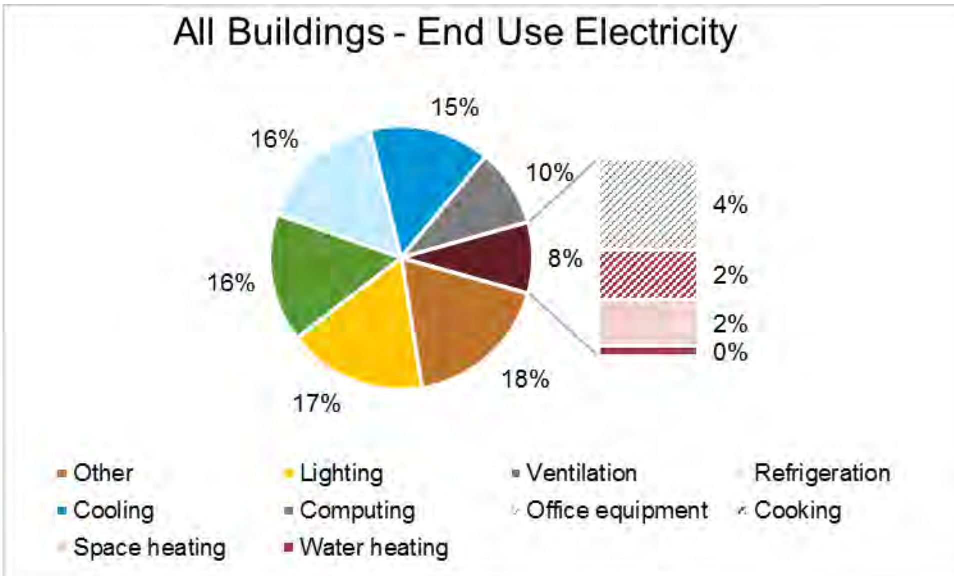


Figure 20. Percentage End-Use Electricity Consumption for All Commercial Buildings
(Data Source: Table E5 in [5])

Figures 21 and 22 show that electricity end-use consumption depends greatly on building type. At 70% and 40%, respectively, food sales and food service buildings lead in the highest percentage of refrigeration load. In contrast, refrigeration accounts for 3% of electricity consumption in office buildings. Outpatient and inpatient healthcare, public order and safety, public assembly, and office buildings have the highest percentages of air conditioning and ventilation load, ranging from 42% to 38%. In warehouse and storage and service buildings, lighting load accounts for 30% of the electricity consumption in the building; in comparison, the lighting load accounts for 16% to 18% of electricity consumption in offices, education, and healthcare buildings. Computing and office equipment account for high percentages of electricity consumption in office, education, lodging, and outpatient healthcare, at 24%, 22%, 17%, and 15%, respectively. Cooking accounts for 16% of electric energy usage in food service, followed by 5% in food sales and 3% in lodging.

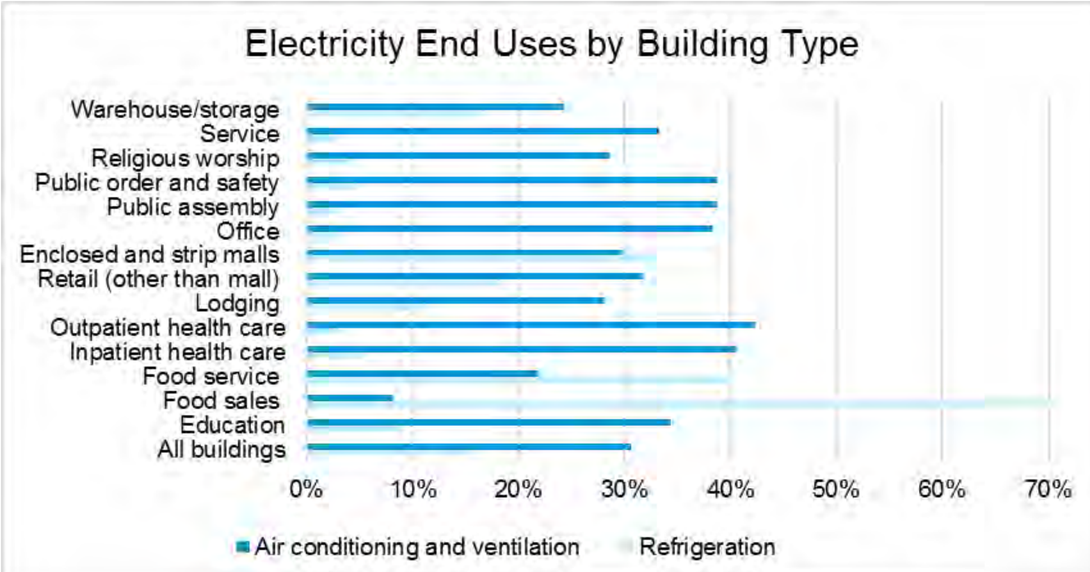


Figure 21. AC and Ventilation and Refrigeration Electricity Consumption by Building Type
(Data Source: Table E5 in [5])

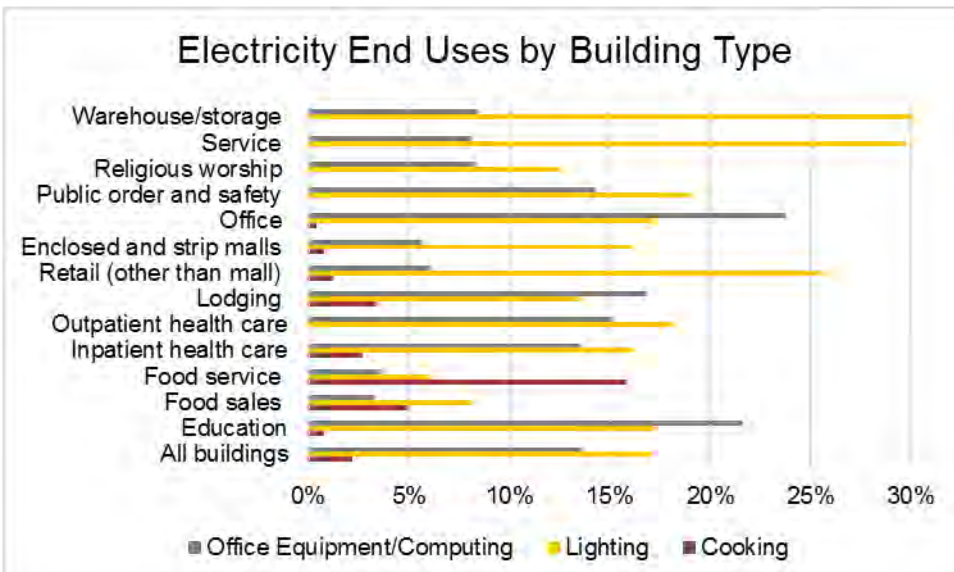


Figure 22. Office Equipment/Computing, Lighting, and Cooking Consumption by Type
(Data Source: Table E5 in [5])

The electric energy intensities for end-use equipment are shown in Figures 23 and 24 for various building types. Food sales and food service buildings had the highest intensities of refrigeration at 34.3 and 18.1 kW-hours per square foot; this is not surprising since refrigeration accounted for the highest percentage of electricity consumption (70% and 40%) in those building types. However, a high percentage of specific end-use consumption does not necessary imply a high electric energy intensity for that load. In enclosed and strip malls, refrigeration equipment accounted for 33% of electricity consumption, but its energy intensity was only 7.0 kW-hours per square foot. As shown in Figure 17, food sales and food service buildings had high electric energy intensities (48.7 and 45.0 kW-hours per square feet), but the density was much lower in enclosed and strip malls (21.1 kW-hours per square foot).

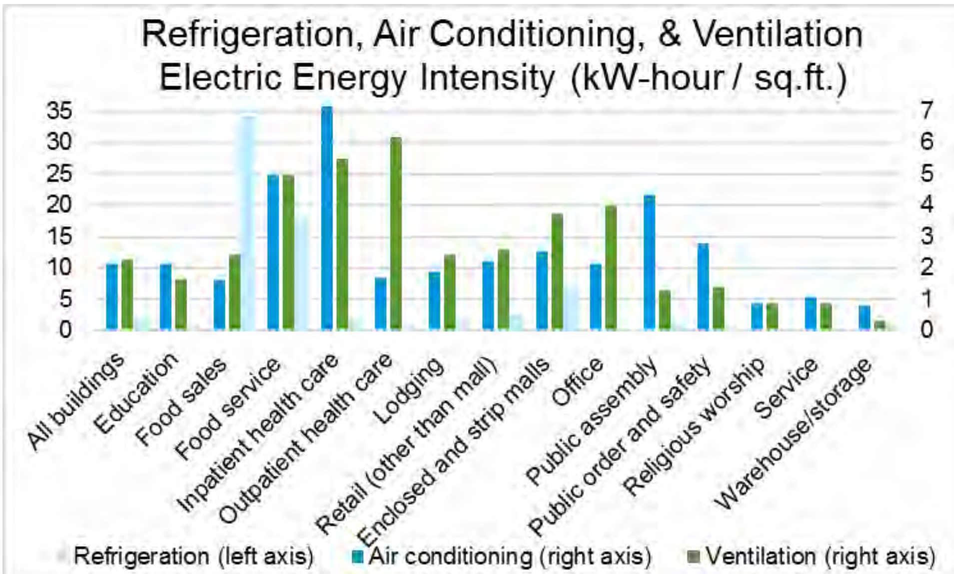


Figure 23. Refrigeration, AC and Ventilation Electric Energy Intensity by Building Type
(Data Sources: Tables C1 and E5 in [5])

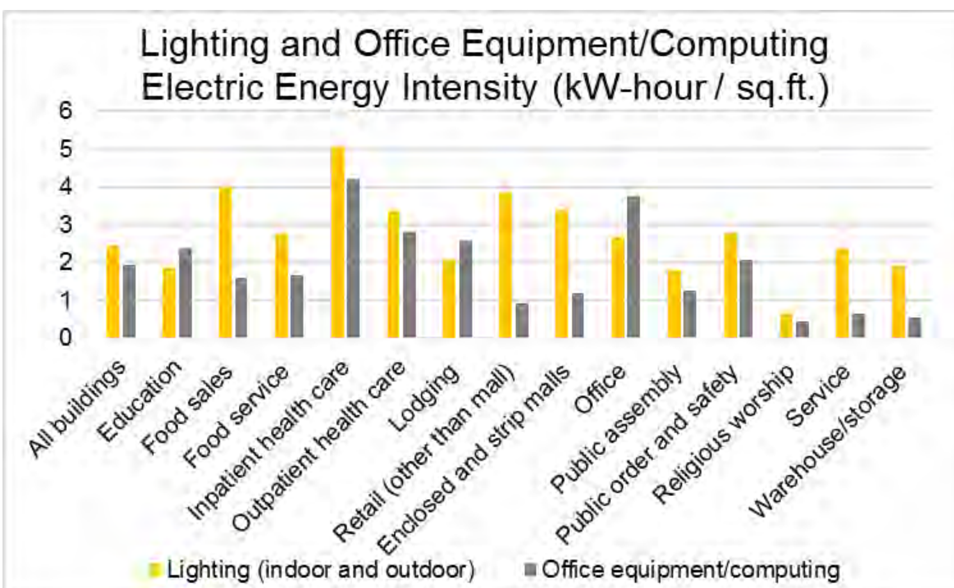


Figure 24. Lighting and Office Equipment/Computing Electric Energy Intensity by Type
Figure 24 (Data Sources: Tables C1 and E5 in [5])

Inpatient healthcare and food service had the highest air conditioning electric energy intensities of 7.2 and 5.0 kW-hours per square foot, and the second highest ventilation electric intensities of 5.5 and 5.0 kW-hours per square foot. In comparison, the air conditioning and ventilation electric energy intensities in office buildings were 2.1 and 4.0, respectively. The ventilation electric energy intensity was 2.3 kW-hours per square foot for all buildings, slightly higher than for air conditioning at 2.1 kW-hours per square foot.

The type of lighting system, illumination level required, and operating hours of the building type determined the lighting energy intensity. Inpatient healthcare and food sales had the highest electric energy intensities for lighting, 5.1 and 4.0 kW-hours per square foot. In comparison, office and warehouse/storage lighting had electric energy intensities of 2.7 and 1.9 kW-hours per square foot, which represented 17% and 30% of the building type's total electricity consumption, respectively.

With respective electric energy intensities of 4.2 and 3.8 kW-hours per square foot, inpatient healthcare and offices had the highest demand for computing and office equipment. Outpatient healthcare, lodging, and education followed with intensities between 2.8 to 2.4 kW-hours per square foot.

Refrigeration, air conditioning, and ventilation loads operate continuously, although power demand may greatly fluctuate throughout the day (and seasonally). Figure 25 illustrates the mean annual power intensities of these loads.

Power demands for indoor lighting will be high when the commercial building is operating. The indoor lighting demand is expected to be much lower when the building is not in operation, but some illumination is still required for life safety and security reasons. Outdoor lighting is more dependent on the season and will illuminate during dark hours. Power demand for computing and office equipment is high during business hours, but some computing and office equipment may be energized all the times. The mean annual power intensities of the lighting and computing and office equipment for commercial office buildings is listed in Table 3. Table 3 also displays the average power intensity if the lighting and computing and office equipment loads were energized only during building operating hours. As illustrated in Figure 9, the mean number of operating hours for office buildings was 55 hours per week in the 2012 CBECS.

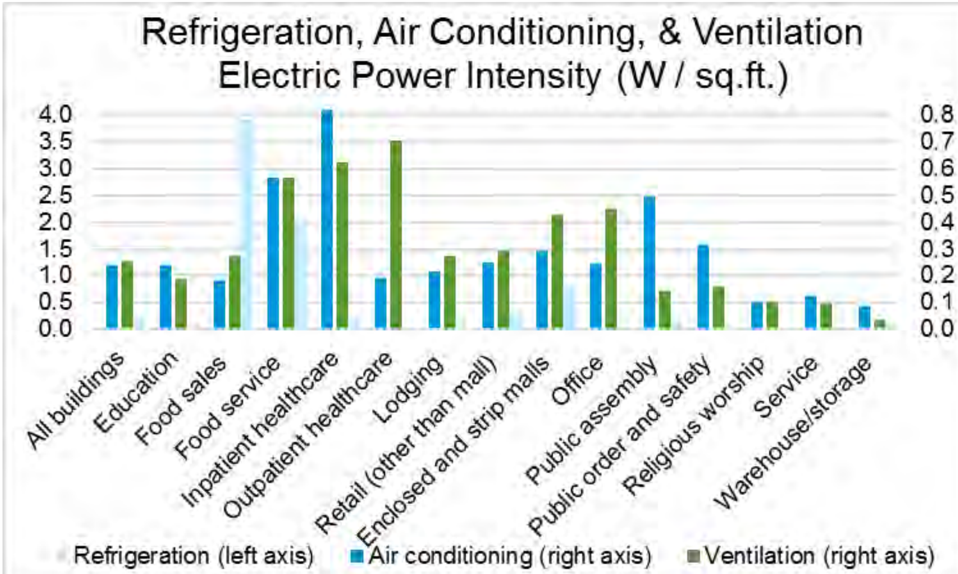


Figure 25. Refrigeration, AC and Ventilation Electric Power Intensity by Type
(Data Sources: Tables C1 & E5 in [5])

Table 3. Estimated Mean Power Intensities (W/ft^2) for Commercial Office Buildings*

End-Use Equipment	Continuous Operation	55 Hours Weekly
Lighting	0.31	0.94
Computing and Office Equipment	0.43	1.32

*Power intensities calculated from data in Tables B1, C1, and E5 in [5].

3.3 Miscellaneous Electric Loads in CDM[8] and Elsewhere

Miscellaneous electric loads (MELs) are usually defined as “the loads outside of a building’s core functions of heating, ventilating, air conditioning, lighting, and water heating…Taken across the entire commercial building sector, MELs now account for roughly 30% of total energy use [7].” Limited studies conducted by Pacific Northwest National Laboratory (PNNL) determined the energy consumption for bank branches in a cold climate was: 45% for interior and exterior lighting, 23% for HVAC, and 32% for MELs [7].

In an earlier report section, Figure 20 illustrated that computers and other office equipment and “other” loads accounted for 32% of commercial building electricity consumption. Figure 14 illustrated the electricity accounts for 61% of energy consumption in all commercial buildings. Based on the mean data from the 2012 CBECS, it might be concluded that MELs

[8] CDM is the Commercial Demand Module of the National Energy Modeling System (NEMS) used by the Energy Information Administration (EIA), a section of the U.S. Department of Energy (DOE).

account for roughly 20% (32% x 61%) of total energy consumption in commercial buildings. The PNNL findings suggest that the data produced from CBECS may underpredict the actual MEL energy consumption, at least in some building types. Although CBECS collects some information on minor end-use equipment, the survey focuses on equipment stock and energy consumption of major end-use equipment. “Given the dispersed and increasingly varied nature of this equipment and appliances [MELS], stock, usage, and consumption data can be difficult to obtain [8].” The NEMS Commercial Demand Module (CDM) projects MEL energy consumption based on unit energy consumption and total stock for each MEL.

The U.S. Energy Information Administration contracted Navigant Consulting, Inc. and SAIC to update and to project MEL energy consumption data for incorporation into NEMS. In 2013, Navigant reported on the estimated number of thirteen miscellaneous electric loads installed in the U.S. and their estimated energy consumption. Table 4 lists the thirteen MELs and the unit and total annual energy consumption for each MEL during 2011. Commercial electricity consumption was 1,319 TW-hours in 2011 [8]; therefore, the MELs selected in the Navigant study represent an estimated 15% of the total electricity consumed by the commercial sector in 2011.

The thirteen commercial miscellaneous electric loads in Tables 4 and 5 were selected in a two-stage process beginning with 173 residential and commercials MELs. The initial commercial list included:

- non-road electric vehicles coffee makers elevators escalators
- other medical equipment fitness equipment office equipment arcades
- automated teller machines (ATMs) water purification/treatment loads fume hoods

During the initial screening, 38 commercial MELs were identified that had significant energy consumption and needed better characterization. Five of these prospective MELs and their estimated energy consumption are also included in Table 4. Other miscellaneous electric loads that were not selected included kitchen equipment (ovens, steamers, griddles, fryers, and broilers) with a significant combined annual energy consumption equal to 39.1 TW-hours [8].

When data was available for the thirteen selected MELs, usage was characterized, and energy consumption was estimated based on power draw in different states (active, sleep, or off). Table 4 also lists the power drawn during the active state. Power consumption is a composite and represents average unit consumption in the U.S. For medical equipment and kitchen ventilation equipment, sub-products were analyzed individually and energy consumption for a composite unit was calculated.

Table 4. Navigant MELs - Total & Unit 2011 Energy Consumption and Active Power Draw

Selected MELs	Total Energy (TWh)	Installed Units (thousands)	Unit Energy (kWh)[1]	Per Unit Active State (W)[1]
Distribution transformers	43	5,470	7,900	
Kitchen ventilation	41	790	52,000	8,071
Desktop computers	30	74,000	400	64
Servers in data centers	29	12,200	2,400	269
Monitors for PCs & laptops	18	93,000	198	38
IT equipment (routers, hubs, switches, security)	12	487,000	25	3
Commercial security systems	7.4	11,000	2500	290
Water distribution equipment*	6.6			
Lab refrigerators & freezers	4.5	1,000	4,500	975
Medical imaging equipment	2.7	178	15,000	22,774
Laptops (including netbooks)	2.1	63,000	34	21
Large video displays (>30") for advertising/entertainment	1.7	1,600	1,084	246
Large video boards for stadiums and arenas	0.2	1	152,000	190,000
Total	198.2			
Other Prospective MELs				
Ice makers/machines	11	2,600,000		
Printers	11	34,000,000		
Vending machines	11	6,600,000		
Televisions	3.8	16,000		
Irrigation systems	3.6			

[1]Appendix G in [8]; *external to the buildings and provided by the public water distribution system.

Most MELs listed in Table 4 were found in all the NEMS CDM building type categories identified later in Table 15. For some MELs, such as distribution transformers and security systems, MEL usage spread across all building types. For many MELs, usage predominated in a small number of building types. By definition, servers in data centers are located only in data centers. Large format video boards are only located in stadiums and arenas. Medical equipment is only located in inpatient healthcare facilities and small offices (outpatient healthcare) based on the 2003 CBECS building type definitions used in the NEMS CDM. Table 5 displays the energy consumption of each Navigant MEL in the predominant building type(s) as a percentage of the total energy the MEL consumes in all commercial building types.

Low-voltage distribution transformers (LVDT), on the customer-side of the utility meter, used 43 TW-hours of site electricity in 2011. The distribution transformer total and unit energy consumption in Table 4 is based on a composite of three transformer sizes listed in Table 6.

The number of transformers was based on the total electricity supplied to the building for other than HVAC and refrigeration loads. The analysis was based on a 1999 study done by the Cadmus group and the U.S. Department of Energy rulemaking engineering analysis[9]. Low-voltage distribution transformers topped the Navigant MEL list in energy consumption, but all transformer energy consumption represents energy loss. Unlike other MELs, transformers are not “end-use” loads; transformers are electrical equipment changing the supply voltage to a voltage that can be utilized by the end-use equipment. Navigant acknowledged that low-voltage distribution transformer losses “are highly dependent on site-specific sizing and site-specific loading profiles.” [8]

Table 6 provides the energy consumption of subcategory equipment for distribution transformers, servers in data centers and medical imaging equipment. Table 6 also includes the annual per unit mean power for the distribution transformers and data center servers. Although kitchen ventilation equipment was not included in the table, it was subdivided by small, medium, and large exhaust fan capacity. Commercial security systems largely consist of video surveillance, physical access control, and intruder and fire detection. Electronic article surveillance systems are typically found in retail and some food sales stores. The power consumption of commercial security systems depends on system type and on building size and type. The subcategory equipment for these MELs was used to develop their composite profiles.

Table 5. 2011 MEL Percentage Energy Consumption by Predominant Building Category

Selected MELs	% Energy Consumption[1]	Predominate NEM CDM Building Category
Distribution transformers	28	Mercantile and service
Kitchen ventilation	84	Education, food sales, and food service
Desktop computers	68	Education; Large office; Small office
Servers in data centers	100	Other
Monitors for PCs & laptops	72	Education; Large office; Small office
IT equipment	72	Education; Large office; Small office
Commercial security systems	---	No predominant building type
Water distribution	20	Warehouse
Lab refrigerators & freezers	100	Education; Healthcare; Other
Medical imaging equipment	100	Healthcare; Small office
Laptops (including netbooks)	67	Education; Large office; Small office
Large video displays (>30”)	41	Mercantile and service
Large video boards	100	Assembly
[1]Calculated from Appendix B in [8]		

[9] Federal Register / Vol. 77, No. 28 / Friday, February 10, 2012 / Proposed Rules 10 CFR Part 431, Energy Conservation Program: Energy Conservation Standards for Distribution Transformers.

Table 6. Subcategory MEL Equipment used in Composite Profile (Annual Basis for 2011)

Selected MELs	Total Energy (TWh)	Installed Units (thousands)	Unit Energy (kWh)	Annual Mean Per Unit Power (W)
Distribution transformers	43	5,470	7,900	902
25 kVA, 1 phase		600	2,200	251
75 kVA, 3 phase		4,100	6,600	753
300 kVA, 3 phase		800	19,200	2,192
Servers in data centers	29	12,200	2,400	274
Volume servers		11,800	2,000	228
Mid-range servers		340	8,000	913
High-end servers		38	50,500	5,765
Medical imaging equipment*	2.7	178	15,000	
MRI		12	111,000	
CT Scan		13	42,000	
Xray		78	9,500	
Ultrasound		75	760	
*Does not include approximately 140,000 dental X-ray and 48,000 mammography machines. Estimation based on seven days per week and may not be consistent with many locations.				

3.4 Receptacle and Plug and Process Load Studies

Different researchers use the acronym MELs in related but somewhat different contexts. "Miscellaneous electric loads" often cover a wide variety of equipment which does not fall under one of the main end-use load categories: heating, air conditioning, ventilation, refrigeration, water heating, lighting, and cooking (considered as an MEL in the Navigant study). Computer and office equipment are usually considered as an MEL, although the EIA NEMS commercial demand module (discussed in Section 4) categorizes it separately. Government sponsored research has been conducted on how to reduce the power consumption associated with receptacle load, referred to as "plug load." Unlike major end-use loads which are hard-wired, the receptacle load has not historically been regulated by building energy conservation codes. In this context, the acronym MELs refers to "miscellaneous and electronic loads," often referring exclusively to the receptacle load.

3.4.1 Lawrence Berkeley National Laboratory Office Receptacle Study

Researchers at Lawrence Berkeley National Laboratory (LBLN) conducted a study of plug-in loads in an office building on site [9]. The 89,500 square feet office building was inhabited by 450 workers. A total of 4,454 plug-loads were inventoried. From the total inventory, 455 plug-loads were carefully chosen to represent the plug-load usage in the building and were monitored for a minimum of six months, up to 16 months. The plug-loads were connected directly to meters which plugged into the receptacle outlets. Every ten seconds average power measurements were collected via a wireless metering system.

The categories for the inventoried devices and their percentage of the total 423 MW-hours estimated annual energy use is displayed in Figure 26. The *miscellaneous HVAC* category included fans and portable heaters. It is interesting to note that the *other* category, which included water coolers, accounted for 38% of the plug-in devices but less than 9% of energy use. The *imaging* category included copiers, facsimiles, printers, multi-machines, and scanners. Standard office and computer equipment categorized under *imaging*, *networking*, *displays*, and *computers* accounted for only 43% of the plug-in devices but 78% of energy use; computers alone accounted for over 50% of energy use. The *appliance* category (2.8% energy use) was included in the study because appliances are outside the business function of an office building.

The study concluded that metering for a two-month period would have provided a reasonable accurate estimate of annual energy consumption for most load categories. For categories such as miscellaneous lighting, in which usage might be impacted by seasons, longer metering periods are needed for better estimations. The LBLN study found the average power densities for the plug-loads were 1.1 W/ft^2 during the day and 0.47 W/ft^2 at night. Furthermore, the LBLN study estimates that plug loads account for 15% of building primary energy use in the United States, a much lower estimate than the PNNL study mentioned in Section 3.3.

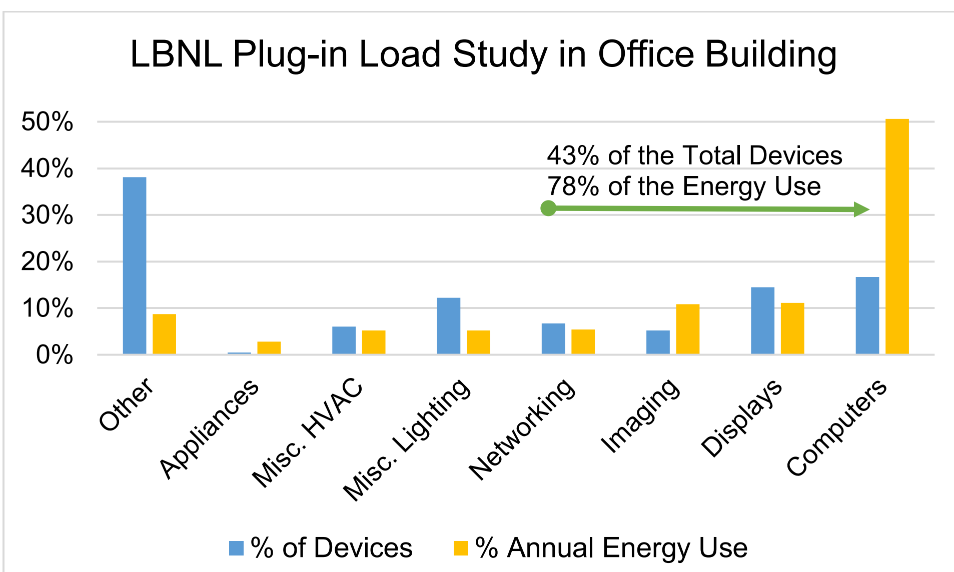


Figure 26. Plug Load Office Building Study at Lawrence Berkeley National Laboratories
(Data Source: [9])

3.4.2 University of Idaho & California PIER Studies on Receptacle Load Power

The University of Idaho conducted a study on six office buildings in Boise, Idaho to characterize the receptacle load profile and to explore the efficacy of different intervention techniques to reduce the energy consumption of plug loads [10]. Data logging equipment was placed at the panel feeders to record true power and energy consumption at fifteen-minute intervals. In panels with circuits supplying other load types, current loggers were used to record current which was subtracted from the total current load of the panel. In some panels with only a few receptacle loads, the circuits supplying the receptacles were monitored directly.

Data was collected for fifteen months, and loggers were downloaded every two to three months. The most common problem was data logger battery failure. On four sites, data was collected for three months before energy reduction interventions occurred. Baseline data was collected for twelve months before intervention on one site and the last site had no intervention.

The results of the University of Idaho study have been summarized in Table 7. Some of the less common receptacle loads included fountain pumps, handheld vacuums, massage chairs, and humidifiers. Two heaters were plugged in at one site and six at another. Fans were found on four sites.

Table 7. Summary of Results in University of Idaho's Receptacle Load Study*

Office type	Land records	World wide logistics	Architect	Elections office	Regulatory agency	Investment analytics
Square feet (ft^2)	4,544	13,688	1,288	1,550	13,072	13,688
FT employees*	31	94	6	7	49	100
FTE* / ft^2	147	146	215	221	267	137
Total plug devices	216	359	50	67	275	392
Devices / 100 ft^2	4.8	2.6	3.9	4.3	2.1	2.9
Devices / FTE	7.0	3.8	8.3	9.6	5.6	3.9
Weekdays						
Average W/ft^2	0.87	0.36	0.84	0.36	0.48	1.75
Peak Hours	6am-6pm	7am-6pm	8am-5pm	7am-5pm	8am-5pm	7am-6pm
Peak kW	6.25	10.5	1.5	1.25	9.5	28
Unoccupied kW	2.75	2.0	0.75	0.25	4.75	22
Peak* W/ft^2	1.38	0.77	1.16	0.81	0.73	2.05
Unoccupied* W/ft^2	0.61	0.15	0.58	0.16	0.36	1.61

*FTE is full-time employees. Data found in [10]. Peak and unoccupied W/ft^2 have been calculated from the peak and unoccupied kW provided in the University of Idaho report.

Other studies have found similar ranges of receptacle power density usage in office buildings. The results in Table 8 were presented by the New Buildings Institute in 2012 for the California Public Interest Energy Research (PIER) Program [11]. Table 8 includes average daytime, average night, and peak power densities for five office buildings in California and British Columbia. The peak to average daytime power density ratios varied from 1.33 (Vancouver) to 2.25 (Irvine Site 3). Average daytime lighting power densities, also included in Table 8, ranged from 0.2 W/ft^2 to 0.5 W/ft^2 and varied between average daytime receptacle power density (Rosemead) to only 20% its value (Los Angeles). The lighting power densities can also be compared with the lighting power allowances and minimum lighting power densities included in Section 5 on energy conservation codes and Section 6 on engineering practices.

Table 8. New Buildings Institute Receptacle and Lighting Load Office Study [11]

Office Location	Irvine CA Site 1	Irvine CA Site 2	Rosemead CA	Los Angeles CA	Vancouver BC
Square feet (ft^2)	8,328	1,500	16,500	8,024	9,000
Lighting Average Daytime W/ft^2	0.2	0.4	0.5	0.3	0.5
Plug Load Weekdays					
Average Daytime W/ft^2	0.8	0.8	0.5	1.5	0.6
Peak W/ft^2	1.6	1.8	0.7	2.1	0.8
Average Night W/ft^2	0.4	0.6	0.3	1.46	0.3

3.4.3 NREL Study on Plug and Process Load Power Density and Other Work

The National Renewable Energy Laboratory (NREL) conducted a study on the “plug and process” loads (“PPL”), which they defined as all loads other than heating, ventilation, air conditioning, and lighting. Buildings which had disaggregated plug and process were selected for the study. Submetering equipment was in already place for all buildings except the DOD and GSA offices. Tables 9 through 11 present the study results of plug and process load densities in buildings ranging from over 18,000 square feet to 365,000 square feet. The office power densities in Table 9 were measured from the four government offices of the Department of Defense (DOD), National Renewable Energy Laboratory (NREL), and General Services Administration (GSA). The buildings in Table 10 represent higher education buildings at Stanford University; the buildings contain classrooms, meeting areas, and faculty offices. The average ratios of peak to average power densities for the offices in Table 9 and the higher education buildings in Table 10 were 2.03 and 2.30, respectively [12].

Table 11 provides average power density of the plug and process load for ten offices. Note that the 0.64 W/ft^2 average density for the single corporate tenant with kitchen was fairly low in comparison with the two highest densities of 1.17 and 2.27 W/ft^2. The highest plug and process load power density was measured at the office of a single corporate tenant with laboratories.

It should also be noted that office buildings, as well as other buildings, house various space types. For example, the U.S. Navy office building (DOD) included in Table 9 contains a library, private offices, office areas with cubicles, two conference rooms, three kitchens, hallways, a print room, a mail room, and a reception area. The plug and process load densities in these different spaces may vary.

Table 9. Plug and Process Load Power Densities of Four Government Offices

Government Office Building	Area (square feet)	Average (W/ft^2)	Peak (W/ft^2)
DOD	18,818	0.24	0.52
GSA (with data center)	18,755	0.34	0.51
NREL	138,000	0.16	0.55
NREL (with data center)	220,000	0.77	1.25
Data center only		0.57	0.82

Table 10. Plug and Process Load Power Densities of Seven Stanford University Buildings

Number of Buildings	Area (square feet)	Average (W/ft^2)	Peak (W/ft^2)
1	115,110	0.23	0.41
1	49,360	0.30	0.64
1	83,130	0.16	0.42
1	26,326	0.40	1.08
3	113,584	0.28	0.63

Table 11. Plug and Process Load Power Densities of Ten Office Buildings

Office Building Type	Area (square feet)	Average (W/ft^2)
Multi-tenant with data center	50,725	1.17
Multi-tenant with data center	365,000	0.19
Multi-tenant with data center	191,799	0.37
Multi-tenant	173,302	0.49
Municipal	172,000	0.40
Single tenant with warehouse	94,621	0.19
Single Corporate tenant with data center	97,500	0.58
Single Corporate tenant with data center	195,721	0.36
Single Corporate tenant with kitchen	91,980	0.64
Single Corporate tenant with laboratories	222,616	2.27

Another study conducted by Baumann Consulting measured the "plug load" (i.e., receptacle load) power density of different space types located in an office occupying the fifth floor of a seven-story building in Washington, D.C [13]. The measured peak daytime demands in Table 12 are significantly higher than typical power densities listed in Tables 7 through 11 for office and higher education buildings. Table 12 is evidence that some space types might require higher receptacle demand power densities than other types and kitchens can have high demand densities. The average plug and process power density of the corporate office space with laboratory listed in Table 11 suggests that many lab spaces might also have higher power density requirements.

Table 12. Baumann Study: Plug Load Power Densities in Different Office Space Types*

Fifth-floor office in Washington, DC	Area (square feet)	Area % of 5th Floor	Average Evening (W/ft^2)	Peak Daytime (W/ft^2)
Office zones	4,890	81.6%	0.58	2.52
Conference zone	470	7.9%	0.35	1.85
Kitchen zone	246	4.1%	0.23	9.05
Other zones	384	6.4%	*Data sources: [13] and Figure 1 and Table 3 in [13]	
Fifth floor	5,990	100%		

3.4.4 Studies on Device Power Consumption

A study conducted by Ecos for the California Energy Commission (CEC) Public Interest Energy Research Program (PIER) involved inventorying the receptacle load at 47 offices, almost 7,000 plug-in devices [14]. A total of 470 plug-in devices were monitored at 25 offices for a two-week period. Data was collected at one-minute intervals. The report presented a careful analysis of the percentage of time many common device types are in active, idle, sleep, standby, and off states. The device types included: computers, monitors, imaging equipment, computer peripherals, lamps, coffee makers, and shredders. Table 13 provides the average power consumption during various states found for some common plug-in devices monitored in the study. The number of devices monitored is also included in the table.

It has been noted in various papers that device nameplate power rating is not representative of the heat that a building gains due to device operation. As Table 13 shows, a device consumes less power when it is not in the active state. The Baumann Study discussed in Section 3.4.3 also measured the power consumption of plug-in devices at 30-second intervals for at least 24-hours per device and at least three 24-hour periods on devices with highly variable usage (such as printers and copiers). The device nameplate power rating is compared with the average in-use and idle power consumption in Table 14. The number of devices represented in the study is also included in the table. It might be noted that the Baumann study involved an energy analysis simulating heat gains inside the building which rested on a lighting power density[10] of 1.1 W/ft^2 based on ASHRAE 62.1 (Table 4 in [13]). This density might be compared with the lighting power allowances and minimum lighting power densities included in Section 5 on energy conservation codes and Section 6 on engineering practices.

Table 13. Measured Power Consumption of Common Office Devices in Various States*

Device	Number	Active (W)	Idle (W)	Sleep (W)	Standby (W)
Desktop computer	61	78.9	45.6	3.2	2.2
Notebook computer	20	74.7	30.3	1.6	1.6
LCD display	84	34.2	26.4	6.2	0.9
Laser MFD	18	75.7	26.1	5.4	5.5
Laser printer	33	130.1	19.0		11.4
Inkjet printer	13	64.0	6.8	4.7	2.7
Computer speakers	18	6.0	2.4		1.7
External drive	2	28.4		10.7	1.0
Ethernet hub or switch	9	17.0	8.0	5.9	1.3
USB hub or switch	2	26.0	14.1	5.9	0.6
LCD television	2	58.2			3.1
Video projector	4	181.9		9.8	4.6
Portable CD player	7	18.0	3.0		1.3
Speakers (audio)	6	32.0	10.0		1
Coffee maker	10	464.0	40.3		1.8
Shredder	4	78.4			0.8
Space heater	4	937.7			1.0
Toaster oven	1	1057.9			0.0

*Devices and data selected from Table 11 in [14]

[10] In email dated December 5, 2016, Justin Lueker, author of [13], stated that "11.8 W/m^2, which translates to about 1.1 W/ft^2" was used. Table 4 of [13] had incorrectly included 127 W/ft^2 for the lighting power density in all occupied spaces, apparently mis-converting 11.8 W/m^2.

Table 14. Baumann Study - Device Nameplate and Idle and In-use Power Consumption*

Device	Number	Nameplate (W)	Idle (W)	In-use (W)
Laptop computer	11	80	0	40-70
Desktop computer	11	100-930	2.5	70-75
LCD display	33	25-40	0	25-40
LED lamp	11	11	0	7.6
Printer	1	1584	15	780 printing 130 scanning
Shredder	1	800	0	200
Server rack	1	--	1175	1175
Conference system	1	--	92.5	543
Refrigerator	1	180	0	100-105
Coffee machine	1	1250	3.3	1300
Toaster	1	1000		765
Microwave	1	1700	0.05	1540
Water cooler	1	700	0	130-160 chilling 553 heating

*Data sources: Tables 1 and 3 in [13]

3.4.5 Receptacle Load Power Densities in Real Estate and Building Design

In the abstract of [12], it is stated: "Tenants [of commercial buildings] require that sufficient electrical power is available for PPLs [plug and process loads] to meet the maximum anticipated load. Lease language often dictates a value of 5 to 10 W/ft^2 for PPLs….Overestimating PPL capacity leads designers to oversize electrical infrastructure and cooling systems."

Cooling requirements in buildings are partially determined by the heat generated by the lighting and electrical equipment, including receptacle load. The receptacle load can also influence peak heating loads. According to [13], the standard practice for HVAC sizing calculations is to assume a plug load density of 1 W/ft^2, published in ASHRAE Research Project RP-1055 (1999) for offices. According to [15], the 2009 ASHRAE Handbook – Fundamentals "states that a 'medium density' office building will have a plug load of 1 W/ft^2." Based on an analysis of results published in ASHRAE-sponsored research project RP-1482 (2010), "Update to Measurements of Office Equipment Heat Gain Data," reference [15] further asserts that peak plug loads as low as 0.25 W/ft^2 are possible. This assertion seems to be based on plug loads consisting of light usage of notebook computers with speakers and one printer per ten workstations.

What is not stated in papers addressing the receptacle demand power density required by tenants is that the estimated power density of a building may be based on the total receptacle load calculated from National Electrical Code Article 220 which requires 180 VA for single or duplex receptacles on one yolk. Furthermore, the power density required by tenants may also, in a sense, be expressing a need to have a space populated with an adequate number of receptacles.

4 EIA MODEL AND PREDICTIONS FOR COMMERCIAL BUILDINGS

4.1 NEMS Commercial Demand Module

The CBECS provides data for the Commercial Demand Module (CDM) of the National Energy Modeling System (NEMS) [15]. As part of NEMS, the CDM generates projections of the commercial sector energy demand for the nine Census division levels identified in Figure 7. Equipment purchases for the major end-use loads in a commercial building are based on a life-cycle cost algorithm which incorporates consumer behavior and time preference premiums. Equipment selection factors are also based on major energy source, such as electricity, natural gas, or distillate fuel oil. The seven major end-use loads in the CDM are heating, cooling, water heating, ventilation, refrigeration, cooking, and lighting. The CDM has also incorporated the three minor end-use loads: personal computers, other office equipment, and miscellaneous end-use loads (MELS). Miscellaneous end-use loading is represented in the “other” category in Figure 20, which illustrated that MELS (excluding computers and other office equipment) were attributed to 18% of the electrical energy consumption in all commercial buildings. Minor and renewable energy sources, as well as district energy services, are also included in the CDM.

The CDM defines eleven building categories based on the 2003 CBECS. Table 15 includes the building categories and ownership since projections for equipment decisions are impacted by these factors. The model is also used to assess how changing energy markets, building and equipment technologies, and regulatory initiatives impact the energy consumption of the commercial sector. The base year for the current CDM is 2003, corresponding to the 2003 CBECS.

The total building “service demand” depends on the building type, size, and location. The CDM models energy-consuming “service demands” because consumers do not directly utilize energy. End-use equipment is purchased to meet service demand for 1) new construction; 2) replacement of equipment at the end of useful life; and 3) retrofit of equipment with useful life remaining, but at the end of economic life. The total energy consumption depends on the average efficiency of the equipment supplying the service demand.

Table 15. Commercial Demand Module Building Categories, Floorspace, and Occupancy*

CDM Building Category	2003 CBECS Building Type	Total Floorspace (million ft^2)	% Govt. Owned	Non-Govt. % Owner Occupied	Non-Govt. %Non-owner Occupied
Assembly	Public assembly Religious worship	7,693	23	52	25
Education	Education	9,874	79	13	9
Food sales	Food sales	1,255	1	43	56
Food services	Food services	1,654	7	30	64
Healthcare	Inpatient healthcare	1,905	18	48	34
Lodging	Lodging	5,096	7	32	61
Mercantile/ Service	Mercantile	15,242	7	34	59
Office	Office	13,466	14	47	40
Two office types: Large (>50,000 ft^2) & small ($\leq$ 50,000 ft^2), includes outpatient healthcare					
Warehouse	Warehouse	10,078	7	37	56
Other	Other	5,395	26	21	53
TOTAL		71,658	21	35	44

*Data Sources: Tables 1, E-4, and 8 in [15]

4.2 EIA 2015-2040 Projections for Commercial Buildings

The EIA projects that floor space and delivered energy consumption in commercial buildings will increase by 1.1% and 0.6% per year respectively from 2015 to 2040. The net result is a decrease in energy intensities due to higher efficiency lighting, heating, cooling, and ventilation systems; it is also due to more stringent building codes. The EIA reports an expected 0.3% per year reduction of electric energy intensity. However, the energy intensity of miscellaneous electric loads is expected to increase by a total of 11.5% [16].

5 COMMERCIAL BUILDING ENERGY CONSERVATION CODES

5.1 U.S. Department of Energy (DOE) Commercial Buildings Models

The DOE building models [2] aid in the development of energy codes and standards. Sixteen reference building energy models, listed in Table 16, have been developed for the U.S. Department of Energy in collaboration with the National Renewable Energy Laboratory (NREL), Pacific Northwest National Laboratory (PNNL), and Lawrence Berkeley National Laboratory (LBNL). The fifteen commercial buildings models (excluding the midrise apartment building model) represent over 60% of the commercial buildings in the United States. Table 16 provides the floor space and the number of floors for each reference model; the corresponding CBECS building type is also included. The remaining percentage of commercial buildings (less than 40%) may be similar to one or more of the reference models, but are not as easy to characterize by a representative type [2].

The building models were developed from the 2003 CBECS, which collected data on 5,215 buildings. The fifteen commercial building models represent 3,279 of the 2003 CBECS buildings with a floor space of 44 billion square feet (62% of the total floor space of the buildings in the study). The buildings used to develop the reference models accounted for 65% of the total energy consumption in the 2003 CBECS.

A version of the reference model for each building has three vintages: buildings constructed before 1980, buildings constructed after 1980, and new construction. About 78% of the U.S. population lives in five of the climate zones identified in Table 1. Population is an indication of geographic building distribution. But reference models have been developed for each of the sixteen climate zones discovered by the DOE; the most populated city in each of these zones appears in Table 1. The DOE developed 768 models to represent each unique combination of commercial building type, vintage, and location [2].

Table 16. DOE Reference Building Models and Equivalent CBECS Building Type

DOE Reference Building	Equivalent CBECS Building Type	Floor Area (in thousand ft^2)[1]	Floors[1]	Parking Lot Area (in thousand ft^2)
Large office	Office	498.6	12	8.9
Medium office	Office	53.6	3	86.8
Small office	Office	5.5	1	325.1
Primary school[a]	Education	74.0	1	14.7
Secondary school[b]	Education	210.9	2	59.3
Stand-alone retail	Retail, other than mall	25.0	1	35.0
Strip mall	Enclosed & strip malls	22.5	1	42.4
Supermarket	Food sales	45.0	1	63.8
Quick service restaurant	Food service	2.5	1	10.1
Full-service restaurant	Food service	5.5	1	22.3
Small hotel[c,d]	Lodging	43.2	4	33.7
Large hotel[d]	Lodging	122.1	6	88.5
Hospital[e]	Inpatient healthcare	241.4	5	77.5
Outpatient health care	Outpatient healthcare	41.0	3	82.9
Warehouse	Warehouse & storage	52.0	1	20.0
Midrise apartment	--	33.7	4	28.6
[a]650 students, [b]1200 students, [c]77 rooms, [d]1.5 occupants each room at 65% occupancy, [e]250 bed; Data Sources: [2] & [1]http://energy.gov/eere/buildings/commercial-reference-buildings				

The models consider the following: building occupancy and operating hours; ventilation requirements and air infiltration; and construction materials. The models incorporate the energy requirements of heating; air conditioning; ventilation; refrigeration; elevators; hot water service demand; commercial kitchens; plug and process loads; and lighting. Data in ASHRAE standards were used for many of the model parameters. The power densities of interior and exterior lighting loads were taken from ASHRAE 90.1-1989 for existing building stock and from ASHRAE 90.1-2004 for new construction. Energy demands for exterior lighting considered building type and specific lighting levels required for façade, main entry and other doors, canopies with heavy and light traffic, drive-throughs, and parking lots. ASHRAE 90.1-1989 and 90.1-2004 set parking lot power requirements at 0.18 and 0.15 W/ft^2 ([2], Table 27), respectively. Parking lot sizes for the reference building models ([2], Table 28) are also included in Table 16.

Based on an office occupancy rate of 200 square feet per person ([2], Table 4), it might be estimated that small, medium and large office buildings have 2493, 268, and 28 employees, respectively. The "plug and process loads" for office buildings were determined based on engineering judgment.

The annual mean energy intensities for new DOE reference model[11] office buildings in Miami are displayed in Figure 27; these intensities represent the total energy supplied by all energy sources, which includes electricity, natural gas, and other sources. For informational purposes in this report, Miami was selected because it had only an annual average of 124 heating degree days from 2011 to 2015 and, therefore, a low demand for heating, which might be supplied by natural gas or another non-electric source. Water heating and kitchen equipment (possibly supplied by natural gas or another source) do not account for a large percentage of energy consumption in office buildings. Therefore, the energy and power intensities displayed in Figure 27 should largely represent electric energy and electric power intensities with a low contribution from other energy sources.

The mean annual energy and power intensities for the DOE "small office" reference model in Miami are 12.9 kW-hours and 1.5 W per square foot. Based on the 2012 CBECS data, Figure 13 illustrates that the mean annual electric energy and power intensities of a commercial building (all building types) located in a hot, humid climate are 18.4 kW-hours and 2.1 W per

[11] New construction annual energy use intensities in kBtu/ft^2 for each of the 16 DOE reference models for each of the 16 reference cities is provided in [18].

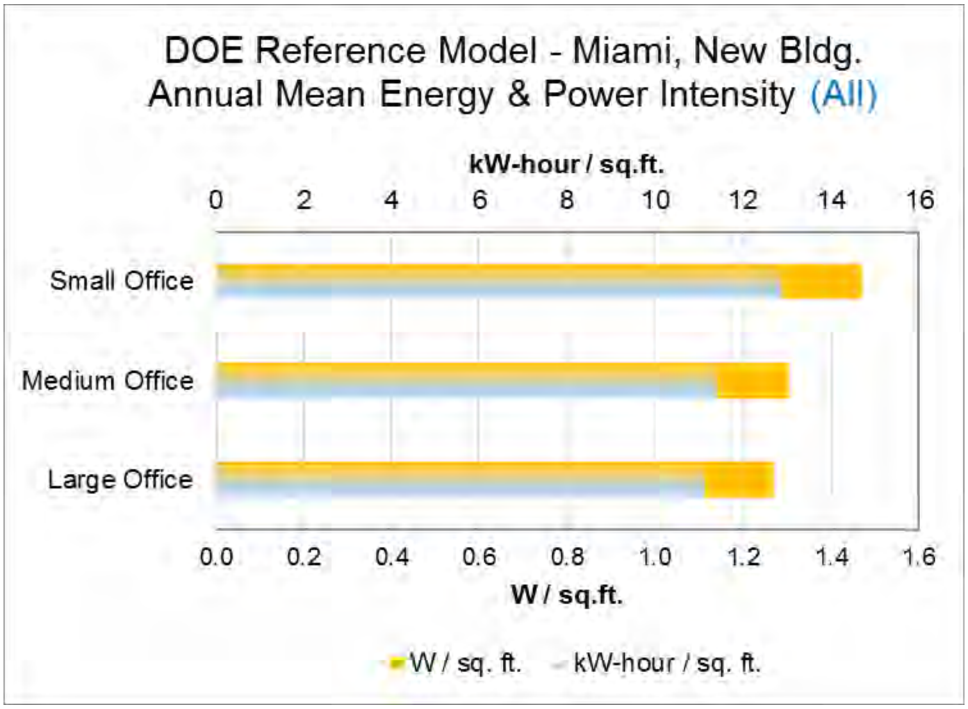


Figure 27. Energy & Power Intensities for DOE Reference Office Buildings in Miami
(Based on data provided in [18] obtained from http://cms.ashrae.biz/EUI)

square foot, respectively. Similarly, Figures 17 and 18 illustrate that the mean annual electric energy and power intensities of a commercial office building are 16.0 kW-hours and 1.8 W per square foot, respectively. When the differences between the data sets represented in the figures are considered, the intensities for new construction in Figure 27 correlate well to the intensities for all building types represented in Figure 13 and to the intensities for the CBECS 2012 office building category (all sizes) in Figures 17 and 18.

5.2 Historical Perspective, Energy Savings, and Coverage

The federal government passed the first energy conservation act in 1975. In 1978, the DOE was given the authority to establish mandatory minimum energy performance standards for appliances. Mandatory minimum energy performance standards have expanded, and coverage includes commercial appliances, lighting systems, motors, transformers, and HVAC equipment efficiencies established in 10 CFR §431. Since the Energy Policy Act of 1992, the U.S. Department of Energy (DOE) has taken an active role in the development, adoption, and impact analysis of model building energy conservation codes for residential, commercial, and federal buildings. [19], [20], [21] Building codes address the energy efficiency of the building envelope regarding fenestration, insulation, air barriers, and air leakage. Building codes address mechanical systems, specifically space and water heating, cooling, ventilation, refrigeration, and exhaust fan requirements. Building codes also address motor and transformer efficiency requirements, electric power and lighting systems, including automatic dimming (lighting) and shut-off requirements. [22], [23], [24]

The estimated site energy savings attributed to the adoption of residential and commercial building energy codes from 2011 to 2015 is 122 TBtu (all energy sources) with a cost savings of $3.0 billion [25, Table 9]. Data in [25, Table B.1] was used to calculate the projected electricity site energy savings for commercial buildings from 2010 to 2030 at 0.27 trillion kWh.

First published in 1975 as ASHRAE 90, ANSI/ASHRAE/IES Standard 90.1-2016, *Energy Standard for Buildings Except Low-Rise Residential Buildings* [22], provides the minimum requirements for commercial buildings. First published in 2000, the 2015 *International Energy Conservation Code* (IECC) [23] provides minimum energy conservation requirements for new commercial and residential buildings. The differences between the commercial building requirements for earlier editions of the ASHRAE 90.1 and IECC are covered in depth in [26]. Since ASHRAE 90.1 is the latest energy code standard released and probably considered more of a benchmark standard for commercial buildings than IECC, ASHRAE 90.1 will be briefly covered in this report.

5.3 ASHRAE 90.1 – General, Power, and Lighting Requirements

ASHRAE 90.1 [22], first published in 2001, establishes the minimum energy efficiency requirements for building design and construction and for maintenance and operation plans. It covers new construction and new systems and equipment in existing buildings except for low-rise residential buildings. The 90.1 standard covers hot water heating, elevators, and escalators. It specifies nominal efficiency levels for low-voltage distribution transformers in accordance with 10 CFR §431.

The standard requires installing energy measurement devices to monitor the total building load and the following building load categories: HVAC, interior lighting, exterior lighting, and receptacle circuits; however, other electrical load categories may account for up to 10% of each monitored load category. Energy usage must be recorded every 15 minutes, and the monitoring system must be able to store data for 36 months.

Automatic receptacle control is also required in at least 50% of general purpose receptacles (125 V, 15 and 20 A) in private offices, conference rooms, print/copy rooms, break rooms, classrooms, and individual workstations. Automatic receptacle control is required on at least 25% of branch circuit feeders installed for modular furniture not shown on construction documents. The control device should turn receptacles off at specifically programmed times or 20 minutes after the space becomes unoccupied.

ASHRAE 90.1 specifies lighting power densities (W/ft^2) for interior and exterior building spaces. Two methods are provided for interior lighting power allowance: a simple building area method and a more flexible space-by-space method. The installed lighting system should not exceed the total power allowed for illuminating the building. Space interior lighting should have a manual control and should be dimmable with at least one intermediate light level. Automatic partial or full shutoff is also required for most spaces 20 minutes after they become unoccupied.

With the building area method, the lighting power densities in Table 17 are used to determine the allowable lighting power for the building [22, Table 9.5.1]. If the building consists of one than one type listed in the table, then the total allowable lighting power is the sum of the lighting power for each area of the building.

The space-by-space method is similar but is a more detailed method of calculating and summing the allowable lighting power for all space types within the building. For example, office buildings might have open or closed offices. Office buildings often contain conference rooms, break rooms, restrooms, storage areas, stairwells, corridors, and other spaces. Furthermore, spaces like corridors require different illuminations levels depending on the building type and purpose. Table 18 includes a few select lighting power allowances for spaces commonly found in office buildings, including laboratories, computer rooms, and workshops [22, Table 9.6.1] sometimes found in engineering and research office buildings. Table 18 also displays the lighting power allowance for corridors in different building types. When the space-by-space method is employed, additional lighting power allowance is permitted for exhibits, retail areas, spaces using non-mandatory lighting controls, and certain room geometries.

For comparison purposes, the lighting power density allowances listed in IECC 2015 [23] Tables C405.4.2(1) and C405.4.2(2) have been included in Tables 17 and 18. The lighting power densities of IECC 2015 and ASHRAE 90.1-2013 are identical except as noted with yellow highlighting.

Table 17. ASHRAE 90.1 & IECC Building Area Method Lighting Power Density Allowances

Building Area Type	90.1-2016 (W/ft^2)	90.1-2013 (W/ft^2)	IECC 2015 (W/ft^2)
Automotive Facility	0.71	0.80	0.80
Convention Center	0.76	1.01	1.01
Courthouse	0.90	1.01	1.01
Dining: Bar Lounge/Leisure	0.90	1.01	1.01
Dining: Cafeteria/Fast Food	0.79	0.90	0.90
Dining: Family	0.78	0.95	0.95
Dormitory	0.61	0.57	0.57
Exercise Center	0.65	0.84	0.84
Fire Stations	0.53	0.67	0.67
Gymnasium	0.68	0.94	0.94
Healthcare Clinic	0.82	0.94	0.90
Hospital	1.05	1.05	1.05
Hotel/Motel	0.75	0.87	0.87
Library	0.78	1.19	1.19
Manufacturing	0.90	1.17	1.17
Motion Picture Theatre	0.83	0.76	0.76
Multi-Family	0.68	0.51	0.51
Museum	1.06	1.02	1.02
Office	0.79	0.82	0.82
Parking Garage	0.15	0.21	0.21
Penitentiary	0.75	0.81	0.81
Performing Arts Theater	1.18	1.39	1.39
Police Stations	0.80	0.87	0.87
Post Office	0.67	0.87	0.87
Religious Buildings	0.94	1.00	1.00
Retail	1.06	1.26	1.26
School/University	0.81	0.87	0.87
Sports Arena	0.87	0.91	0.91
Town Hall	0.80	0.89	0.89
Transportation	0.61	0.70	0.70
Warehouse	0.48	0.66	0.66
Workshop	0.90	1.19	1.19

Table 18. ASHRAE 90.1 & IECC Lighting Power Allowances for Selected Space Types

Common Space Types	90.1-2016 (W/ft^2)	90.1-2013 (W/ft^2)	IECC 2015 (W/ft^2)
Classroom/Training Room	0.92	1.24	1.24
Conference Room	1.07	1.23	1.23
Copy/Print Room	0.56	0.72	0.72
Computer Room	1.33	1.71	1.71
Electrical/Mechanical Room	0.43	0.42	0.95
Laboratory	1.45	1.81	1.81
Office – enclosed	0.93	1.11	1.11
Office – open	0.81	0.98	0.98
Restroom	0.85	0.98	0.98
Stairwell	0.58	0.69	0.69
Storage - < 50ft²	0.97	1.24	0.63
Storage - > 50ft²	0.46	0.63	0.63
Workshop	1.14	1.59	1.59
Corridor			
…in a facility for visually impaired	0.92	0.92	0.92
…in a hospital	0.92	0.99	0.99
…in a manufacturing facility	0.29	0.41	0.41
…all other corridors	0.66	0.66	0.66

5.4 Development of ASHRAE 90.1 Lighting Power Allowances[12]

The ASHRAE lighting power densities (LPD) have been developed by the 90.1 Lighting Subcommittee with support from a team at Pacific Northwest National Laboratory (PNNL). The LPDs are developed using spreadsheet models based on the IES recommended illumination levels for visual tasks required in specific building spaces. The models incorporate source efficacy data from efficient lighting products, typical light loss factors, and coefficient of utilization values for applicable luminaire types. Light loss factors represent the amount of light lost due to lamp and room surface depreciation and dirt accumulation.

[12] The first three paragraphs of this section were initially drafted by the report author based on [27], but were revised by Eric Richman at PNNL on October 27, 2016. In conversation with Eric Richman on September 8, 2016, he remarked that LED lighting systems had been added to the lighting sources represented in the model used to develop the lighting power allowance in ASHRAE 90.1-2016.

The coefficient of utilization represents the amount of the total lamp lumens which will reach the work plane in a specific room configuration (room cavity ratio) with specific surface reflectances. For the interior space models, ceiling, wall, and floor reflectances were selected as 70%, 50%, and 20% to represent most common building design practices. For each specific space type, appropriate room cavity ratios were chosen from 2 to 10 to represent common geometries for that space type.

Lumen power densities were developed for over 100 different space types and applications. Professional lighting designers on the subcommittee provided additional model input and oversite for design related issues such as task versus general lighting in spaces, appropriate lighting systems, and appropriate room cavity ratios for specific building areas. The ASHRAE space type power densities represent the power needed to illuminate typical spaces using reasonable efficient lighting sources and good effective design. Whole building LPD values are also developed using weighted averages of space LPD values and the mix of spaces in typical building types.

The following simple equations are not part of the ASHRAE 90.1 design process for lighting power allowance. They are general lighting design equations used in the zonal cavity method [28]. They are included here to help clarify the basic process of determining the total luminous flux (lumens), the number of luminaires (i.e., lighting fixtures), and the electric power needed to illuminate a space. Lighting design rests on providing adequate illumination (in lumens) for a space. Different spaces in a building (with different visual tasks) require different levels of illumination.

$$Luminous\ Flux\ (total) = \frac{Illuminance\ required\ for\ task\ (in\ fc\ or\ lux) \cdot floorspace}{coefficient\ of\ illumination \cdot light\ loss\ factor}$$

$$Number\ of\ luminaires = \frac{Luminous\ flux\ (total)}{Lumens\ per\ selected\ luminaire}$$

$$Electric\ Power\ (total\ in\ watts) = Number\ of\ luminaires \cdot Power\ required\ per\ luminaire$$

The placement of the luminaires must also meet certain spacing criteria [28].

6 ENGINEERING PRACTICES

6.1 Electric Utility Demand Load and Transformer Sizing for Commercial Buildings

Austin Energy released employee reference materials on evaluating customer demand load in a 2012 suit filed with the Public Utility Commission of Texas. The Austin Energy material included a table on commercial building demand in VA/ft^2, power factor, and load factor. Figure 28 displays the demand load per square foot in volts-amperes (VA) and watts, and the loading factor expressed as a percentage. Figure 19, developed from the Austin Energy table, shows that restaurants had the highest average power consumption.

As shown in Figure 28, fast-food and sit-down restaurants also have the highest demand load (32 and 25 VA/ft^2, respectively), but their load factors are less than 50%. Large and small food stores, refrigerated warehouses, and hospitals (with demand loads of 13.1, 20,6, 17.8, and 14.5 VA/ft^2, respectively) are the only occupancy types with load factors exceeding 50%, perhaps due to high refrigeration load and long operating hours. The 79% load factor of large food stores accounts for its relatively high average load of 9.2 watts per square foot (shown in Figure 19) even though the demand load is about average. Some occupancy types, including schools (17.5 VA/ft^2), have higher demand loads but only restaurants and small food stores have higher average power densities (shown in Figure 19).

The Austin Energy manual recommends several methods of estimating the demand load for commercial customers. The preferred method is estimating demand based on a similar customer, such as another business of the same franchise, comparable size, and located in the same climate zone. If this method is not feasible, the VA demand load is determined from the demand estimation per square foot for a similar occupancy type as shown in Figure 28. An estimated demand load is also calculated using the demand factors in Table 19 with the connected load, listed on the electrical plans submitted for the building. Depending on the proximity of the estimations, the demand load is assigned to equal the lesser demand or the demand based on occupancy type and building size.

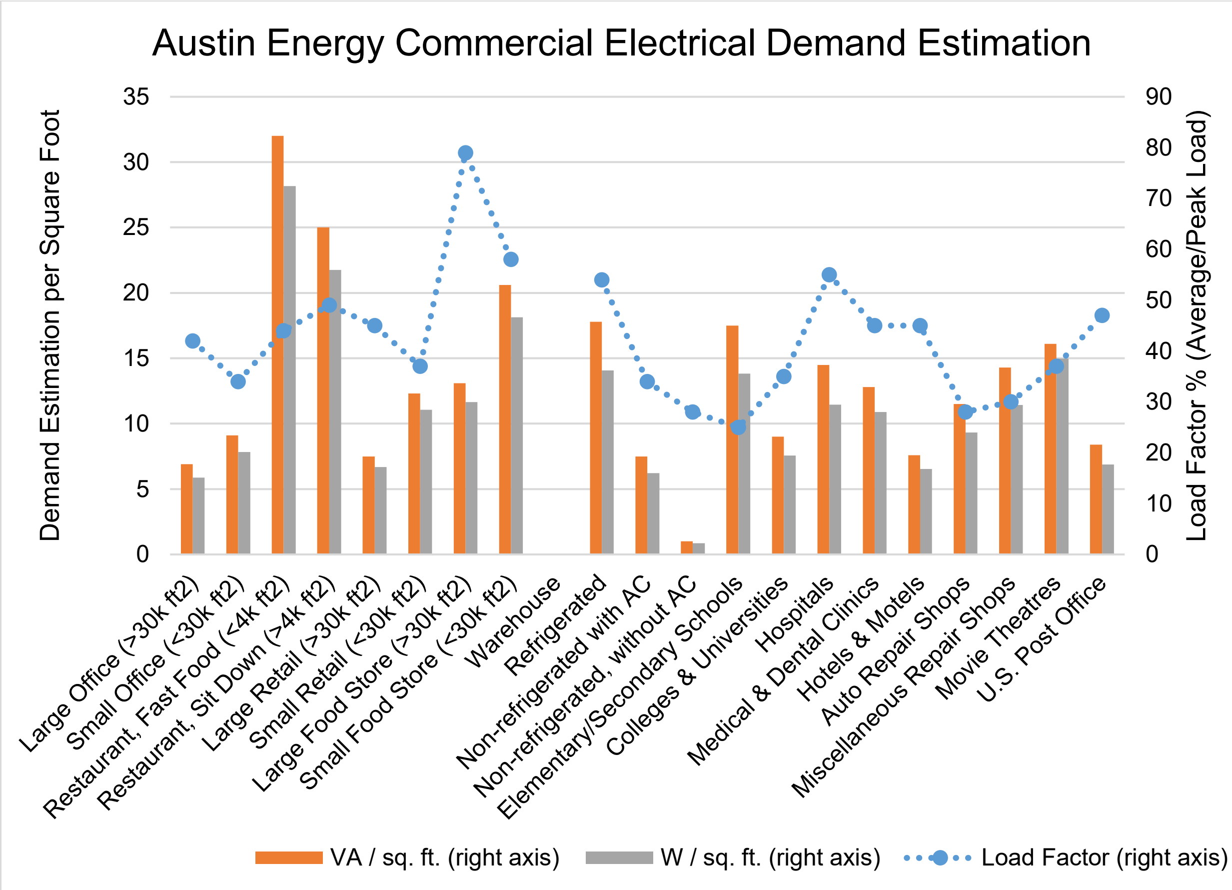


Figure 28. Austin Energy – VA and Power Demand Load in Commercial Buildings
(Data Source: [6])

Table 19. Austin Energy Demand Factors for Connected Commercial Loads

Austin Energy Demand Factors for Connected Commercial Loads			
General Lighting[a]	General Receptacles	Air Conditioning[b]	[a]May be adjusted based on application and hours of usage
0.8	0.1	0.8-1.0	[b]1.0, 0.9, or 0.8 for 1, 2-5, or 5+ units
General Power	Laundry	Water Heaters	
0.3	0.5-0.8	0.2	
Cooking	Refrigeration	Air Compressors	
0.3-0.5	0.5	0.2-0.5	
Elevators[c]	Escalators	Motors[d]	[c]Most operate less than 15 minutes
N/A	0.6	0.3-0.5	[d]Largest + 50% remaining motors

Austin Energy also provided guidelines for transformer loading. Table 20 includes some of the recommended loading ranges for three-phase, pad-mounted transformers based on a maximum load factor of 60% and a balanced three-phase load. A transformer secondary voltage of 208Y/120 V is available with transformer ratings from 75 to 750 kVA. A transformer secondary voltage of 277Y/480 V is available with transformer ratings from 75 to 2500 kVA.

Table 20. Austin Energy Three-Phase Pad-mount Transformer Loading Guidelines[a,b,c]

Transformer Nameplate kVA	Initial kVA Loading Range	kVA Loading Change-out Point
75	0-85	100
150	85-175	200
225	175-275	300
300	275-350	400
[a]For 61-75% load factor, limit initial loading to 75% nameplate, change out at 110%		
[b]For 76-90% load factor, limit initial loading to 70% of nameplate, change out at 100%		
[c]For 90-100% load factor, install next size and limit initial loading to 80%, change out at 100%		

6.2 Traditional Design Practices for Electrical Systems in Buildings

6.2.1 Building Demand Load, Panel, and Feeder Sizing

Consulting engineers and electrical system designers determine building loads by applying demand load factors to connected loads in a similar manner to Austin Energy's guidelines for their employees. In the design process, the first step is to identify (or estimate) the major equipment loads: heating, ventilating, air conditioning, electric water heaters, elevators (if any), and any other owner or tenant equipment. The engineer determines the lighting and receptacle load. The total demand load on the main panel or a sub-panel is based on the connected loads and the category demand factor for each type of connected load. The demand load on a panel might be calculated by organizing the connected loads into categories and the applying demand factors displayed in Table 21. [28]

It has been noted in [29] that the listed ampere requirements on packaged HVAC units are lower than NEC Article 440 requirements for calculating the ampacity of the multiple motors found in field installed air conditioning equipment. Comparisons of the power requirements of packaged HVAC equipment with the total ampacity that would be required to supply all the motors packaged inside the equipment validate this assertion.[13]

The National Electrical Code is a standard which specifies the minimum requirements for electrical installations. The National Electric Code is adopted (with or without amendments) by states. Final approval of the design and installation of an electrical system in a building rests on

[13] Based on the report author's experience reviewing the electrical and mechanical plans of several commercial buildings.

the authority having jurisdiction. In some circumstances, engineers may find it prudent to exceed code guidelines or comply with local regulations. [28]

The demand load at the main panel may be less than the sum of the demand loads on each panel. For example, the summer air conditioning load may be larger than the winter heat load. Rooftop air conditioning units are likely to be connected directly to the main panel, but electric resistance heat is likely to be connected directly to subpanels. Furthermore, the total receptacle demand load calculated at the main panel will be less than the sum of the receptacle demand loads on the subpanels. Consider three panels supplying connected receptacle loads of 10, 10, and 20 kVA with demand loads of 10, 10, and 15 kVA (summing to 35 kVA). The receptacle demand load on the main panel is 25 kVA.[14]

Table 21. Traditional Engineering Demand Factors for Building Loads*

Load Category	Demand Factor	Comments
Air conditioning	0 or 1	If heating and ac do not operate at the same time, the larger load has demand factor of 1.
Resistance heat & motors for heating	0 or 1	
Water heating	1	
Lighting	1.25	"Continuous," circuit loading cannot exceed 80%
Receptacle	1 x 1st 10kVA, 0.5 x remainder	180VA per receptacle is general minimum standard, see NEC 220.14 and 220.44
Motors	1	See NEC 430.24
Largest motor	0.25	See NEC 430.24
Other loads	1 or 1.25	1.25 for continuous, 1 otherwise
Kitchen	0.65 – 1.0	Depending on number of items, see NEC 220.56
Spare capacity	1	

*Demand factors from [28]

6.2.2 Branch Circuit Sizing and Protection

Branch circuits are directly connected to the end use equipment, including resistance heating, water heaters, motors (such as elevators), lighting fixtures, and receptacle load. Circuit breakers are not allowed to continuously carry 100% of their current loading. Therefore, for non-motor loads, the overcurrent protective device is the next standard size higher than 1.25 times the required load current. Wire size selection is based on the rating of the overcurrent protective device. [28]

[14] Correct use of receptacle demand factor in NEC Table 220.44 verified through email with Derek Vigstol, Senior Electrical Specialist at NFPA, October 14, 2016.

Determining the appropriate branch circuit wire size and overcurrent device is more complex for motor loads. For branch circuits supplying a single motor, the wire size should be selected as the next standard size higher than 1.25 times the motor's full load amp (FLA) rating. The sizing of the overcurrent protective device depends on the delay-time characteristics of the protective device. The appropriate sizing for a thermal-magnetic circuit breaker would be next standard size higher than 1.75 times the motor full load amps. For an overcurrent protective device such as a time-delay fuse, the device rating should be higher than 1.25 times the FLA. When a branch circuit serves several motors, the wire size is based on 1.25 times the FLA of the largest motor plus the sum of the FLAs of the smaller motors. The calculation is identical for time-delay overcurrent protective devices. For molded case circuit breakers, the calculation is similar except the largest motor FLA is multiplied by 1.75. [28]

Wiring sizing for feeders and branch circuits must also comply with voltage drop requirements.

6.2.3 In-House Transformers and Connecting Equipment Selection

Step-down transformers in building electrical systems are based on the demand load being supplied. The next size transformer higher than the calculated demand is selected. The size of the overcurrent protection device on the secondary must not exceed 1.25 times the rated secondary current. The size of the overcurrent protection device on the primary is selected as the next standard size higher than 1.25 times the rated primary current. The primary and secondary conductors are based on the overcurrent protective device ratings. [28]

6.3 NEC Lighting Requirements and Other Lighting Guidelines

6.3.1 NEC and NEC Comparison with ASHRAE Requirements

Interior and exterior lighting systems for buildings are designed to ensure adequate levels of illumination to meet the visual tasks required in a space. Appropriate selection and placement of lighting fixtures are equally important in the design process. Table 220.12 of the 2017 National Electrical Code specifies the minimum lighting load (in VA/ft^2) for specific occupancy types with two permitted exceptions. The first exception, added to the 2014 edition, allows the lighting load to comply with the energy code adopted by the authority having jurisdiction if a monitoring system is installed and the demand factors in Table 220.42 (applicable to dwelling units, hospitals, hotels, and warehouses) are not applied. The second exception, added to the 2017 edition, allows the minimum lighting power density to be reduced by of 1 VA/ft^2 for office and bank areas in a building which complies with an adopted energy code.

Table 22 shows that the minimum NEC lighting power densities (in VA/ft^2) have changed little since 1968, yet lighting technologies have advanced and have become much more energy efficient in the last fifty years. Also included in Table 22, the lighting power allowances (in W/ft^2) in ASHRAE 90.1, even the 2004 edition, are considerably lower than those in the NEC for most occupancy types. Furthermore, the commercial reference building model for new construction developed for the U.S. Department of Energy uses the lighting power allowances in ASHRAE 90.1-2004; this suggests that power requirements of modern lighting systems to provide adequate illumination are more in alignment with ASHRAE 90.1-2004 than the 2017 NEC.

It must be remembered that the minimum lighting power density requirements were likely included in the NEC to ensure that adequate illumination was provided for the visual tasks of the space. In the last half century, the light output efficiency (lumens per watts) has increased significantly. The U.S. Department of Energy has set minimum lamp efficiency requirements on some types of linear fluorescent and halogen lamps.[15] It should also be noted that at one time, office tasks included reading from paper and required higher illumination levels than current office tasks which focus on computer interaction and reading some higher quality printed material. Consequently, overhead lighting systems that were once designed to produce between 750 to 1000 lux can now be designed to produce between 300 and 500 lux [30].

[15] Effective July 14, 2012 40-205W Halogen PAR lamps and some linear T12, T8 and T5, and U-bend fluorescent lamps must meet 2009 DOE regulations established in Federal Register Vol. 74, No. 133, Part II Department of Energy 10 CFR Part 430 Energy Conservation Program: Energy Conservation Standards and Test Procedures for General Service Fluorescent Lamps and Incandescent Reflector Lamps; Final Rule, July 14, 2009.

Table 22. NEC (VA/ft^2) and ASHRAE 90.1 (W/ft^2) Lighting Power Density by Occupancy

Type of Occupancy	NEC 1968	NEC 1971	NEC 1981	NEC 2017	90.1-2004	90.1-2013
Armories and auditoriums	1			1		
Banks	2	5	3½	3½		
Barbershops & beauty parlors	3			3		
Churches	1			1	1.3	1
Clubs	2			2		
Courtrooms	2			2	1.2	1.01
Dwelling Units	3			3		
Garages – commercial (storage)	½			½		
Hospitals	2			2	1.2	0.94
Hotels, motels & apts. (no cooking)	2			2	1	0.87
Industrial commercial (loft) bldgs.	2			2		
Lodge rooms	1½			1½		
Office buildings	5		3½	3½	1	0.82
Restaurants	2			2	1.4	0.9
Schools	3			3	1.2	0.87
Stores	3			3	1.5	1.26
Warehouses (storage)	¼			¼	0.8	0.66
Assembly halls, & auditoriums*	1			1		
Halls, corridors, closets, & stairways*	½			½		
Storage spaces*	¼			¼		
*Except in individual dwelling units, See Table 18 for 90.1-2013 and 90.1-2016 allowances						

6.3.2 IEEE, IES, and Federal Lighting Recommendations

A joint IEEE I&CPS and IES committee[16] has been tasked with drafting a new IEEE Technical Book 3001.9 *Recommended Practice for Industrial and Commercial Lighting Systems*. The initial draft was rescinded and is under revision. When released, the IEEE Technical Book 3001.9 will not overlap with the IES Handbook contents and IES recommended practices; it will refer the reader to the appropriate work published by IES. The initial draft copyrighted in 2012 included the design lighting power densities and required illumination levels for federal buildings from the 2003 and 2005 PBS-P100, *Facilities Standard for Public Service Buildings* [31], released by the U.S. General Services Administration.

Table 23 lists the nominal average recommended illumination levels for various space types within a building as specified in the 2003 PBS-P100. Table 23 includes the lighting

[16] The committee is composed of members from the IEEE Industrial and Commercial Power Systems group and from the Illuminating Engineering Society of North America. Steven Townsend, 3001.9 Working Group Chair, responded to inquiry about technical book status in an email dated October 21, 2016, and attached rescinded draft standard to the response email.

demand load for building areas published in the 2005 PBS-P100; the estimated demand load did not stipulate maximum design values. Also included in Table 23 are the lighting power allowances calculated to comply with the 2014 PBS-100, which states that the lighting load must use 30% less energy than required by the ASHRAE 90.1-2007 space-by-space method. The 2014 PBS-P100 does recognize that the actual lighting power density demanded by a space is reduced when lighting controls are used to reduce the illumination levels. Lighting controls might be employed due to: partial illumination provided by daylight, lack of occupancy, or reduced light levels desired [31, 2014 ed., pg. 136].

Table 23. Recommended Illumination Levels and Lighting Densities in PBS-P100

Building Area	PBS-P100 2003 (Lux)	PBS-P100 2005 (VA/ft^2)	ASHRAE 90.1-2007 (W/ft^2)	PBS-P100 2014 (W/ft^2)
Office: Enclosed 1	500	1.5	1.1	0.77
Office: Open1	500	1.3	1.1	0.77
Conference/Meeting/Multipurpose	300	1.5	1.3	0.91
Classroom/Lecture/Trainings	500	1.6	1.4	0.98
Lobby	200	1.8	1.3	0.91
Atrium: first three floors	200	1.3	0.6	0.42
Atrium: each additional floor		0.2	0.2	0.14
Lounge/Recreation		1.4	1.2	0.84
Dining Area	150-200	1.4	0.9	0.63
Food Preparation	500	2.2	1.2	0.84
Restrooms	200	1.0	0.9	0.63
Corridor/Transition	200	0.7	0.5	0.35
Stairs	200	0.9	0.6	0.42
Active Storage		1.1	0.8	0.56
Inactive Storage		0.3	0.3	0.21
Electrical, Mechanical, and Telecommunication Rooms	200	1.3	1.5	1.05

6.4 Federal Recommendations in Building Electrical System Design

6.4.1 GSA's PBS-P100, Facilities Standards for the Public Buildings Service

The Public Buildings Service (PBS) of the U.S. General Services Administration (GSA) provides a workspace for 1.1 million federal civilian employees and is one of the top real estate holders in the United States. Most of the buildings are courthouses, land ports of entry, and federal office buildings. The PBS-P100, *Facilities Standards for the Public Buildings Service,* is a mandatory standard which covers the design and construction of new federal buildings and major renovations to existing buildings. [31, 2014 ed.]

The General Services Administration (GSA) tends to own and operate buildings longer than the private sector. Buildings may undergo major or minor renovations as the building function changes. “Electrical and communication systems should provide ample capacity for increased load concentrations in the future and allow modifications to be made in one area without causing major disruptions in other areas of the building [31, 2003 ed., pg.181].” GSA buildings are generally constructed to more exacting specifications, but all buildings should be designed and constructed with the life cycle of the building in mind.

6.4.2 PBS-P100 Advanced Building Metering and Control

New federal buildings must install advanced electric metering equipment. Meters must be capable of monitoring phase voltages, phase current, demand power consumption, power factor, and reactive power. Meters must communicate via MODBUS/TCP/IP. [31, 2014 ed]

6.4.3 PBS-P100 Demand Load Calculations

In PBS-P100 2014, the demand power requirements for the following connected load categories are established:

- Motor and equipment loads*
- Elevator and other vertical transportation loads*
- Lighting
- Receptacle
- Miscellaneous*
  - Security, communication, alarm, and building automation systems
  - Heat tracing
  - Kitchen equipment
  - Central computer servers and data centers
  - Uninterruptible power supply (UPS) and battery rooms
- *Must comply with power requirements and full-load efficiencies in ASHRAE 90.1-2004.

The lighting load requirements in PBS-P100 have been addressed in the Section 6.3.2. The minimum receptacle load power densities for typical installations is included in Table 24. Circuits for 120-V convenience receptacles must be limited to 1,440 VA (180 VA each).

Electrical systems are sized according to the total demand load from the load categories included in the bullet-point list and the spare capacity listed in Table 25. However, the 2014 PBS-P100 cautions:

Before adding the spare equipment ampacity to account for future load growth, it is important that the load study reflects actual demand loads rather than connected loads. The designer must apply realistic demand factors by taking into account various energy-conserving devices such as variable frequency drives applied to brake horsepowers, energy-efficient motors, occupancy sensors, and so on. The designer must also avoid adding the load of standby motors and must be careful to distinguish between summer and winter loads by identifying such “noncoincidental” loads. A “diversity factor” must be applied to account for the fact that the maximum load on the elevator system, as a typical example, does not occur at the same time as the peak air conditioning load. [31, 2014 ed., pg.153]

Table 24. 2014 PBS-P100 Minimum Receptacle Load Power Density

Building Area	Service Equipment W/ft^2	Distribution Equipment W/ft^2
Office: Enclosed	1.30	2.50
Office: Open	1.30	3.25
Non-workstation areas	0.50	1.00
Core and public areas	0.25	0.50
Technology/server rooms	50	65

Table 25. 2014 PBS-P100 Additional Spare Capacity

	Spare Ampacity	Spare Circuit Capacity
Panelboards for branch circuits	50%	35%
Panelboards – lighting only	50%	25%
Switchboards & distribution panels	35%	25%
Main switchgear	25%	25%

6.4.4 PBS-P100 Treatment of Harmonics

The branch circuit distribution system supplies equipment which generates harmonics. Harmonic loads include:

- Computers Laser printers Copiers Fax machines File servers
- Variable Frequency Drives Electronic ballasts Telecommunication equipment

Harmonic distortion can cause overheating in transformer and conductor neutrals, motor failure, false tripping of protective devices, computer operational problems, and hardware component failures. K-rated transformers (K13 or higher) with a 200% neutral can be used to dissipate the additional heat generated by harmonic distortion. However, the 2014 PBS-P100 states that harmonic mitigating transformers are preferred since they cancel the harmonic frequencies. Panelboards supplied by K-rated or harmonic-mitigating transformers must be provided with a 200% neutral. [31, 2014 ed.]

7 OVERSIZING AND "RIGHTSIZING" TRANSFORMERS

A corollary of this project on evaluating the electrical feeder and branch circuit loading is the loading level of transformers. Previous work suggests that oversizing transformers results in increased transformer energy losses and greater arc flash hazards. One objective of addressing transformer efficiency in this section is to illustrate the importance of "right selecting" transformers to reduce transformer energy losses.

7.1 1999 Cadmus Transformer Loading Study [32]

A 1999 study on 89 low-voltage dry-type distribution transformers with three-phase 480-V primaries[17] and capacity ratings between 15 and 300 kVA determined that the average RMS load factor was approximately 16% of the transformer rating. Only 14% of the transformers had RMS average loads greater than 35%.

Table 26 illustrates that the group of twelve transformers rated 15 to 30 kVA had the highest average and maximum RMS load factors. The average and maximum RMS load factors increased as transformer capacity decreased in the four lower capacity groups (i.e., 15 to 30, 45, 75, and 112.5 to 150 kVA). The two largest capacity transformer groups (112.5 to 150 and 225 to 300 kVA) had maximum RMS load factors at approximately 35%; however, the average RMS load factors for the two groups deviated by about 8%. This deviation was attributed to the relatively small sample number and the diversity in the building operations (building types, hours, etc.).

Table 26. Measured Transformer Load Factor in 1999 Cadmus Study

RMS Load Factor	15-30 kVA	45 kVA	75 kVA	112.5-150 kVA	225-300 kVA
Average	23.4%	15.6%	14.0%	12.3%	19.9%
Maximum	62.4%	50.0%	40.2%	34.3%	35.6%
Minimum	1.3%	1.1%	0.9%	0.0%	11.0%
Number of Trans-formers (89 Total)	12	28	34	10	5

Transformer loading is expected to fluctuate; one or two phases may even be more heavily loaded. Transformer selection is usually based on the demand load with spare capacity for future load built into the calculation. The average peak loading factor of the transformers studied was only one-third of transformer capacity.

---

[17] Dave Korn, a principal investigator in the study, confirmed in email on October 17, 2016 that the transformers were three-phase 480 V on the primary, and "All or nearly all secondaries were 208V/120V."

The transformers were evenly selected from five building types: office, manufacturing, healthcare, school and institutions, and retail. Some buildings operated with one shift of workers and other buildings operated with two or three shifts. However, different building types and operating hours were found to cause little change in transformer loading. The transformers mainly served general lighting and receptacle load, which consisted primarily of office equipment and task lighting. Other loads included small water heaters, pumps, exhaust fans and other HVAC equipment, low-voltage manufacturing equipment, forklift battery chargers, and sign lighting.

All buildings had been constructed or modified in the last ten years. Most transformers had also been manufactured in the last ten years, but all were less than fifteen years old. In the initial phase of the study, 353 transformers in 43 buildings were observed. Nameplates on some were missing or inaccessible; 335 transformers were surveyed, and loading data was collected on 89 of those for a two-week period. Roughly 50% of the transformers surveyed were rated 45 or 75 kVA. By rise type, 80% of the transformers surveyed were 150°C temperature rise.

The transformers were between 90 and 98% efficient in power delivery. Winding losses are proportional to the square of the current flowing through the windings. The core losses are relatively constant and independent of transformer loading. Core losses account for a significant percentage of transformer losses when transformers are lightly loaded (0 to 30%); on the other hand, winding losses account for a significant percentage of transformer losses when transformers are heavily loaded (65 to 100%).

Spot measurements of power factor, total harmonic distortion and K-factor were taken when the transformer monitoring equipment was installed and removed. The roughly 80% of the measured K-factors (estimation based on Figure 4-5 in [32]) were 4 or less. K-factor is a metric of a transformer's ability to withstand harmonics. Higher harmonics are associated greater heat losses. A K-factor equal to 4 corresponds to a non-linear loading of 50% [33].

Table 27. 1999 Cadmus Study – Power Factor, Total Harmonic Distortion, and K-Factor

Spot Measurement	Power Factor	Total Harmonic Distortion	K-Factor
Average	0.87	21	2.7
Median	0.91	12	1.4

7.2 Transformer Loading and Efficiency

The U.S. Department of Energy mandates efficiency requirements and defines test procedures for measuring distribution transformer energy loss in the Code of Federal Regulations.

Transformer efficiency is a function of transformer loading; 10 CFR §431.196 specifies the evaluation of transformer load losses at 35% of rated load with an operating temperature of 75°C (55°C temperature rise above a 20°C ambient temperature). The regulation does not explain why 35% is the reference load level, although other work has suggested that the origin is a 1997 report which states: "…most low-voltage dry distribution transformers have a peak load of only about 50-60% of their rated capacity." It further states, "A per unit RMS load of 0.35 is a reasonable assumption." [34] As shown in Figure 29, maximum transformer efficiency also occurs in the vicinity of 35% loading.

Furthermore, Figure 30 shows that the power losses as a percentage of power supplied increase when transformers are more lightly and heavily loaded. The power lost as a percentage of power supplied to the EL-6 amorphous core is lowest from 10% to 40% of the rated load; furthermore, the losses are lower than the traditional core materials EL-4 and EL-5 for loading of 50% and less. The EL-5 standard core transformer has lower losses than the EL-4 and EL-6 at 60% the rated load and higher. However, the power loss as a percentage of power supplied for the EL-5 is lowest from 30% to 60% loading. Figures 29 and 30 use efficiency data for Eaton 45 kVA transformers with 480Δ-208Y V windings and 115°C rise type, but constructed using three different core materials.[18]

Transformers loaded close to the transformer rating are associated with higher power losses as a percentage of the power supplied. Power loss and supply calculations in Figures 30, 31, and 32 are based on loading at a 0.95 power factor, real power losses (W), and real power supplied (W). In Figure 31, real power losses are calculated for Eaton 480Δ-208Y V, 115°C rise, EL-5 (23QGD080) transformers rated at 30, 45, and 75 kVA supply loads ranging from 7.5 to 45 kVA.[19] The 30 kVA transformer does supply the 7.5 kVA load with the lowest power losses, 9 W in comparison with 15 to 16 W. However, Figures 31 and 32 illustrate that power losses for the transformers at these loading levels generally decrease as the transformer kVA rating increases. In Figure 32, Eaton 480Δ-208Y V, 150°C rise transformers with aluminum windings rated from 75 to 300 kVA supply loads from 75 to 225 kVA.[20]

---

[18] Robert Yanniello, Vice President of Engineering & Technology, Eaton's Electrical Systems & Services Group, provided the transformer efficiency data at loading levels of 10 to 100%, in 10% increments attached to email dated October 21, 2016.

[19] Robert Yanniello, provided the transformer efficiency data at loading levels of 10 to 100%, in 10% increments attached to email dated November 15, 2016. The efficiencies were linearly interpolated to determine the efficiencies at other loading levels.

[20] Robert Yanniello, provided a pdf file "DOE 2016 Tech Data 3-28-2016," attached to email dated October 21, 2016. The file contained efficiency data at 25, 50, 75, and 100% loading levels for Eaton

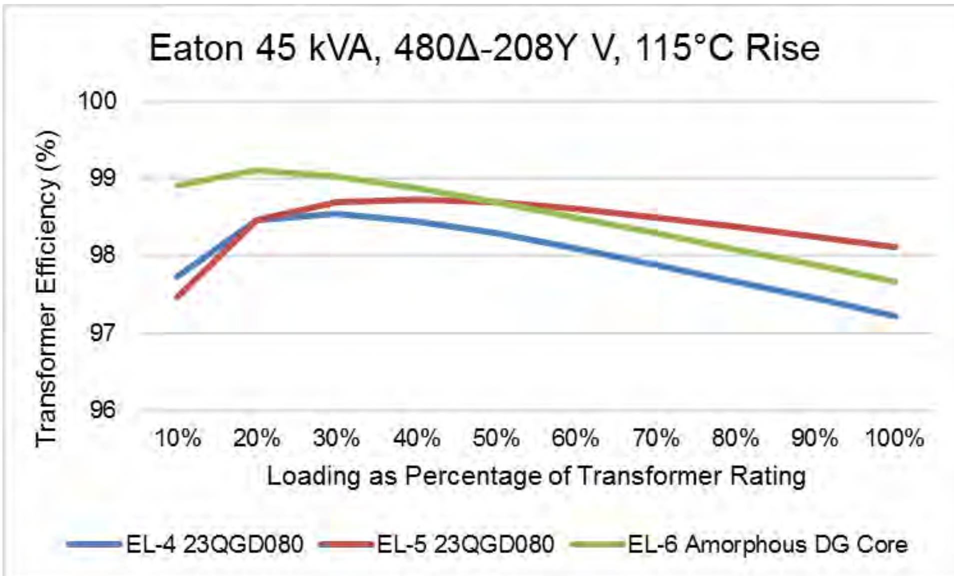


Figure 29. Efficiency Curves for Three Eaton 45 kVA, 480Δ-208Y-V Transformers

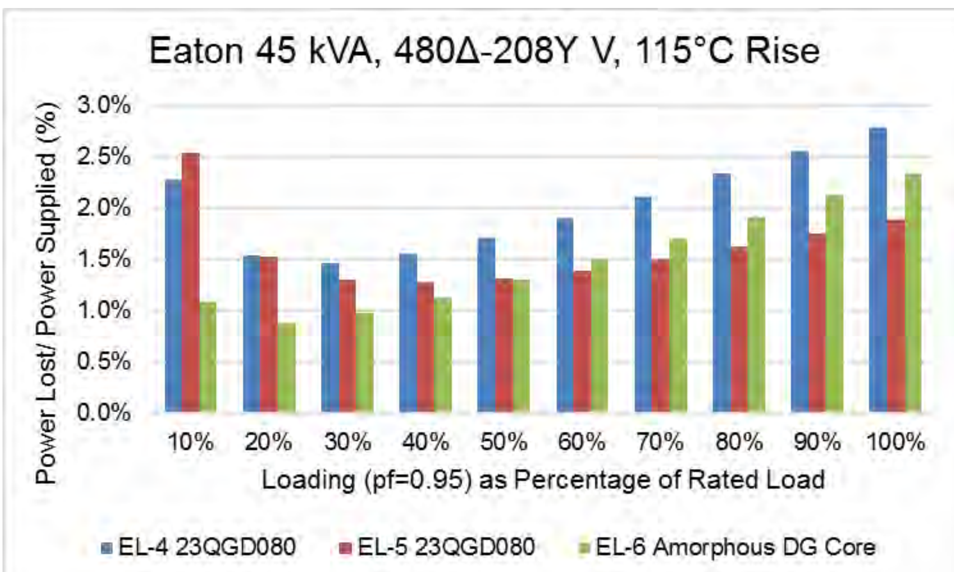


Figure 30. Power Losses as Percentage of Power Supplied for Three Eaton Transformers

---

transformers, including the three-phase 480Δ-208Y/120V, 150°C with aluminum windings (model V48M28T…) in Figure 32. Again, linear interpolation was used to determine other efficiency values.

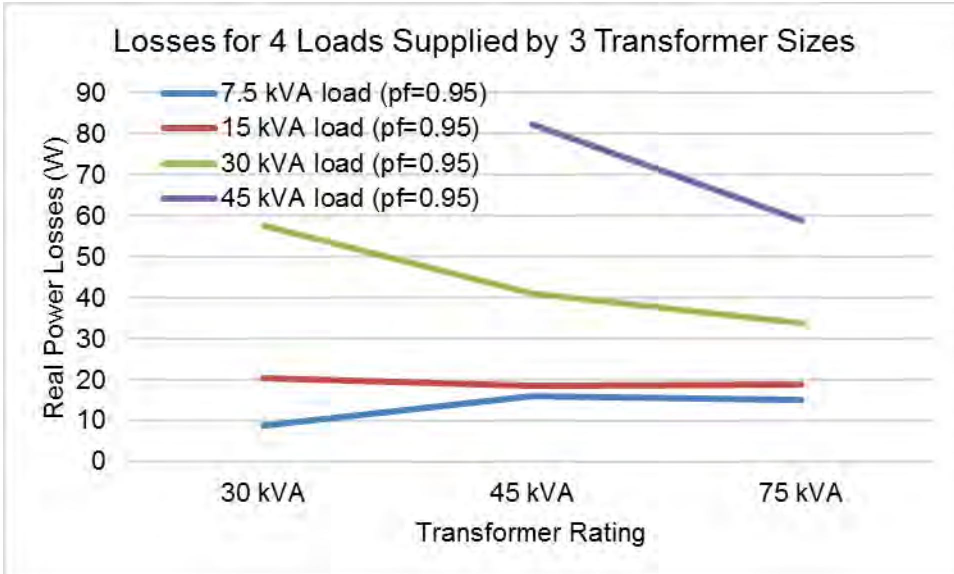


Figure 31. Power Losses: 7.5 to 45 kVA Loads Supplied by 30 to 75 kVA Transformers

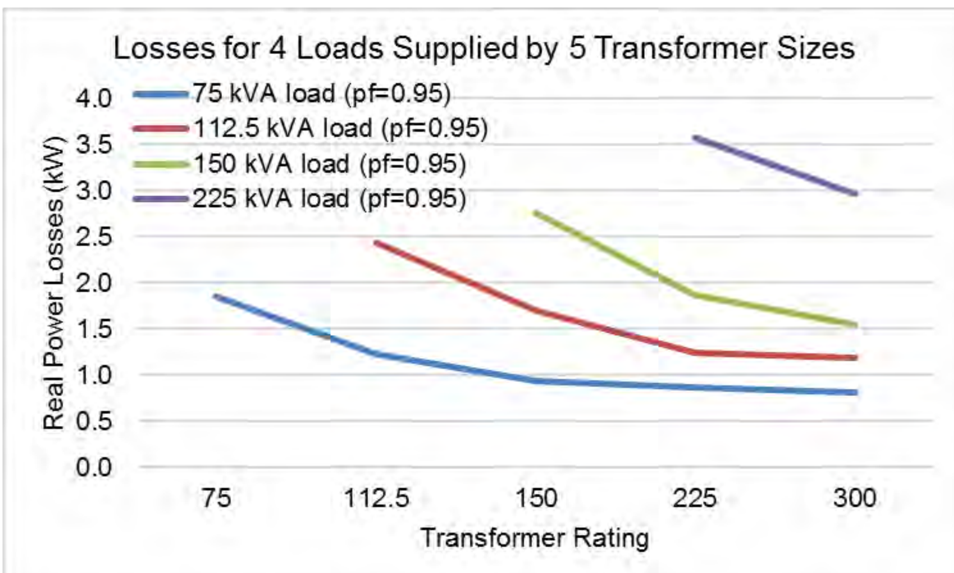


Figure 32. Power Losses: 75 to 225 kVA Loads Supplied by 75 to 300 kVA Transformers

Figures 29 and 30 illustrate that transformer efficiency is dependent on the core material. Transformer efficiency is also dependent on temperature-rise type. Figures 33, 34, and 35 show that transformer types with lower rather than higher rise temperatures are more efficient for all three Eaton 45 kVA, 480Δ-208Y V transformers in Figures 29 and 30 with traditional EL-4 and EL-5 refined steel cores, as well as the amorphous core EL-6. Transformers with a 150°C

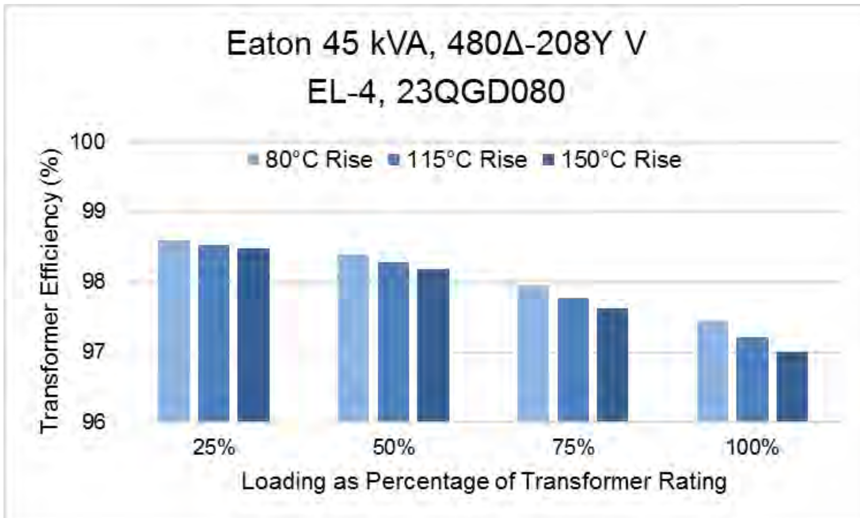


Figure 33. Efficiency as Function of Rise for 45 kVA, 480Δ-208YV, EL-4 Core Transformer

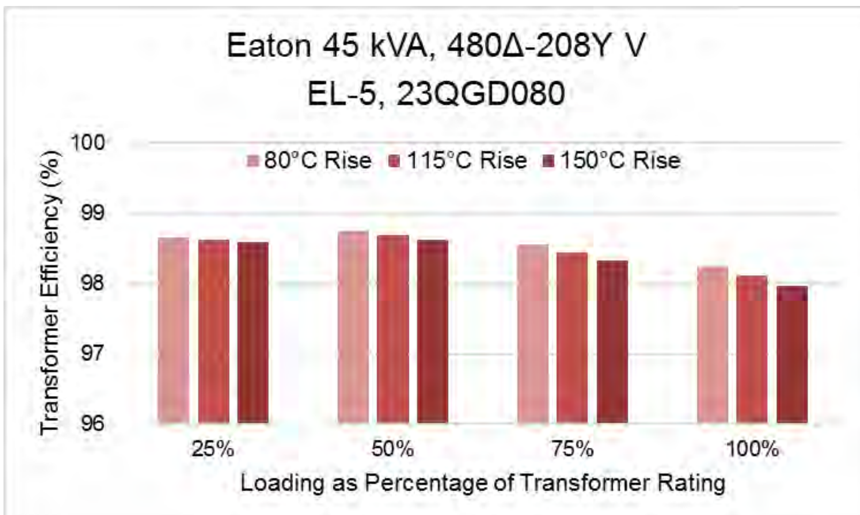


Figure 34. Efficiency as Function of Rise for 45 kVA, 480Δ-208YV, EL-5 Core Transformer

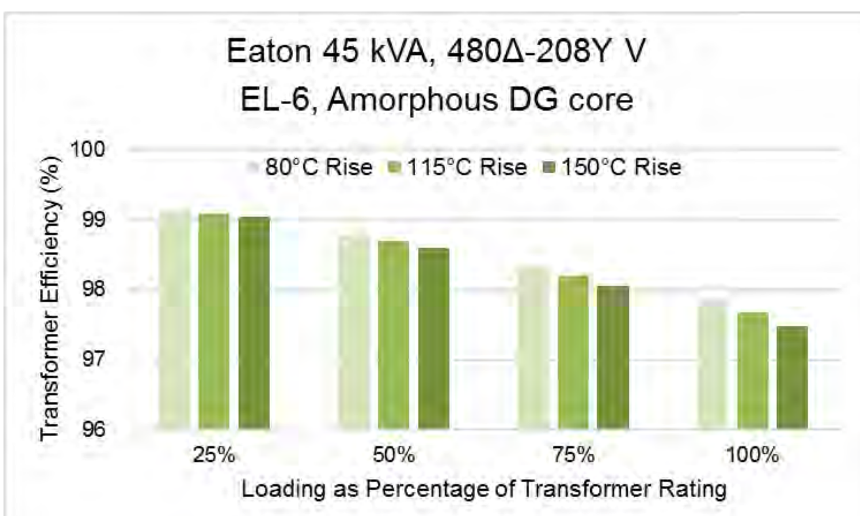


Figure 35. Efficiency as Function of Rise for 45 kVA, 480Δ-208YV, EL-6 Amorphous Core

temperature rise is the standard selection, but temperature rise specifications of 80°C and 115°C are also common. A temperature rise specification of 150°C allows the transformer temperature to rise 150°C (302°F) above the ambient temperature (20°C), so a fully loaded commercial transformer can exceed 300°F [35]. Data provided by Eaton on the percentage of three-phase transformers manufactured in 2016 by rise type is included in Table 28.[21] Single-phase transformers have similar percentages. Other manufacturers are expected to sell similar relative percentages.

When transformers with no K-factor rating (i.e., K-factor = 1) supply non-linear loads, the harmonics generated by nonlinear loads reduce expected transformer efficiency and can reduce transformer life. Harmonics increase transformer load and no-load losses, but the increase in eddy current losses is the most significant. Transformers with K-factors higher than one are specially designed to reduce eddy current losses in the windings. Core laminations may be individually insulated, and the size of the transformer core and windings may be increased [36]. K-factor, a weighting of the harmonic load current, is defined by the following equation, where n is the harmonic number and i_n is the magnitude of the harmonic current.

$$K - factor = \sum i_n^2 n^2 \; / \; \sum i_n^2$$

Pure linear loads have a K-factor of one. Higher harmonics are associated with greater heat losses.

Harmonics are commonly generated in building systems, and transformers are sometimes de-rated and oversized to compensate for the presence of harmonic current. However, selecting the appropriate K-factor transformer may be more economical [37] and is a better approach to reducing power losses. Data provided by Eaton on the percentage of three-phase transformers (115°C rise type) manufactured in 2016 by K-factor is included in Table 29. Single-phase transformers have similar percentages. Furthermore, other manufacturers are expected to sell similar relative percentages.

Table 28. Eaton Percentage of Transformers Manufactured in 2016 by Rise Type

150°C Rise	115°C Rise	80°C Rise
82%	14%	4%

[21] Robert Yanniello provided the data in Tables 28 and 29 in email dated October 21, 2016. The data represent ventilated, dry type distribution transformers with low-voltage primary and secondary windings. Mr. Yanniello provided clarification on the data in email dated November 21, 2016.

Table 29. Eaton Percentage of Transformers Manufactured in 2016 by K-Factor Rating

K-Factor = 1	K-Factor =4	K-Factor = 13	K-Factor = 9 OR K-Factor = 20
94%	2%	4%	<1%

7.3 Transformer Sizing and Arc Flash Hazards in Building Systems

The Request for Proposal soliciting contractors for this Phase I research project stated: “In addition, larger than necessary transformers that supply power to feeder and branch circuits expose unnecessary flash hazard to electricians working on live equipment.” The author of this report does not necessarily agree that this statement is true for dry-type distribution transformers in building systems with low-voltage primary and secondary windings. This section provides the results of sample calculations for three typical 480 V building systems[22] listed in Table 30. The systems represent low-, medium-, and higher- capacity systems with available three-phase, RMS short-circuit currents ranging from over 14 kA to over 50 kA at the main distribution panel. Certainly, there are some “high capacity” systems with higher available fault currents, but a representative system has not been developed for this work.

Transformers which step down 480 V to 208Y/120 V are used in buildings systems to supply lower-voltage mechanical loads, including water heaters, various fans, sump pumps and ductless heat pumps, as well as other specialized equipment and receptacle load. Feeders supplying transformers with different ratings are sized according to transformer capacity and any overcurrent protective devices present. Feeder lengths are determined by the physical layout of the electrical system in the building.

Since feeder impedance is a function of length, shorter feeders, supplying in-house distribution transformers located near the main switchgear or main switchboard, tend to have less impedance than longer feeders. Feeders with larger ampacities supplying transformers with higher kVA ratings have less impedance per unit length than those supplying transformers with lower kVA ratings. None the less, the feeder impedance further decreases the available fault current at the transformer. For illustration purposes, the impedances of the feeders supplying the transformers have been neglected, so that the direct impact of different transformer ratings on potential arc current is not obscured by different feeder impedances.

Figures 36 and 37 display the faults currents calculated at the secondary of 480-208Y/120 V transformers rated from 15 to 300 kVA supplied by “low,” “medium,” and “higher”

[22] The three typical systems were developed for use in [38] and later used in [39].

Table 30. Three Typical 480-V Building Systems

Capacity	Low	Medium	Higher
Utility System kVA and X/R	100,000kVA X/R=6	250,000kVA X/R=8	500,000kVA X/R=10
Utility Transformer kVA and X/R (%Z = 5.32)	750 kVA X/R=5.7	1,500 kVA X/R=8.1	2,500 kVA X/R=8.3
Main Feeder (40') Conductor Size and Conduit	4 sets 4 #350 kcmil, 3" conduit	6 sets 4 #400 kcmil, 3" conduit	11 sets 4 #500 kcmil, 3" conduit
Service Entrance Rating (A)	1,200	2,000	4,000
Service Entrance Impedance	19.1mΩ, X/R=5.3	9.37mΩ, X/R=7.1	5.51mΩ, X/R=7.5
Available 3-phase RMS Isc (A)	14,528	29,578	50,304
IEEE 1584-2002 Iarc (A) [a]	8,610	15,575	24,249

[a] 1584 Iarc based on arcing in an enclosure and an arc gap width of 1.25".

capacity systems. The available three-phase, RMS short-circuit currents are determined from the following equations:

$$Isc_{secondary} = \frac{120}{Z_{secondary}}$$

$$Z_{transformer} = \left(\frac{208^2}{VA\ Rating}\right) \cdot \left(\frac{\%Z_{transf}}{100}\right) \cdot \left(\cos\left(\arctan\left(\frac{X}{R}\right)_{transf}\right) + jsin\left(\arctan\left(\frac{X}{R}\right)_{transf}\right)\right)$$

$$Z_{secondary} = Z_{up\ to\ transformer} \cdot \left(\frac{208}{480}\right)^2 + Z_{transformer}$$

Some values associated the transformer impedance calculation are included in Table 31, based on Eaton 480Δ-208Y V, 150°C rise transformers[23] with aluminum windings rated from 15 to 300 kVA.

The impedance of the transformer has a far more limiting effect on the available fault current than the impedance of the electrical system up to the location of the transformer for the three typical systems in Table 30. (The system impedances referred to the transformer secondary are 3.58, 1.76, and 1.03 mΩ, respectively.) For the transformers rated up to 112.5 kVA, the available three-phase, short-circuit current does not even reach 7 kA. At higher transformer ratings (150 kVA and higher) in Figure 36, the transformer impedance decreases and the limiting effect of the electrical system impedance on the available short-circuit current becomes more evident in lower and medium capacity systems.

[23] In email dated November 29, 2016, Robert Yanniello attached excel file "Tech Data as 06-06- 2016," providing Eaton transformer %Z, X, and R (all at Trise +20°C) data.

Table 31. Impedance for 480Δ-208Y/120 V, 150°C Rise, 15 – 300 kVA Transformers

kVA Rating	%Impedance	X/R	Impedance (mΩ)*	Catalog Number
15	3.74	0.50	107.9	V48M28T15EE
30	2.44	0.48	35.2	V48M28T30EE
45	3.51	0.97	33.7	V48M28T45EE
75	3.61	1.31	20.8	V48M28T75EE
112.5	4.37	1.92	16.8	V48M28T12EE
150	3.46	1.72	10.0	V48M28T49EE
225	4.29	2.86	8.2	V48M28T22EE
300	4.45	2.62	6.4	V48M28T33EE

*The magnitude of the transformer impedance is with respect to the secondary winding.

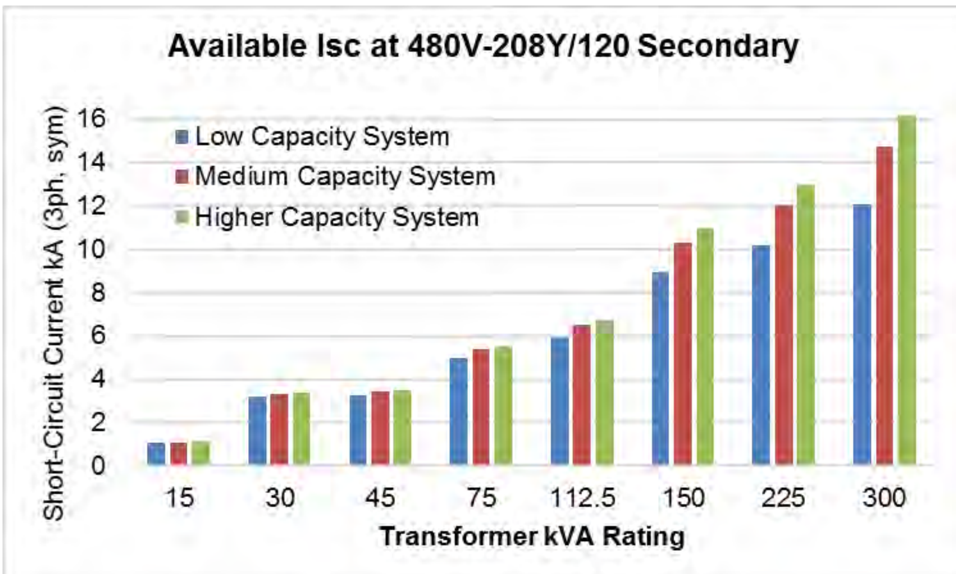


Figure 36. Available Short-Circuit Current at Transformer Secondary in Typical Systems

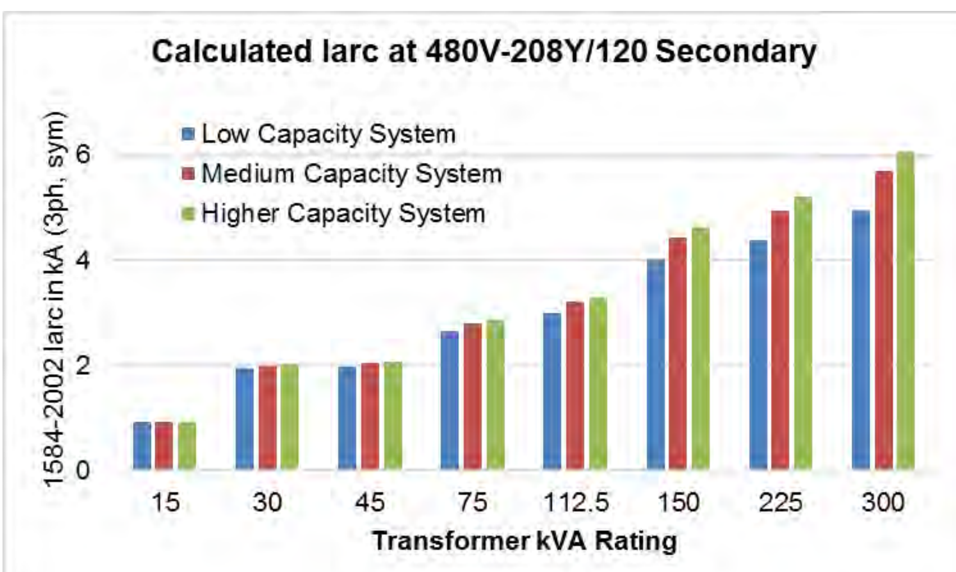


Figure 37. 1584-2002 Arc Current at Transformer Secondary in Typical Systems

The three-phase arc currents have been calculated using the IEEE 1584-2002 [40] arc current model based on a three-phase voltage of 208 V and a gap width of 1 inch in an enclosure. The calculated arc current at the transformer secondary only exceeds 6 kA (6,075 A) for the 300 kVA transformer in the higher capacity system. Furthermore, the 1584-2002 arc current equation tends to overpredict low-voltage, low-magnitude arcing faults currents. In addition, it is difficult to sustain arcing at 208 V (three-phase), especially for lower-magnitude short-circuit currents, wider gaps (including 1 inch), and equipment configurations which do not create a protected space that can be easily ionized.

Moreover, the greatest threat posed by electrical arc flash hazards is burn injury. Burn injury not only depends on the total incident energy but also depends on the rate of heat transfer. The heat flux of lower-magnitude arc currents is less intense, and heat is lost in the vicinity of the arc. The 1584-2002 calculated incident energies after 100 ms are displayed in Figure 38. The calculated incident energies at a distance of 18” are based on a panel configuration in a grounded electrical system. The calculated incident energies (which inherently assumes a sustainable arc) do not reach 2 cal/cm^2 even for a 300 kVA transformer in a higher capacity system.

Figures 37 and 38 demonstrate that “oversizing” in-house 480-208Y/120 V transformers one size higher does not pose a significant risk of the arc flash hazard generated at the transformer secondary. For electrical systems in commercial buildings, the service transformer size is typically determined by or negotiated with the electric utility provider. Tables 19 and 20

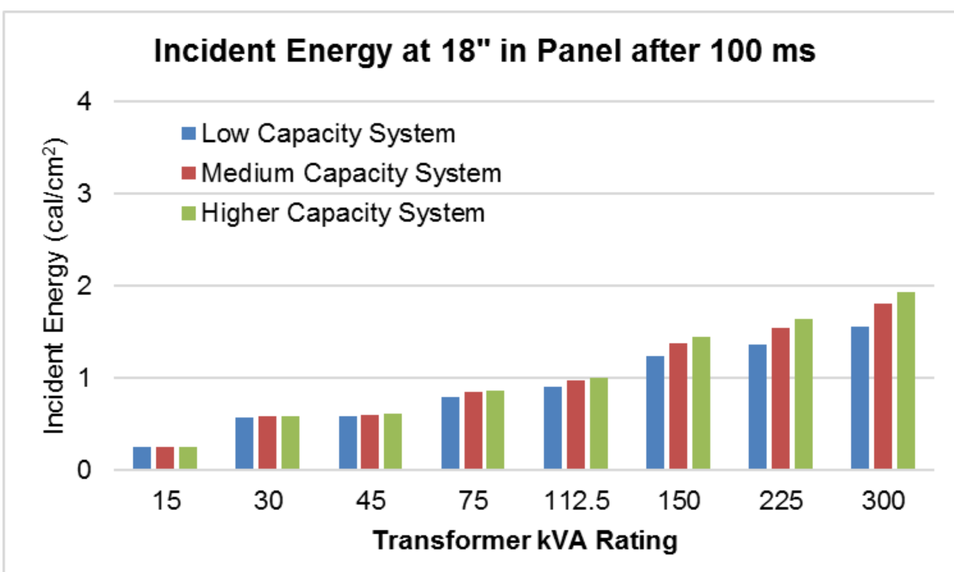


Figure 38. 1584-2002 Incident Energy after 100 ms at Secondary in Typical Systems

illustrated that electric utilities may size transformers based on different capacity requirements and different demand factors than established in the National Electrical Code.

8 DATA COLLECTION AND ANALYSIS PLAN FOR EVALUATION OF ELECTRICAL FEEDER AND BRANCH CIRCUIT LOADING PROJECT PHASE II

8.1 Motivation for Project

Although electrical systems are utilized from the bottom up, they are designed from the top down. When a building is constructed, the transformer supplying the main feeder is installed before the procurement of all electrical equipment serving the building. Engineers determine the building power requirements based on the connected and demand load calculations subdivided into the following (or similar) categories:

- Receptacle Lighting Heat Cooling Motor Other Spare

The “Heat” load might consist of electric heating elements in the HVAC system, permanent space heating, and water heaters. In a commercial building, the “Motor” load might include elevators, exhaust fans, and pumps required for building function. The “Other” load might consist of any dedicated building equipment identified early in the design process. The “Heat,” “Cooling,” “Motor” and “Other” loads are based on known building service demands. The power required for these loads may be determined from the specified equipment or estimated from other equipment capable of meeting the service demand.

Spare capacity may be added to one or all building panels to accommodate both anticipated and unforeseen additional load growth. Panel and feeder sizing are based on the demand power requirements and often include spare capacity.

Branch circuit requirements for receptacle load power density are specified in NEC 220.14. The receptacle load is calculated at 180 VA for each single or multiple receptacles on one yolk. Equipment with four or more outlets is calculated at a minimum of 90 VA per receptacle. For feeder and service-load calculations, NEC 220.44 permits that the receptacle demand load may be calculated as 100% of the first 10 kVA plus 50% of the remaining kVA. Many practicing engineers question the 180 VA design requirement in today’s changing technology market and with changing receptacle usage. Moreover, the NEC 180 VA requirement dates back 1937. The National Electrical Code has been adopted statewide in 47 states, and its enforcement lies upon the authority having jurisdiction. However, even engineers in areas with statewide adoption have been known to not always adhere to the NEC. A review of a few sets of electrical plans uncovered three variations of the NEC feeder and service-load receptacle calculations, in addition to engineering judgment in the branch circuit design.

Like heat, cooling, motor, and other loads, lighting fixtures are fixed loads with specific power requirements. The Illumination Engineering Society has set guidelines on the illumination levels required to adequately light a space for specific work tasks. Engineers and lighting designers design fixture layouts to provide adequate illumination levels. But it has also been estimated that up to 40% of all lighting projects are designed by electrical contractors.[24] The NEC specifies the minimum lighting load power density by occupancy type in Table 220.12 and included as Table 32 here.[25] As Table 32 illustrates, the load requirements have largely been in effect since at least 1968 with few modifications, yet lighting technologies have advanced and become much more energy efficient in the last fifty years.

Table 32. NEC (VA/ft^2) and ASHRAE 90.1 (W/ft^2) Lighting Power Density by Occupancy

Type of Occupancy	NEC 1968	NEC 1971	NEC 1981	NEC 2017	90.1-2004	90.1-2013
Armories and auditoriums	1			1		
Banks	2	5	3½	3½		
Barbershops & beauty parlors	3			3		
Churches	1			1	1.3	1
Clubs	2			2		
Courtrooms	2			2	1.2	1.01
Dwelling Units	3			3		
Garages – commercial (storage)	½			½		
Hospitals	2			2	1.2	0.94
Hotels, motels & apts. (no cooking)	2			2	1	0.87
Industrial commercial (loft) bldgs.	2			2		
Lodge rooms	1½			1½		
Office buildings	5		3½	3½	1	0.82
Restaurants	2			2	1.4	0.9
Schools	3			3	1.2	0.87
Stores	3			3	1.5	1.26
Warehouses (storage)	¼			¼	0.8	0.66
Assembly halls, & auditoriums*	1			1		
Halls, corridors, closets, & stairways*	½			½		
Storage spaces*	¼			¼		
***Except in individual dwelling units**						

[24] Statement made in email from Mark Lien, Illumination Engineering Society (IES) Industry Relations Manager, September 9, 2016.
[25] Table 32 is identical to Table 22. Section 8, the data collection plan, has been written as a separate document which can be reviewed independently of earlier report Sections 1 – 7.

The commercial reference building model for new construction, developed for the U.S. Department of Energy, uses the lighting power densities of ASHRAE 90.1-2004. Lighting power densities for ASHRAE 90.1 building area types equivalent to NEC occupancy types are listed in Table 32 for comparison purposes. The lighting power densities of ASHRAE 90.1-2013 and even 90.1-2004 differ significantly from the 2017 NEC.

Two exceptions to the NEC lighting power density requirements are permitted. The 2014 edition permitted an exception if the building complies with local energy codes and a monitoring system is installed. In the 2017 NEC, the lighting load specified by Table 220.12 for office and bank areas may be *reduced by* 1 VA/ft^2 when the local authority has adopted an energy code specifying an overall lighting density less than 1.2 VA/ft^2. At least 45 states have energy conservation codes in effect. California has its own state code, and part of Hawaii has a locally adopted code. Other states except Vermont have adopted ASHRAE 90.1-2004 or a later edition. In many states, the adopted energy codes are not enforced. However, even before state adoption of NEC's 2014 edition, engineers in various areas nationwide have based lighting power density requirements on local energy conservation codes (and therefore likely lower than NEC requirements).

The National Electrical Code may be considered the Gold Standard for the design and installation of electrical equipment. For the NEC to remain the unrefuted standard nationwide, the requirements of the NEC must be well-founded and up-to-date with today's technology and building design. At one time, the NEC focused exclusively on the design and installation of electrical equipment. Today it also encompasses safety issues addressed by NFPA 70E, *Standard for Electrical Safety in the Workplace*; these issues include electric shock, arc flash hazards, and other forms of electrical injury. Recent NEC 2017 exceptions in Section 220.12 demonstrate that the NEC is also becoming responsive to growing national concern for energy conservation.

U.S. government passed its first energy policy act in 1975. Since the Energy Policy Act of 1992, the U.S. Department of Energy (DOE) has taken an active role in the development, adoption, and impact analysis of model building energy conservation codes. The DOE also establishes minimum efficiency standards for appliances and equipment, which includes mandating greater efficiency requirements for transformers effective January 2016. For several years, government entities and electric utility providers have publicized the energy saving benefits of replacing older electrical equipment, including transformers and lighting fixtures, with new more energy efficient equipment. Financial incentives are often given.

There has been recent interest in “rightsizing” transformers to reduce energy losses associated with older oversized transformers. A 1999 Cadmus study of in-house low-voltage dry-type transformers found the average RMS loading of transformers at 16% of capacity [32]. A Navigant study on miscellaneous electric loads (MELs) estimated 43 TW-hours of energy loss generated by low-voltage dry-type transformers in commercial buildings in 2011 [8]; this transformer energy loss was higher than the energy consumption of any of the other thirteen MELs in the study.

Environmental science focuses on the importance of sustainability in new building construction. Sustainability is becoming a more important issue in the electrical system design in buildings. Specifying oversized electrical equipment might be viewed as wasteful of national and planetary resources. “Rightsizing” equipment may save in capital investment. Excess capacity may lead to higher available fault current and concern has been expressed about the potential for greater electrical safety hazards, including arc flash hazards.

The intent of this research study is to evaluate electrical feeder and branch circuit loading given present NEC requirements, electrical safety, and energy conservation and sustainability issues.

The lighting and receptacle loads are of particular interest because of the long-standing minimum power densities established by the NEC. The lighting and receptacle load power densities in new building construction need to be measured to ensure that the NEC requirements reflect today’s technology and usage in building spaces. However, design requirements for receptacle power density (which is not a “fixed” load) also need to accommodate the anticipated future growth in plug-loads and the development of unforeseen new types of plug-loads over the life cycle of the building.

Finally, many commercial buildings are provided 480 V which is stepped down to 208Y-120 V by in-house transformers. The research project recommends monitoring load levels on all transformers within the building and supplying the main service.

8.2 Relevance of Project Focus

In June 2016, electric utilities had close to 150 million customer accounts, including 18.3 million commercial accounts. Assuming each customer has at least one electrical service feeder, the number of service feeders must be close to 150 million and the numbers of distribution feeders and branch circuits must exceed a billion. Feeders and branch circuits might be considered pipelines for electricity. In 2015, residential, commercial, and industrial sectors purchased over 3.7 trillion kW-hours of electricity.

The U.S. Energy Information Administration (EIA) estimated that, in 2012 in the United States, there were close to 5.6 million commercial buildings with a total floor space over 87 billion square feet. The EIA also estimated that lighting accounted for 17% of all electricity consumption; furthermore, miscellaneous electric loads including computing and office equipment accounted for 32% of the total electricity consumption. In the 2012 Commercial Building Energy Consumption Survey (CBECS) funded by the EIA, office buildings alone accounted for 19% of the total number of commercial buildings, 19% of the total floor space, and 20% of electricity consumption.

A study on the electrical feeder and branch circuit loading in commercial buildings will provide substantive data, more valuable than estimation, on the major and minor end-use loads in commercial buildings in the U.S. The average age of a commercial building is 32 years. The results of this project may also serve as an impetus for retrofitting equipment to realize energy savings and quality enhancements. In addition, new data on transformer loading and measured power losses of working transformers might warrant a reassessment of the transformer efficiency test procedures specified by the U.S. Department of Energy. The results from this project will provide NEC code-making panels data to reassess current NEC branch-circuit, feeder, and service load calculations, particularly for lighting and receptacle load. The results of this project may stimulate additional national, standards, and professional group discussion on energy conservation and sustainability, specifically regarding building electrical systems.

8.3 Selection of Study Type and Participating Study Buildings

8.3.1 Objective

The objective is to locate fifty[26] commercial buildings where electrical feeder loading can be monitored for one calendar year. Previous studies in the reliability of electrical equipment found that at least forty samples were needed for the results to be statistically meaningful [41]. Ten additional office buildings have been added to enhance the statistical value and to compensate

[26] In December 21, 2016 email, Bob Arno stated: “I do have one concern minor in nature, I would target double the facilities for data collection in the anticipation of achieving solid data on 50. I know this will add additional cost but anticipating equipment failure, facility pullout, Murphy’s law, this is an effort you will want to do only once with positive results.” The report author agrees that monitoring additional sites will enhance the value of the data collected. It will be left to Phase II project personnel to double the sites monitored if resources are available.

for any sites withdrawing, data being lost, or any unforeseen event which might reduce the value of the building's contribution to the study.

8.3.2 Types of Commercial Buildings

Three potential groups of commercial buildings have been identified for study. The group selected for study may depend on budget, interest, and Phase II sponsorship.

8.3.2.1 Commercial Building Type Option 1 Study

- Fifteen of the Sixteen Commercial Building Types as identified in the 2012 CBECS
    - 192 buildings total -- 12 for each of type except offices and none for vacant
    - 12 for office buildings up to 50,000 ft^2 and 12 for those over 50,000 ft^2

An electrical feeder and branch circuit loading study is needed for different types of commercial buildings. The 2012 CBECS, costing in the tens of millions, collected detailed information about 6,720 commercial buildings to project the energy consumed by major and minor end-use loads in all commercial buildings. Although the study collects information about building electricity usage, the specific energy consumption of end-use loads is not measured; it is estimated based on survey information about building HVAC equipment, lighting types, general numbers of computer and office equipment, etc.

The U.S. Department of Energy has developed its Commercial Building Reference Models from the 2003 CBECS and information found in ASHRAE standards. The U.S. Department of Energy, the U.S. Energy Administration (a sector of the DOE), and standards need data on the electricity consumption of specific load types in all commercial building types. The U.S. government might use this information to help shape energy policies and to develop more accurate models for electricity consumption. Consumption data on heating, cooling, ventilation, and refrigeration equipment would shed light on demand and mean power consumption with respect to “nameplate” requirements, building needs, and electrical system design requirements. Inventory information and nameplate power requirements for lighting and receptacles would shed light on usage and power demand requirements.

Furthermore, the U.S. Department of Energy mandates efficiency requirements and defines test procedures for measuring distribution transformer energy loss in the Code of Federal Regulations. Transformer efficiency is a function of transformer loading; 10 CFR §431.196 specifies transformer loading during the testing at 35% of rated load. If 35% loading is not representative of transformer loading, the DOE test procedure may not provide a good assessment of energy loss in working transformers.

Different building types may have different load profiles and transformer loading.

8.3.2.2 Commercial Building Type Option 2 Study

- Large University Campuses
  - 137 commercial buildings, with a focus on 50 office buildings as follows:
  - 25 offices up to 50,000 ft^2 and 25 offices over 50,000 ft^2
  - 25 residence halls, 25 education buildings, 25 laboratories, 12 hospitals

Large university complexes might benefit from this study on electrical feeder and branch circuit loading because the results might help bring about changes in standards which might ultimately reduce capital investment in new construction. Results may also provide evidence for realizing energy savings through decisions to retrofit older, lossy equipment. Older equipment also has a higher probability of failing, interrupting service, and even starting a fire; furthermore, it is more likely to pose an electrical hazard not only to maintenance workers but also to end users, including students. New equipment may also bring additional benefits such as improved lighting quality.

8.3.2.3 Commercial Building Type Option 3 Study

- Fifty Commercial Office Buildings
  - 25 offices up to 50,000 ft^2, ideally equally divided into three groups: 1,000-10,000 ft^2, 10,000-25,000 ft^2, and 25,000-50,000 ft^2
  - 25 offices over 50,000 ft^2, ideally with 10 offices over 100,000 ft^2 and 5 over 200,000 ft^2

The Request for Proposal issued by for the Fire Protection Research Foundation stated the initial focus was commercial office occupancies.

8.3.3 Geographic Distribution of Study Buildings

The monitoring sites should be selected to represent different climate zones, time zones, and Census regions. Many aspects of climate can influence daily power requirements, including temperature, humidity, precipitation, cloud cover, and winds. In offices conducting interstate business, time zones might influence operating hours. In different regions of the country, building construction and engineering design practices may differ due to climate differences and local building and energy conversation codes.

Site locations should be selected to represent each IECC climate region shown in Figure 39[27], but a higher percentage of monitoring sites should be concentrated in climate zones with higher population densities which also have greater building densities. A population density map produced by the United States Census Bureau has been attached as Appendix A.

[27] Figure 39 is identical to Figure 4. See footnote 26.

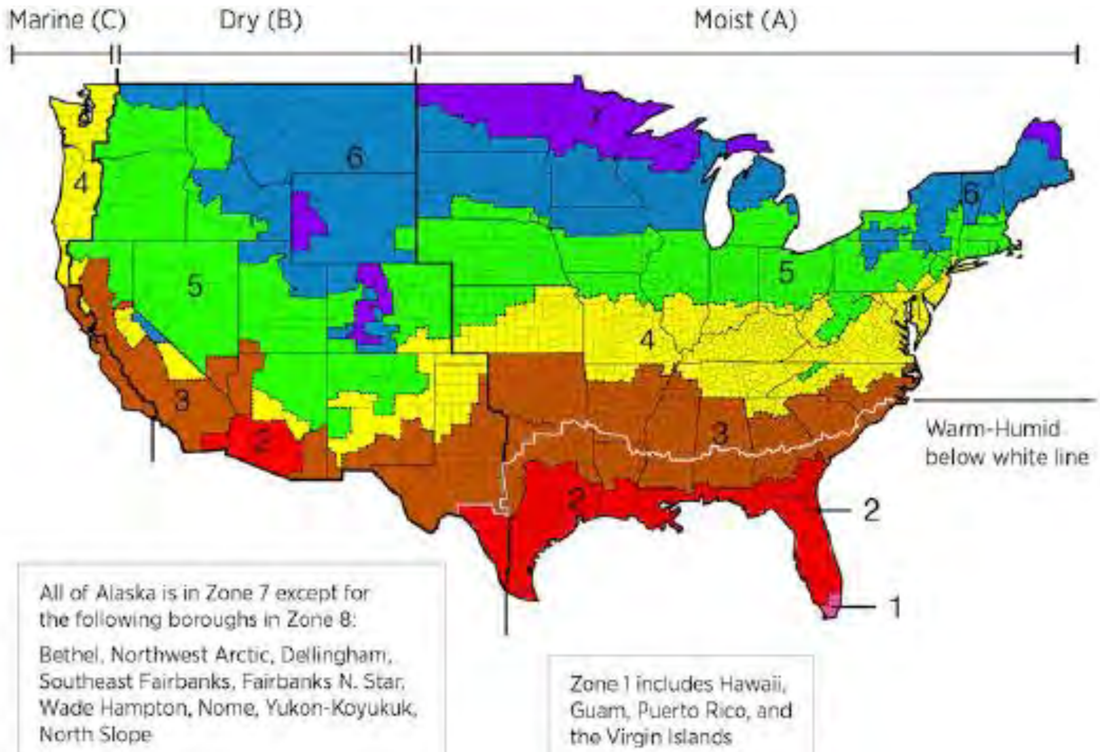


Figure 39. IECC Climate Regions in the U.S.
(Source: U.S. Department of Energy, and reference [4])

Table 33. Geographic Selection and Number of Monitoring Sites

	13 IECC Zones	3 DOE Added	Most Populated City	Office	Residence Halls	Education	Labs	Hospitals
1	1		Miami	1				
2	2A		Houston	5	4	4	4	2
3	2B		Phoenix	2				
4	3A		Atlanta	5	3	3	3	1
5	3B	Other	Las Vegas	3				
6	3B	CA-coast	Los Angeles	3	4	4	4	2
7	3C		San Francisco	3				
8	4A		Baltimore	7	4	4	4	2
9	4B		Albuquerque	1	2	2	2	1
10	4C		Seattle	3				
11	5	5A	Chicago	7	4	4	4	2
12	5	5B	Denver	4	2	2	2	1
13	6	6A	Minneapolis	3				
14	6	6B	Helena, MT	1	2	2	2	1
15	7		Duluth, MN	1				
16	8		Fairbanks, AK	1				
			Total	50	25	25	25	12

The distribution of site selection is suggested in Table 33, modeling a study focusing on university campuses (Building Type Option 2). If all major commercial building types (Building Type Option 1) are selected for study, the geographic distribution for each building type should be similar to the distribution for the hospital geographic distribution in the table. If the commercial office building study (Building Type Option 3) is conducted, office buildings should be selected as in Table 33. Ideally, site selection for the two main groups of 25 office buildings (based on size) should be distributed as residence halls, education, or laboratories in the table.

8.3.4 Criteria for Building Selection

Prospective buildings should be less than three years old (preferably two) with all equipment installed and operating. The building should be functioning at designed capacity (regarding building function, the number of employees, etc.). Prospective buildings should submit electrical plans, including panel schedules and riser diagram.

Site selection should be based on the disaggregation of loads so that the power consumption of different load types can be determined. Figure 40 illustrates feeder monitoring when load types are disaggregated at the main switchboard (a site ranked "optimal"). Buildings with electrical system riser diagrams similar to Figure 40[28] are likely to be equipped with building automation systems and advanced metering systems to monitor power requirements and energy consumption. Figure 40 is the ideal candidate for System Monitoring Option 1 or 2, discussed in Section 8.4. System Monitoring Option 1 or 2 may also be feasible for an electrical system with a riser diagram similar to Figure 41, which may be ranked "optimal" or "good." However, monitoring and personnel resources for data collection will be more intensive and expensive.

Sites with a riser diagram similar to Figure 42 may be ranked "acceptable." For illustration purposes, Monitoring System Option 3, monitoring receptacle and lighting loads, is shown in Figures 41, 42, and 43. Prospective buildings with riser diagrams similar to Figure 43 do not rank "optimal," "good," or "acceptable." Ideally, such buildings should not be selected for monitoring. However, such buildings may provide some limited data as shown in Figure 43, if building owners are willing to provide it and research funding is limited. However, metrics such as average or demand lighting or receptacle power density for the building cannot be determined from partial building data and utilization levels in specific building zones vary.

---

[28] In reviewing the draft report, Bob Wajnryb, Senior Electrical Engineer at The Ohio State University, stated in an email dated December 16, 2016: "Based on personal experience, Figure 40 does not often occur." The report author agrees.

8.3.4.1 Ranking Prospective Sites

- Optimal – All lighting and receptacle loads on dedicated panels
- Good – 90% of all lighting and receptacle loads in building are on dedicated panels
- Good – Panels with receptacle and lighting loads are 90% dedicated to respective load
- Acceptable – 80% of all lighting and receptacle loads in building are on dedicated panels
- Acceptable – Panels with receptacle and lighting loads are 80% dedicated

8.3.4.2 Additional Consideration Factors in Site Selection

- Building size
- Building service voltage
- Monitoring resources (number, type, and cost) required for building study
- Number of in-house transformers and their rating
- Primary energy sources for heating, cooling, and hot water

Ideally, selected buildings will have management and contact personnell interested in participating in the project and willing to assist.

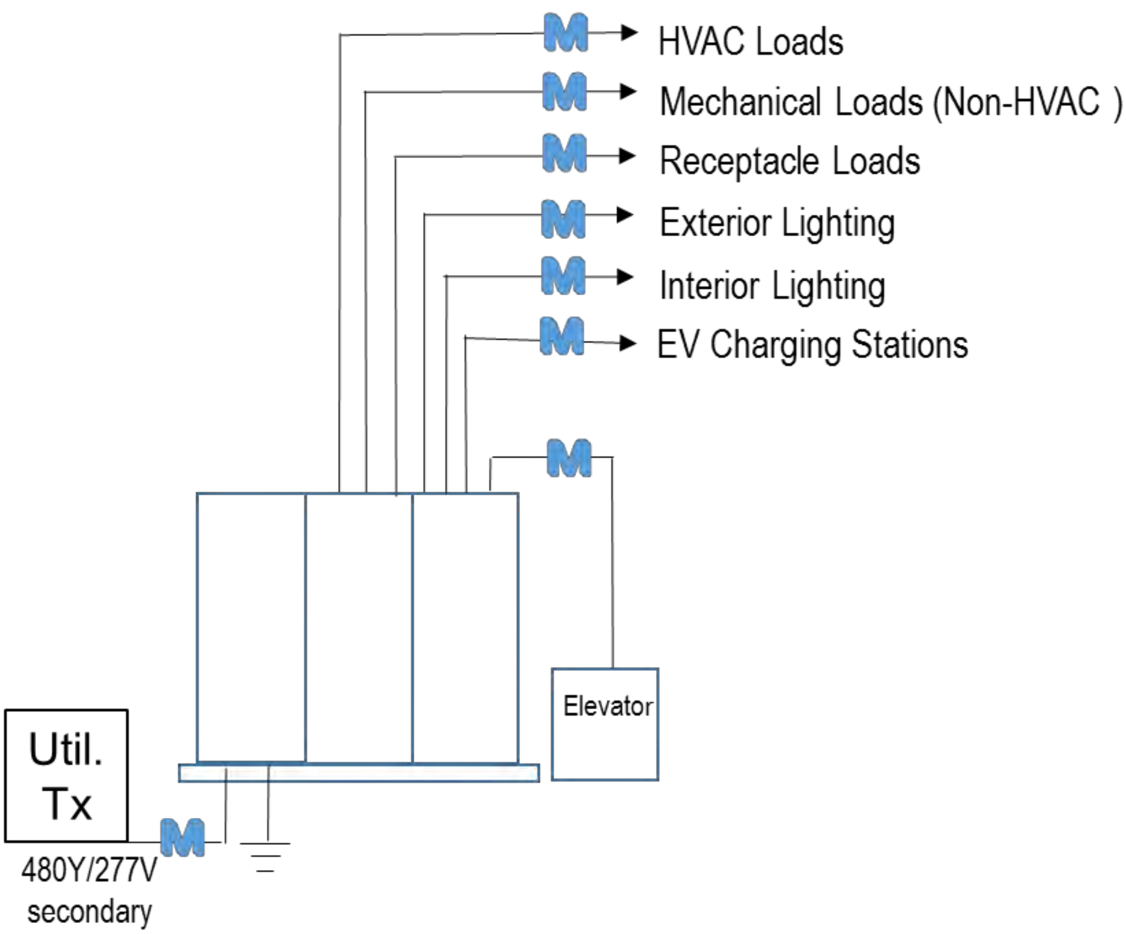


Figure 40. Monitoring Optimal Site with Load Separation

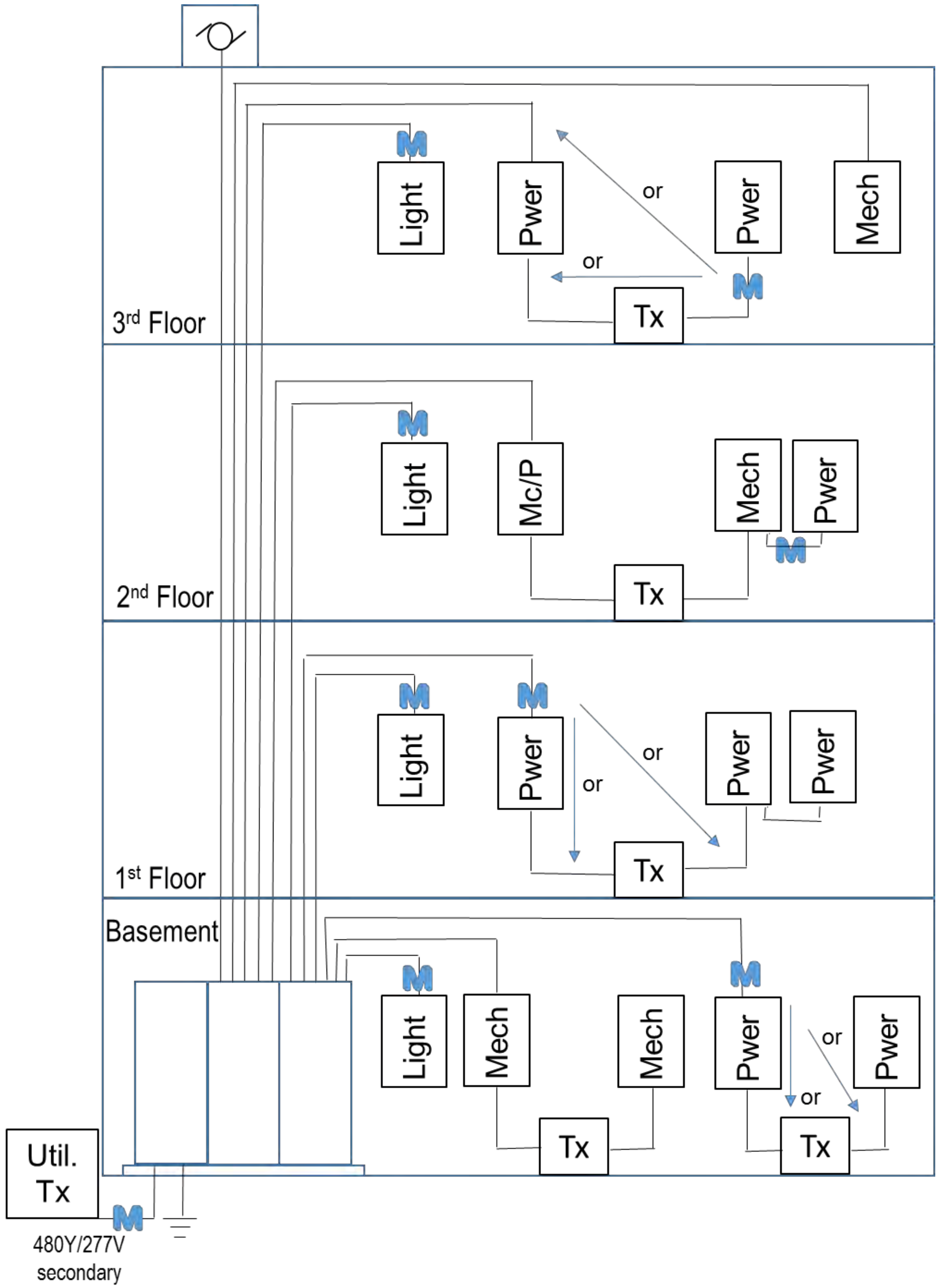


Figure 41. Monitoring “Good” or “Optimal" Site

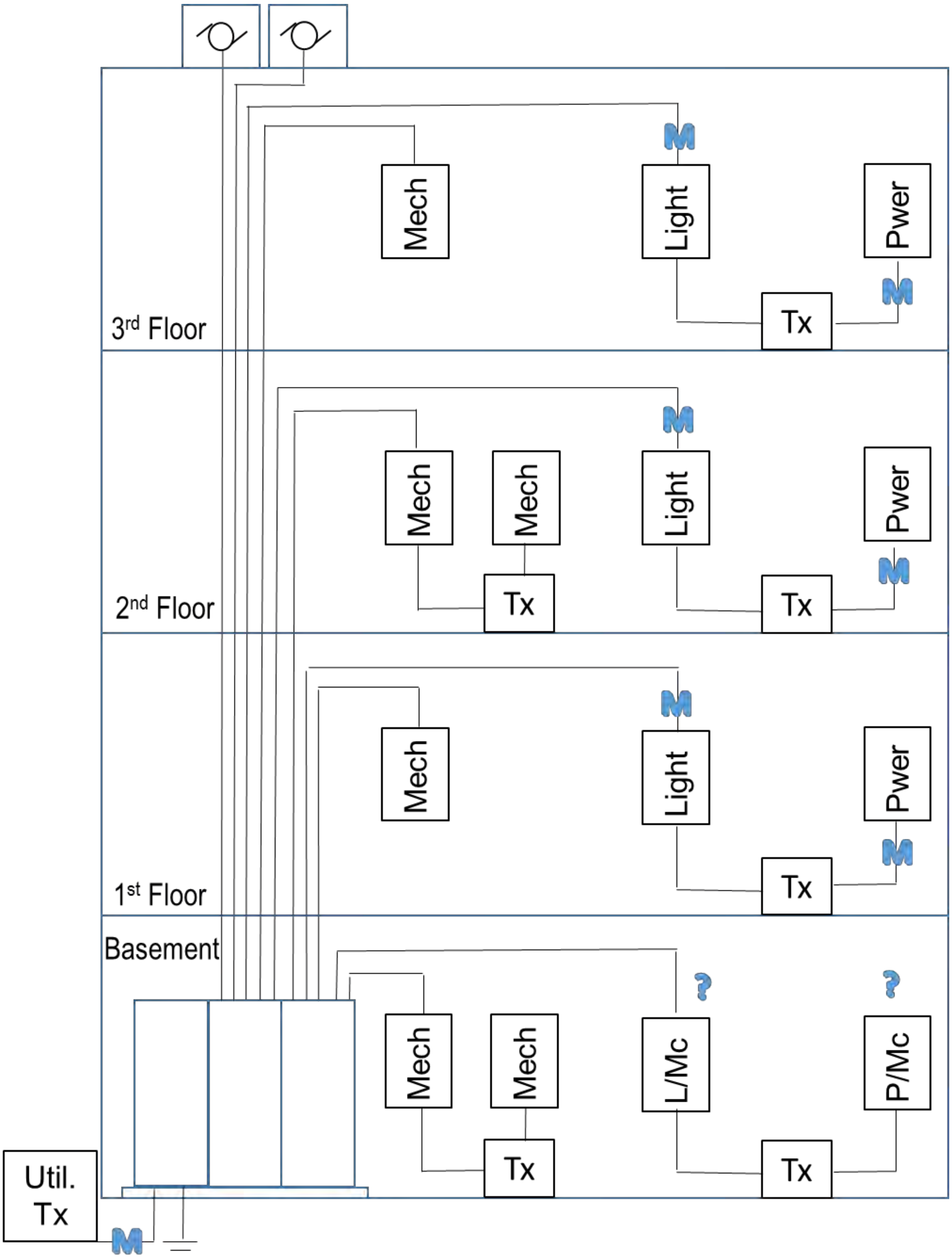


Figure 42. Monitoring Acceptable Site

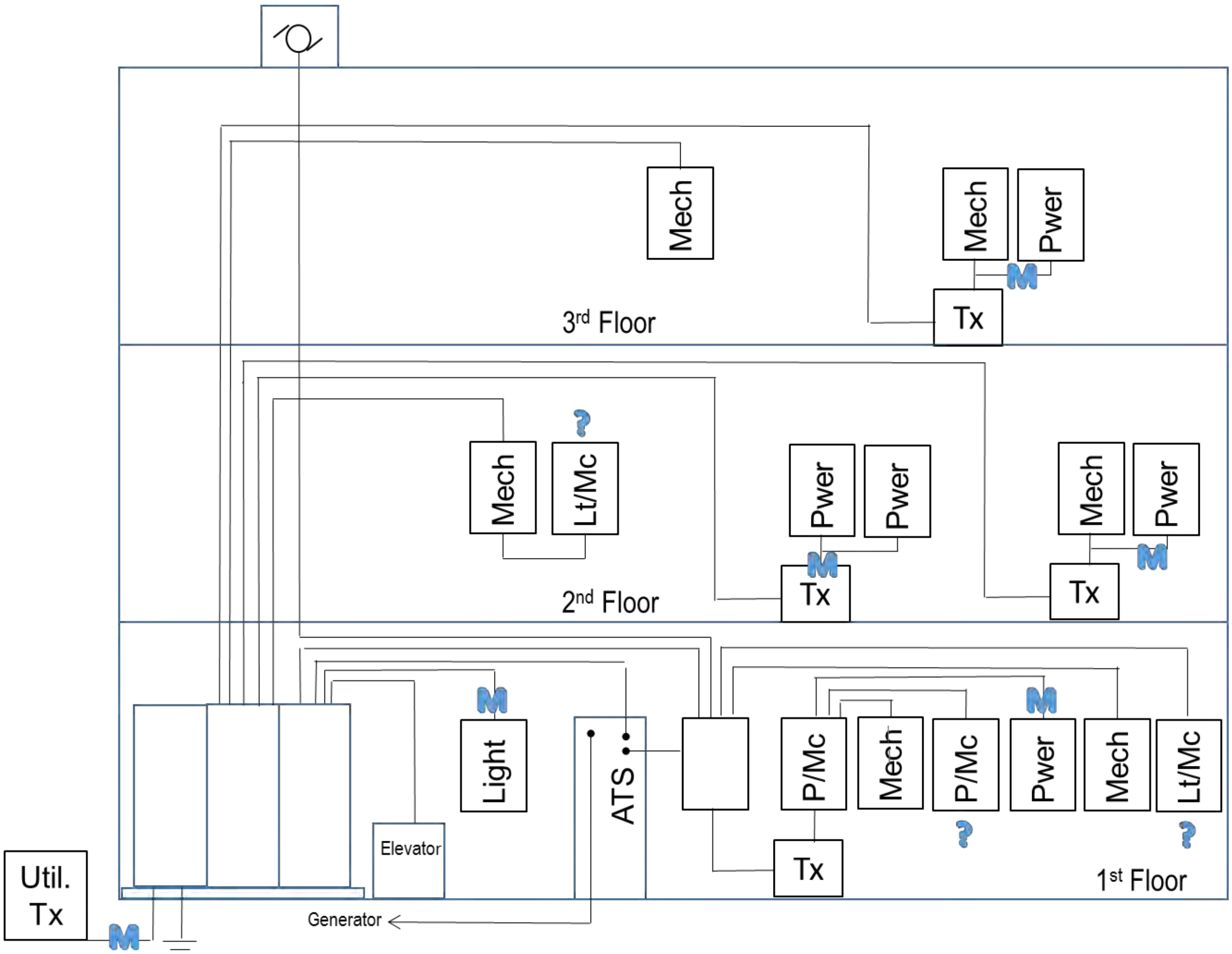


Figure 43. Monitoring a Site Not Meeting "Optimal," "Good," or "Acceptable" Ranking

8.3.5 Required Building Documents and Information[29]

1. Electrical plans, including outdoor lighting plan and lighting fixture schedule
2. For all on-site transformers, the following nameplate information: manufacturer name, model, and date; capacity; type (temperature rise); impedance; K-factor rating; primary and secondary voltages (and currents where specified); primary and secondary winding connection type
3. Mechanical plans with detailed HVAC and other mechanical equipment load information (including manufacturer and model information) for mechanical loads powered by electricity

[29] Bob Yanniello commented in December 15, 2016 email: "This is certainly a very inclusive list. Upon seeing it, I question if we could ever afford to capture it for the number of sites we felt were needed for a statistically accurate sample size." The report author has attempted include as much detail as possible. Phase II project personnel should omit details which are not considered essential at that time.

4. Two-years of utility load data (including the year which monitoring takes place)
5. Building size (should be included on drawings)
6. General description of building function and how employees carry out work (in an office building, if work primarily conducted through telephone and computer use, do employee tasks involve engaging with the general public, etc.)
7. Photos of the building, representative interior spaces, and major equipment including the parking lot, main entry, office areas, reception area, breakroom or kitchen, corridor, server/IT room, mechanical and electrical room, RTUs, transformers, etc.
8. Numbers of full-time and part-time employees and the target number of employees (with quarterly updates during the monitoring period). Additional employee demographics on age, gender, and race desirable if available.
9. If other buildings in addition to offices are selected for study, additional building benchmark information will need to be provided. For example, hospitals would need to provide the number of beds and monthly reports on utilization. Educational buildings would need to provide student capacity and utilization.
10. Building operation and maintenance manuals
11. General building operating schedule and fixed or flex employee work hours on weekdays and weekends
12. General building schedules for heating, cooling, and ventilation (automatic, occupancy sensing or manual, location specific; fixed by time of day, day of week, season; determined by employee comfort or directly controlled by employees)
13. Schedule for lighting operation (automatic, occupancy sensing, or manual, fixed by time of day, day of week, season)
14. Schedule and response time of any automatic or occupancy sensor controlled receptacles
15. Any building policies for turning off office equipment, computers, and monitors during weekdays, evenings, or weekends
16. Inventory of items connected to receptacles (including manufacturer name and year, model, power requirements if available). Receptacle inventories should be labeled by building floor and space areas (as can be identified on building plans). Inventories can be self-reported by employees (including cleaning and maintenance staff) and updated or verified quarterly. The inventory list should also contain corded-equipment or tools (such as vacuum cleaners and drills) which are connected to receptacles on an as-need basis.
17. Any energy conservation codes or standards to which building was constructed (should be included in drawings)

8.3.5.1 Collection of Building Information

Project management will generate form documents to collect building information from building contact personnel. Preferred document form is an Excel file for easy organization and analysis. Excel files might also be transformed for use in Access.

8.4 Site Monitoring

The request for proposal stated: “The goal of this project is to develop a data collection plan to provide statistically significant load data for a variety of occupancy and loading types to provide a technical basis for considering revisions to the feeder and branch circuit design requirements in the National Electrical Code.” A large-scale project to evaluate electrical feeder and branch circuit loading would be significantly enhanced by expanding the study to include harmonics, power quality, power reliability, and voltage stability issues.

8.4.1 System Monitoring Options

The extent of electrical system monitoring in the buildings selected to participate in the Phase II research project depends on the interests of the sponsors and funds raised. It also depends on the level of load disaggregation in the buildings selected for site monitoring and the presence of existing advanced metering systems. Five options for monitoring the electrical systems in the study buildings are presented in Table 34.

The subsequent paragraphs in this section discuss the data to be collected for System Monitoring Option 1, which will facilitate the greatest gain in knowledge for undertaking a research project of this magnitude. If one of the lesser monitoring options is selected, the extent of monitoring should be cut back as appropriate to the selected monitoring option and the capabilities of the monitoring equipment used in the study. Similarly, the discussion of

Table 34. System Monitoring Options for Study Buildings

	Five Options for System Monitoring
1	Monitor all loads, harmonics and neutral current measurements (at least spot) on transformers and receptacle panels; continuous or two-month monitoring or spot measurements on receptacle branch circuits; obtain detailed service data (power quality and reliability and voltage stability)
2	Monitor all loads
3	Monitor lighting and receptacle loads
4	Monitor receptacle (or lighting) load
5	Monitor receptacle load, including branch circuits, no restriction on building age

data analysis in Section 8.5 addresses System Monitoring Option 1. If one of the lesser monitoring options is selected, the data analysis will be more limited, based on the monitoring option selected and the data available for analysis.

The following require continuous one-year monitoring[30] of current, voltage, and power. Some project sponsors like government agencies may prefer monitoring all sites during a single calendar year beginning on January 1 and ending on December 31. Otherwise, it may be easier to begin monitoring once a suitable monitoring site has been identified and the site is ready to participate; conducted in this manner, the window of data collection for all sites should be 18 months or less.

- Main service feeder (may be provided as electric utility data, but need current and voltage harmonic content)
- All feeders supplying panels (will also provide information about transformer loading)
- All motor control centers
- All individual loads rated over 10 kVA, including any RTUs, elevator motors, dock equipment, water heaters, and large pumps. Exception: When HVAC equipment such as fan powered terminals and fixed space heating equipment are fed from a dedicated panel, monitoring the panel is sufficient.
- Also, current harmonics and power may be monitored on all feeders supplying transformers. (Power loss may be calculated as power supplied to feeder supplying transformer subtracted from power supplied to downstream feeder supplying panel.)

Ideally, the lighting panels would be dedicated to the lighting load. However, if other loads are fed from lighting panels, they should be continuously monitored individually, unless they represent less than 20% of the panel's demand load.

In larger buildings supplied by 480 V service equipment, 208 V panels primarily serve receptacle load. However, a wide range of miscellaneous equipment may also be served; these loads include ductless air conditioners and heat pumps, water heaters, low-voltage lighting, and smaller mechanical loads including dock equipment, pumps, fans, and electric vehicle charging stations. Ideally, the building will have low-voltage panels dedicated to receptacle load.

However, monitoring dedicated receptacle panels does not provide sufficient information about the power requirements of receptacle branch circuits. Receptacles are placed throughout buildings to provide convenient and easy access to electric power. In office buildings, receptacle locations include office areas, conference rooms, break rooms, kitchens, restrooms, hallways, reception areas, filing and storage rooms, server/IT rooms, and exercise rooms. Receptacle

---

[30] Robert Arno, Project Technical Panel member, believes one year of monitoring is required for scientifically valid data. Mr. Arno, a manager at Harris Corporation, is an IEEE Fellow and Chairman of the IEEE Standard 493, Gold Book.

load varies according to space, scheduling, time of day, and day of the week. It was concluded in [9] that plug-load monitoring for two[31] months was needed to provide a sound estimate of receptacle energy consumption. The report author initially suggested that branch circuits be monitored during the coldest months to capture portable heater usage and seasonal task lighting, although portable fans and dehumidifiers may be used during warmer months. However, project sponsors[32] have commented that space heaters are often used in warmer weather, and fans are used during winter months, depending on an individual's personal comfort level. Therefore, for accurate branch-circuit receptacle load measurements, it seems that one year of monitoring is necessary.

8.4.2 Monitoring Equipment

Monitoring equipment cannot be selected until after Phase II further develops. These developments must include the selection of commercial building study type and system monitoring option and on the amount of funds raised for the project. The selection of monitoring equipment depends on existing metering equipment already on site; it may also be constrained by the building electrical system and cooperation of the building owners and site personnel.

This section is intended to provide a preliminary look at some equipment types. Monitoring options provided by other manufacturers may be more desirable regarding capabilities, better pricing especially in large quantity, or even possible sponsorship through equipment donation. A more comprehensive study of monitoring equipment should be conducted after further development of the Phase II project. Four different metering devices have been included in the following bullet point list. Additional information published by the manufacturer about this equipment is included in Appendix B.

- Main Feeder Monitoring: GE EPM 4600 Multi-feed Power and Energy Metering System
    - Monitoring 6 feeders at main switchboard, estimated cost $6,200 plus roughly $75 per split-core current transformer ($75x3x6), total estimated[33] = $7,550
    - EPM 4600 also available for monitoring 8 feeders
    - Monitors phase and feeder – W, VA, VAR, current, voltage, power, power factor, and neutral current and frequency

[31] A plug-load study at Lawrence Berkeley National Labs [9] found that a 2-month study of plug-loads was long enough to estimate annual energy consumption with reasonable accuracy. The study monitored 455 plug loads for at least 6 months and many for over a year. The monitored plug-loads were selected from 4,454 inventoried plug-loads in an 89,500 square feet office building on site.

[32] In December 15, 2016 email, Robert Yanniello remarked that lighter summer clothing may cause some office employees to feel cold in air conditioning. In December 16, 2016 email, Bob Wajnryb stated, "Many times have come across space heaters in use in warm weather and fans in use in the cold weather depending on the individual."

[33] Cost provided by John Levine of Levine, Lectronics, and Lectric, Inc. in email on November 29, 2016.

  - Built-in RS-485 and USB communications; Ethernet and WiFi optional
  - Data logger for voltage, frequency, and energy usage at 15-minute intervals. May record for a minimum of 68 days to over a year, depending on options
- Panel Metering: Honeywell E-Mon Class 3400 Smart Meter[34] (and Data Logging)
  - Split core current sensors allow installation in existing systems
  - Stores kW and kVAR data for up to 72 days in 15-minute increments
  - Display also shows voltage, current, and power factor per phase
  - Built-in Ethernet and RS-485 Communications
  - Price: $950-$1,109 – for 200A and 400A 120/208V and 277/480V panels[35]
- Panel Metering: Onset Data Loggers for Real Power or Phase RMS Currents[36]
  - 250A Accu-CT split core current transformer, $45x3=$135
  - H22-001 Hobo Energy Logger $364, FlexSmart TRMS $95x2 = $190, USB Interface cable $59, estimated system cost = $748 for monitoring RMS three phase currents or $793 for RMS neutral current also
  - UX90-001 State logger $92, WattNote transducer for 208Y/120V panel $229, HOBOware Pro software $99, input voltage lead set $75, estimated system cost $630 for monitoring three-phase power
  - Length of data storage variable, likely over a year for three-phase power
- Panel and Branch Circuit Monitoring: GE ASPMETER-A Metering Panelboard
  - Monitors panel phase currents, voltages, powers, and pfs, also neutral current
  - Monitors panel kVA, total pf, average three-phase and phase voltages, frequency
  - Monitors branch circuit current, power, and power factor
  - MODBUS RTU Communication, sample frequency < 2 seconds
  - Panelboard with GE ASPMETER-A, B, or C options, approximate cost $6,250[37]

If loads are disaggregated at the main switchboard, as shown in Figure 40, the GE EPM 4600 metering system might be ideal. The EPM 4600 collects a wide range of measurements. It contains onboard memory for voltage and energy storage. More importantly, it should be fairly easy to establish communication with one central monitoring device so that the wide range of measurements can be accessed real time. For electrical safety reasons, the main switchboard would need to be shutdown to install the GE EPM 4600 in an existing switchboard.

For more limited panel metering, a trusted Honeywell E-Mon meter is a good option. In addition to kW and KVAR usage, the meter displays current, voltage, and power factor which could be transferred via a MODBUS (or other) communication protocol. If running communication lines is not feasible, at least real and reactive power consumption is stored in memory.

---

[34] Another manufacturing representative (not identified to protect privacy) remarked to the report author in December 2016 that for pricing and reliability, E-Mon devices are hard to beat.
[35] Quote provided by Jake Wamble at Mayer Electric, Marietta, GA on November 4, 2016.
[36] Quotes provided by Rebecca Fish from Onset Computer Corporation on December 14, 2016.
[37] Cost estimate provided by Michael Seal, GE Energy Connections, in email dated December 12, 2016.

Onset Computer Corporation data loggers may be a good option when running communication lines is not an option or economy is essential. For a cost of $630, the UX90 data logger should be able to store three-phase power measurements recorded at 15-minute intervals for over a year. The Onset H22 Energy logger can record a wide variety of measurements. It can be configured to store the three phase currents for $748, or $793 if the neutral current is added.

A panelboard monitoring system like the GE ASPMETER-A is an excellent device for monitoring current and power consumption at a panel's branch circuits and mains. The ASPMETER is not a data logger; therefore, communication would need to be established with the panel. The GE ASPMETER is a complete panelboard which would replace an existing panelboard in a building. Panelboard replacement may be an attractive option in older buildings on university campuses where the panelboard is old and valuable knowledge can be gained through the installation of a new panelboard. The GE ASPMETER-A or similar product would provide data for consideration of the NEC's general requirement of 180 VA per receptacle in branch-circuit load calculations.

8.4.3 Method of Data Collection on Site and to Project Personnel

The project should provide an internet location where each monitoring site can upload the requested documentation and information. If the data is not accessible to project personnel via the Internet, but instead is collected by on-site employees (by downloading from device storage or LAN), data should be uploaded monthly (or more frequently). In buildings equipped with advanced monitoring, real-time data may be accessible to project personnel via the Internet.

8.5 Data Analysis[38]

8.5.1 Evaluation of Lighting Load

1. Review electrical drawings and lighting schedule; note the primary type of lighting used in different building spaces.
2. Calculate building lighting power densities from connected and demand load on panel schedules. Compare with NEC lighting power density. (If time and building layout permit, calculating lighting power density for office area specifically may be a useful comparison.)

[38] Bob Yanniello commented in December 15, 2016 email: "…I question if we could actually fund such an exhaustive data analysis?" However, Bob Arno commented in December 21, 2016 email: "I think it will be very beneficial and not too costly to add in the power Reliability and Quality. This data will be beneficial to many areas of NFPA and other organizations."

3. Review measured data. Observe any hourly, weekly, and seasonal patterns. Record peak power. Calculate mean power and other useful statistics.
4. Compare measured data with panel schedule connected and demand load.
5. As feasible from measured data, calculate peak and mean lighting power densities. Compare with power densities in Step 2.

8.5.2 Evaluation of Receptacle Load

1. Review electrical drawings. As feasible with a time constraint, record the number of receptacles assigned to each branch circuit. Compare receptacle count with connected and demand load listed on receptacle panel and the main distribution panel schedules.
2. Review measured branch circuit and panel data. Observe any hourly, weekly, and seasonal patterns. Record peak power. Calculate mean power and other useful statistics. Identify any correlations between space type and branch circuit loading.
3. Compare measured data with panel schedule connected and demand load.
4. With results of Step 3, comment on NEC receptacle VA requirements and panel and main service receptacle load after receptacle demand factors applied.
5. Review receptacle inventory. As feasible and time permits, analyze power requirements of the inventoried plug-in equipment and compare with measured load and calculated load. Comment on NEC receptacle VA requirements.

8.5.3 Evaluation of Other Loads

1. Review electrical and mechanical drawings and panel schedules. Note presence or absence of electrical heating, cooling, and hot water equipment. Note connected and demand load for “large” loads (over 10kVA) and any panels which exclusively serve one type of equipment (other than lighting and receptacle).
2. As feasible, compare panel schedule connected and demand load requirements with power requirements listed on the mechanical schedule. (Ideally, these will be manufacturer requirements, if not look up manufacturer requirements as time constraints and feasibility permit).
3. Review measured data. Observe any hourly, weekly, and seasonal patterns. Record peak power. Calculate mean power and other useful statistics.
4. Compare measured data with panel connected and demand load, and also with manufacturer requirements for any “large” loads monitored.

8.5.4 Evaluation of In-House Feeder Sizing and Transformer Loading

1. Review and comment on transformer power loss with reference to expected efficiency based on DOE requirements. As feasible and time permits, compare measured losses with estimations based on standard transformer tables and efficiency curves.
2. Review and comment on harmonic content. Calculate K-factor, if not directly measured. Compare measured K-factor with transformer K-factor rating, and K-factor rating recommended for load type.
3. Compare NEC feeder size requirements with feeder size and peak and mean measured loading. Note impact of spare capacity added to panels.
4. Compare panel schedule connected and demand load on panel served by transformer with transformer capacity, and peak and mean transformer loading.

8.5.5 Evaluation of Main Feeder Size and Service Transformer Loading

1. Review and comment on transformer power loss with reference to expected efficiency based on DOE requirements. As feasible and time permits, compare measured losses with estimations based on standard transformer tables and efficiency curves.
2. Review and comment on harmonic content, including in the context of IEEE 519.
3. Calculate K-factor, if not directly measured. Compare measured K-factor with transformer K-factor rating, and K-factor rating recommended for building type.
4. Review the measured load data. Observe hourly, weekly, and seasonal patterns. Note if main service loading similar to previous year. Calculate peak and mean power density for the building.
5. Compare connected and demand power requirements of main service panel, feeder size, and transformer rating, and feeder size and transformer rating needed to meet peak power measured.

8.5.6 General Evaluation of Power Quality

1. Note any power interruptions and duration.
2. Review voltage data. Comment on voltage stiffness and relationship to levels established in ANSI C84.1. Note the presence and frequency of any voltage fluctuations, sags, or surges.
3. Review and comment on harmonic levels.

8.6 Deliverables

The final deliverables will be:

- The report containing an extensive loading evaluation of each site and a comparison of sites, noting commonalities and differences.
- An executive summary with a database or one more spreadsheets. Key site information will be provided, including square foot, year of construction, number of employees, DOE geographic region, service voltage, and energy source for heating, cooling and hot water. Other summary information will include mean and peak power consumption (W/ft^2) of lighting, receptacle, HVAC, and other loads as applicable. Transformer capacity and mean and peak power requirements will also be included.
- Individual site archives: all requested documentation and information and data.

8.7 Budget

The budget depends largely on research project sponsorship and the commercial building study type selected. If universities sponsor the project, provide the monitoring equipment, and provide a working staff to install the equipment and supervise data collection on site, the only out-of-pocket expense would be for project management. Project management costs might be estimated to cover a two-year period from project inception to delivery of the final report. Otherwise, depending on the project scale and the buildings selected for study, project costs could reach $1 or even $2 million.

9 REFERENCES

[1] U.S. Energy Information Administration (part of the U.S. Department of Energy), http://www.eia.gov/electricity/data.cfm.

[2] Michael Deru, Kristin Field, Daniel Studer, Kyle Benne, Brent Griffith, and Paul Torcellini (NREL), Bing Liu, Mark Halverson, Dave Winiarski, and Michael Rosenberg (PNNL), Mehry Yazdanian, Joe Huang, and Drury Crawley, *U.S. Department of Energy Commercial Reference Building Models of the National Building Stock,* NREL/TP-5500-46861, February 2011.

[3] Michael C. Baechler, Theresa L. Gilbride, Pam C. Cole, Marye G. Hefty, and Kathi Ruiz, Pacific Northwest National Laboratory, *Building America Best Practice Series Volume 7.3, High Performance Home Technologies: Guide to Determining Climate Regions by County*, August 2015, PNNL-17211 Rev. 3.

[4] Energy Vanguard *U.S. Climate Zones*, http://www.energyvanguard.com, accessed September 10, 2016.

[5] U.S. Energy Information Administration Commercial Building Energy Consumption Survey (CBECS), 2012 CBECS Survey Data, http://www.eia.gov/consumption/commercial/data/2012, accessed from September through December 2016.

[6] Austin Energy, *Customer Demand Load and Revenue Evaluations*, v. 1.1.0, June 1, 2012, located in Texas Public Utilities Commission Docket No. 40827, Response to OPC 1-47, Attachment 1.

[7] Emily Rauch and Michael Baechler (PNNL) and Greg Sullivan (Efficiency Solutions, LLC), *Assessing and Reducing Miscellaneous Electric Loads (MELs) in Banks*, prepared for U.S. Department of Energy, PNNL-20973, September 26, 2011.

[8] *Analysis and Representation of Miscellaneous Electric Loads in NEMS*, prepared by Navigant Consulting, Inc. and SAIC for the Energy Information Administration, December 2013.

[9] Steven Lanzisera, Stephen Dawson-Haggerty, H.Y. Iris Cheung, Jay Taneja, David Culler, Richard Brown, “Methods for Detailed Energy Data Collection of Miscellaneous and Electronic Loads in a Commercial Office Building,” *Building and Environment*, 2013, vol. 65, pp. 170-177.

[10] Brad Acker, Carlos Duarte, and Kevin Van Den Wymelenberg, *Office Plug Load Profiles*; Technical Report 20100312-01, Integrated Design Lab, University of Idaho, prepared for Idaho Power Company, March 13, 2012, Boise, ID.

[11] Cathy Higgins, “Office Plug Loads Energy Use and Savings Opportunities,” presentation on January 26, 2012, for the California Public Interest Energy Research Program; credit of data source: New Buildings Institute.

[12] Michael Sheppy, Paul Torcellini, and Luigi Gentile-Polese, “An Analysis of Plug Load Capacities and Power Requirements in Commercial Buildings,” National Renewable Energy Laboratory, NREL/CP-5500-61528, presented at the 2014 ACEEE Summer Study on Energy Efficiency in Buildings, Pacific Grove, California, August 17-22, 2014.

[13] Justin, Lueker, Annie Marston, Raghuram Sunnam, and Oliver Baumann, Baumann Consulting, “Simulating Empirically-Determined Plug Loads to Improve the Knowledge of Design Loads and Assess Building Performance Improvement Opportunities,” ASHRAE and IBPSA-USA SimBuild 2016 Building Performance Modeling Conference, Salt Lake City, UT, August 8-12, 2016.

[14] Laura Moorefield, Brooke Frazer, and Paul Bendt, *Office Plug Load Field Monitoring Report*, April 2011, California Energy Commission, PIER Energy-Related Environmental Research Program, CEC-500-2011-010.

[15] Christopher K. Wilkins, Mohammad H. Hosni, “Plug Load Design Factors,” *ASHRAE Journal*, May 2011, pp. 30-34

[16] *Commercial Demand Module of the National Energy Modeling System: Model Documentation 2014*, U.S. Energy Information Administration, August 2014.

[17] *Annual Energy Outlook 2016 with projections to 2040*, U.S. Energy Information Administration, Washington D.C., DOE/EIA-0383(2016), August 2016.

[18] ASHRAE Standard Benchmark Energy Utilization Index, October 2009, http://cms.ashrae.biz/EUI, accessed December 7, 2016.

[19] *The History of Energy Efficiency*, January 2013, Alliance Commission on National Energy Efficiency Policy.

[20] O.V. Livingston, P.C. Cole, D.B. Elliott, and R. Bartlett, Pacific Northwest National Laboratory, *Building Energy Codes Program: National Benefits Assessment, 1992-2040*, March 2014, PNNL-22610 Rev1 report, prepared for U.S. DOE under contract DE-AC05-76-RL01830.

[21] Stephanie J. Battles, “Historical Perspective on Energy Codes and Appliance Standards,” Energy Information Administration 2008 Energy Conference, April 7-8, 2008, Washington, D.C.

[22] ANSI/ASHRAE/IES Standard 90.1-2016, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, 2016, ASHRAE, Atlanta, GA.

[23] *2015 International Energy Conservation Code*, May 2014, International Code Council, Inc., Country Club Hills, Illinois.

[24] *2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings*, CEC-400-2015-037-CMF, June 2015, California Energy Commission.

[25] R.A. Athalye, B. Liu, D. Sivaraman, R. Bartlett, and D.B. Elliott, Pacific Northwest National Laboratory, *Impacts of Model Building Energy Codes*, October 2016, PNNL-25611 report, prepared for U.S. DOE under contract DE-AC05-76RL01830.

[26] Eric Makela Jennifer Williamson, and Erin Makela, Pacific Northwest National Laboratory, *Comparison of Standard 90.1-2010 and the 2012 IECC with Respect to Commercial Buildings,* September 2011, PNNL-20720 report, prepared for the U.S. Department of Energy under Contract DE-AC05-76RL01830.

[27] Eric E. Richman, Carol C. Jones, JoAnne Lindsley, “An Empirical Data Based Method for Development of Lighting Energy Standards,” *Journal of the Illuminating Engineering Society*, vol. 28, no. 2,1999.

[28] John H. Matthews, *Introduction to the Design and Analysis of Building Electrical Systems*, Van Nostrand Reinhold: New York, 1993.

[29] Michael A. Anthony, Thomas L. Harman, and James R. Harvey, “Rightsizing Commercial Electrical Power Systems,” *IEEE Industry Applications Magazine*, July/August 2016, pp. 41-46.

[30] Eric E. Richman, Pacific Northwest National Laboratory, “Requirements for Lighting Levels,” 2015, found on a federal government website in October 2016 (which can no longer be found), but still available from various document sites on the web. The document appears to have been created for Army facilities and has a page 2 header, *Energy and Water Conservation Design Requirements for SRM Projects*.

[31] *Facilities Standards for the Public Buildings Service*, U.S. General Services Administration, Office of the Chief Architect, editions March 2003, March 2005, and March 2014.

[32] David L. Korn, Gene E. Fax, and James J. Siegmund, Cadmus Group, *Low-Voltage Transformer Loads in Commercial, Industrial, and Public Buildings*, prepared for Northeast Energy Efficiency Partnerships, Inc., December 7, 1999.

[33] "Ch. 2 What are Harmonics?", K-Factor Training Federal Pacific, http://federal pacific.com/ training/k-factor/chapter-2.htm, accessed on October 12, 2016.

[34] P.R. Barnes, S. Das, B.W. McConnell, and J.W. Van Dyke, Oak Ridge National Laboratory, *Supplement to the "Determination Analysis" (ORNL-6847) and Analysis of the NEMA Efficiency Standard for Distribution Transformers*, Report ORNL-6925, September 1997, prepared for the U.S. Department of Energy under contract DE-AC05-96OR22464.

[35] Kenneth Duane Harden, "Optimizing Energy Efficiency Standards for Low Voltage Distribution Transformers," Master's Thesis, Purdue University, Fort Wayne, Indiana, May 2011.

[36] Edvard Csanyi, "Transformer Extra Losses due to Harmonics," Electrical Engineering Portal, posted June 22, 2012, http://electrical-engineering-portal.com/transformer-extra-losses-due-to-harmonics.

[37] "K-Factor Defined," Application Note AN102, Xitron Technologies, http://www.xitrontech.com/assets/ 002/5787.pdf, accessed December 11, 2016.

[38] Tammy Gammon, "Improved Arcing-Fault Current Models for Low-Voltage Power Systems (<1 kV)", Ph.D. Thesis, School of Electrical Engineering, Georgia Institute of Technology, Atlanta, GA, 1999.

[39] H. Bruce Land and Tammy Gammon, "Addressing Arc-Flash Problems in Low-Voltage Switchboards: A Case Study in Arc Fault Protection*," IEEE Transactions on Industry Applications*, vol. 51, no. 2, March/April 2015, pp. 1897-1908.

[40] IEEE Standard, 1584-2002, *IEEE Guide for Performing Arc-Flash Hazard Calculations*, The Institute of Electrical and Electronic Engineers, New York, New York, 2002.

[41] Peyton S. Hale, Robert G. Arno, and D. David Dylis, "Reliability and Availability Data Collection Program for Power Distribution, Power Generation, and HVAC Components of Commercial, Industrial, and Utility Installations," *IEEE Systems Technical Conference on Industrial and Commercial Power 2005*," Saratoga Springs, NY, 2005, pp. 199-203.

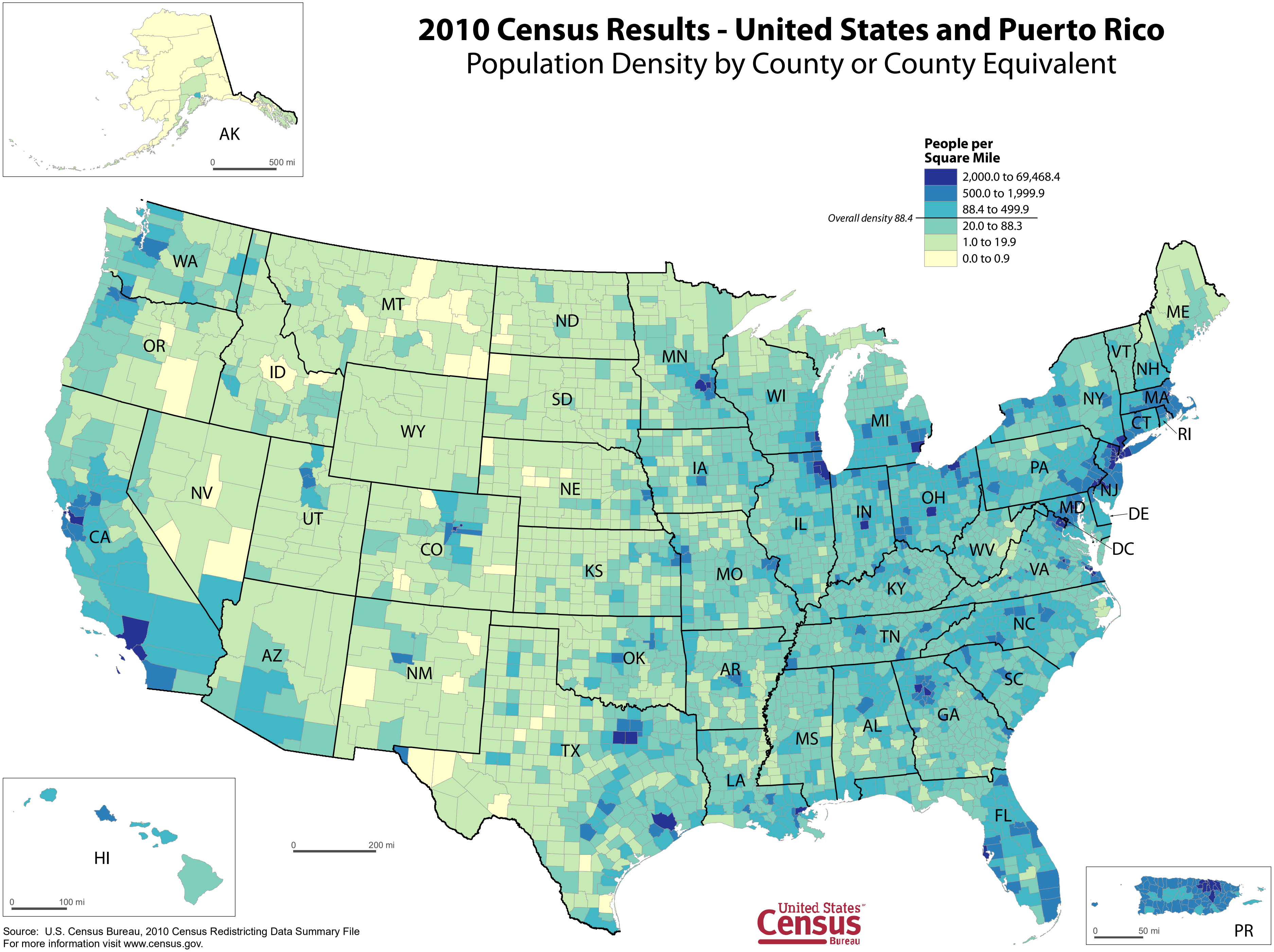
10 APPENDICES

Appendix A. U.S. Census Bureau Population Density Map

(Source: United States Census Bureau)

2010 Census Results - United States and Puerto Rico

Population Density by County or County Equivalent



Source: U.S. Census Bureau, 2010 Census Redistricting Data Summary File
For more information visit www.census.gov.

Appendix B. Manufacturer Monitoring Equipment Information

Appendix B.1 GE EPM 4600 Multi-feed Power and Energy Metering System

(Reference source for Multilin™ EPM 4600 is GE Energy Connections. Reprint permission granted by General Electric.)

Multilin™ EPM 4600 Metering System

Chapter 2: EPM 4600 Metering System Overview and Specifications

The EPM 4600 unit is a multi-port, high-density power and energy metering system, designed to be used in high-density metering environments such as data centers, commercial high-rise complexes, high-density power distribution panels, and branch circuits.

FIGURE 2.1: EPM 4600 Metering System

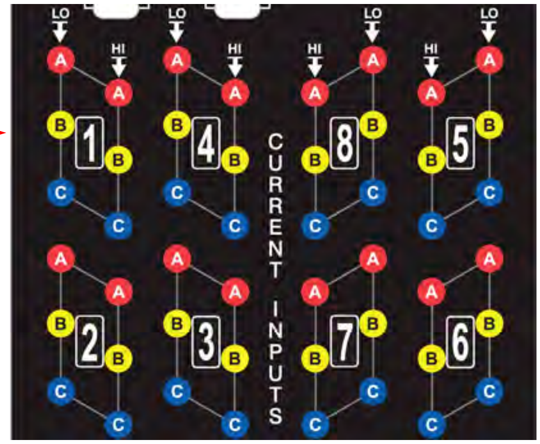
The EPM 4600 metering system provides 8 three phase or 24 single phase meters served by one central processing unit, which delivers the measured data in multiple formats via RS485 serial communication, USB port communication, RJ45 Ethernet, or 802.11 WiFi Ethernet options. The EPM 4600 metering system also has data logging and load profiling capability to provide historical data analysis.

The EPM 4600 unit can be ordered as either an EPM 4600-T for three phase systems or as an EPM 4600-S for single phase systems. The EPM 4600 unit is designed to be a cost-effective instrument for high density metering. It is important to note that for this design to function properly, all loads must be powered from a common voltage (or three phase voltage) set.

The EPM 4600 metering system was designed using the following concept:

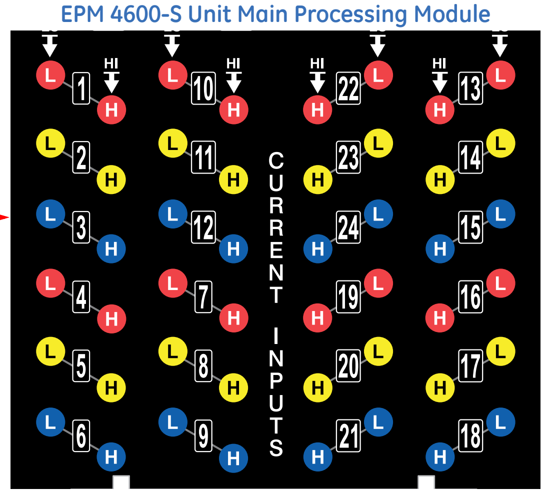
EPM 4600-T Unit Main Processing Module

Each Current Input Circuit is Considered a Meter



EPM 4600-S Unit Main Processing Module

Each 3 Phase Current Input is Considered a Meter



The EPM 4600 metering system offers up to 32 MegaBytes of non-volatile memory for per-circuit Energy usage trending. The EPM 4600 unit provides you with up to 5 logs: two historical logs, a log of limit alarms, a log of I/O changes, and a sequence of events log.

The EPM 4600 metering system is designed with advanced measurement capabilities, allowing it to achieve high performance accuracy. It is rated as a 0.5% Class accuracy metering device, meeting ANSI C12.20 and IEC 62053-22 0.5% classes.

Optional Display

The EPM 4600 unit offers an optional touch-screen color LED display. The display is available in two sizes: 3.5" (DIS3500) and 5.7" (DIS5700). The display lets you view readings from all of the meters on the EPM 4600 unit. See "Using the Optional Display" on page 10-1 for DIS3500/DIS5700 display details.

Voltage and Current Inputs

Universal Voltage Inputs

Voltage inputs allow measurement up to Nominal 480VAC (Phase to Reference) and 600VAC (Phase to Phase). This insures proper safety when wiring directly to high voltage systems. The EPM 4600 unit will perform to specification on 69 Volt, 120 Volt, 230 Volt, 277 Volt, and 347 Volt power systems.

Higher voltages require the use of potential transformers (PTs). The EPM 4600 unit is programmable to any PT ratio needed.

Current Inputs

The EPM 4600 unit can be ordered with either a 10 Amp or a 2 Amp secondary for current measurements. Depending on the EPM 4600 metering system model, there are either 8 three phase current inputs, or 24 single phase current inputs. The current inputs are only to be connected to external current transformers that are approved or certified.

The 10 Amp or 2 Amp secondary is an ordering option and as such it cannot be changed in the field. The 10 Amp secondary model (10A) allows the unit to over-range to 10 Amps per current circuit. The 2 Amp secondary model (02A) allows the unit to overrange to 2 Amps per current circuit.

Ordering Information

Table 2–2: EPM 4600 Meter Order Codes

	PL4600	– *	– *	– *	– *	– *	Description
Base Unit	**PL4600**						
Feed Configuration		T					Three Phase
		S					Single Phase
Frequency			5				50 Hz AC frequency system
			6				60 Hz AC frequency system
Current Inputs				10A			Up to 10A Current
				02A			Up to 2A Current
Software					A		Transducer
					B		Basic Logging-2MB Memory
					C		Advanced Logging-32MB Memory
Communications						S	Serial (RS485) Modbus
						W	WiFi, RJ45 100BaseT Ethernet

Example:

PL4600-T-6-10A-B-S

EPM 4600 metering system with three phase circuit configuration, 60 Hz Frequency, 10 Amp Secondary, B Software option, and Serial (RS485) Modbus communication.

NOTE on Frequency: It is important to specify the frequency to insure the highest possible calibration accuracy from the factory.

Table 2–3: EPM 4600 Display Order Codes

	PL4600	–	*	Description
Displays	**PL4600**	-	**DIS3500**	3.5" Touch Screen Display with Installation Kit
			DIS5700	5.7" Touch Screen Display with Installation Kit

Software option

The EPM 4600 metering system is equipped with a Software option, which is a virtual firmware-based switch that lets you enable features through software communication. The Software option allows feature upgrades after installation without removal from service.

Available Software option upgrades are as follows:

- Software option A: Transducer
- Software option B: Basic logging with 2 MegaBytes* memory
- Software option C: Advanced logging with 32 MegaBytes* memory

* The table below shows the number of days of logging available with B and C, for the EPM 4600-T and EPM 4600-S circuit configurations, based on a 15 minute logging interval. Note that both EPM 4600-T and EPM 4600-S units have Log 1; Log 2 is used for EPM 4600-T units, only, and Log 3 is used for EPM 4600-S units, only.

Model	Wiring	Log 1 B	Log 2/3 B	Log 1 C	Log 2/3 C
EPM 4600-T	Three Phase/ 8 circuits	68 days	105 days	3617 days	2872 days
EPM 4600-S	Single Phase/24 circuits	136 days	47 days	7235 days	1247 days

Obtaining a Software option:

Contact GE Digital Energy's inside sales staff at sales@gedigitalenergy.com and provide the following information:

1. Serial number(s) of the EPM 4600 unit(s) you are upgrading. Use the number(s), with leading zeros, shown in the GE Communicator Device Status screen (from the GE Communicator Main screen, click **Tools>Device Status**).
2. Desired Software option.
3. Credit card or Purchase Order number. GE Digital Energy will issue a Software option encrypted key.

Enabling the Software option:

1. Open GE Communicator software.
2. Power up your EPM 4600 unit.
3. Connect to the EPM 4600 unit through GE Communicator software (see "Communicating with the Meter" on page 5-1).
4. Click **Tools>Change Software option** from the Title Bar. A screen opens, requesting the encrypted key.
5. Enter the Software option key provided by GE Digital Energy.
6. Click the **OK** button. The Software option is enabled and the EPM 4600 unit resets.

Measured Values

The EPM 4600 metering system provides the following measured values, all in real time instantaneous. As the following tables show, some values are also available in average, maximum and minimum.

Table 2.1: Single Phase Circuit Configuration

Measured Values	Instantaneous	Avg	Max	Min
Voltage L-N	X		X	X
Current	X	X	X	X
WATT	X	X	X	X
VAR	X	X	X	X
VA	X	X	X	X
PF	X	X	X	X
+Watt-Hour	X			
-Watt-Hour	X			
Watt-Hour Net	X			
+VAR-Hour	X			
-VAR-Hour	X			
VAR-Hour Net	X			
VA-Hour	X			
Frequency	X		X	X
Current Angle	X			

Table 2.2: Three Phase Circuit Configuration

Measured Values	Instantaneous	Avg	Max	Min
Voltage L-N	X		X	X
Voltage L-L	X		X	X
Current per Phase	X	X	X	X
Current Neutral (see NOTE, below)	X	X	X	X
WATT (A,B,C,Tot.)	X	X	X	X
VAR (A,B,C,Tot.)	X	X	X	X
VA (A,B,C,Tot.)	X	X	X	X
PF (A,B,C,Tot.)	X	X	X	X
+Watt-Hour (A,B,C,Tot.)	X			
-Watt-Hour (A,B,C,Tot.)	X			
Watt-Hour Net	X			
+VAR-Hour (A,B,C,Tot.)	X			
-VAR-Hour (A,B,C,Tot.)	X			
VAR-Hour Net (A,B,C,Tot.)	X			
VA-Hour (A,B,C,Tot.)	X			
Frequency	X		X	X
Voltage Angles	X			
Current Angles	X			

NOTE

Neutral current is calculated only when the voltages are connected; if voltages are not connected, the neutral current will not be calculated.

Utility Peak Demand

The EPM 4600 metering system provides user-configured Block (Fixed) window or Rolling window Demand modes. This feature lets you set up a customized Demand profile. Block window Demand mode records the average demand for time intervals you define (usually 5, 15 or 30 minutes). Rolling window Demand mode functions like multiple, overlapping Block windows. You define the subintervals at which an average of Demand is calculated. An example of Rolling window Demand mode would be a 15-minute Demand block using 5-minute subintervals, thus providing a new Demand reading every 5 minutes, based on the last 15 minutes.

Utility Demand features can be used to calculate Watt, VAR, VA and PF readings. Voltage provides an instantaneous Max and Min reading which displays the highest surge and lowest sag seen by the meters. All other parameters offer Max and Min capability over the user-selectable averaging period.

Specifications

Power Supply

Range:	Universal, 90-300VAC @50/60Hz or 150VDC
Power Consumption:	18VA, 12W, Maximum

Voltage Inputs (Measurement Category III)

(For Accuracy specifications, see “Accuracy” on page 2-12.)

Range:	Universal, Auto-ranging up to 576VAC L-N, 721VAC L-L
Supported hookups:	EPM 4600-T: 3 Element Wye
	EPM 4600-S: Single Phase, 2 wire, 3 wire
Input Impedance:	4.2M Ohm/Phase
Burden:	0.09VA/Phase Max at 600 Volts; 0.014VA at 120 Volts
Pickup Voltage:	20VAC
Connection:	7 Pin 0.400” Pluggable Terminal Block
	AWG#12 -26/ (0.08 -2.5) mm2
Fault Withstand:	Meets IEEE C37.90.1
Reading:	Programmable Full Scale to any PT ratio

Current Inputs

(For Accuracy specifications, see “Accuracy” on page 2-12.)

Class 10:	5A Nominal, 10A Maximum
Class 2:	1A Nominal, 2A Maximum
Burden:	0.005VA Per Input Max at 11 Amps
Pickup Current:	0.1% of Nominal Class 10: 5mA Class 2: 1mA
Current Input Terminals:	8-32 Threaded Studs
Reading:	Programmable Full Scale to any CT ratio
Continuous Current Withstand:	20 Amps
Maximum Voltage across Current Inputs:	1VAC

Maximum Voltage from Current Inputs to Ground: 50VAC

NOTE

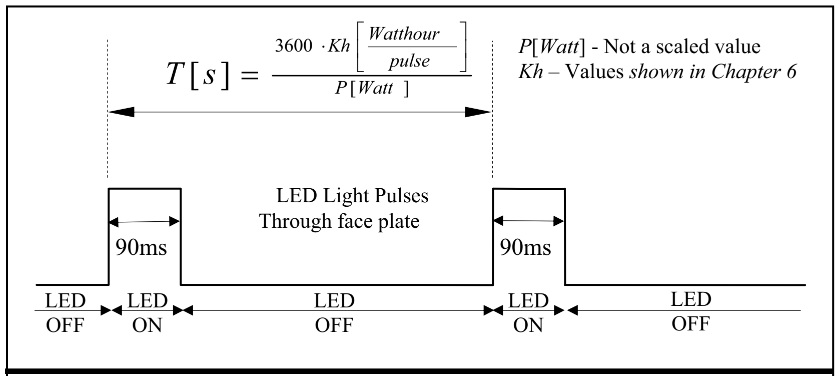
For detailed electrical specifications for the optional display see “DIS3500/DIS5700 Specifications” on page 10-3

Wh Pulses

Red LED light pulses through top cover (see “Performing Watt-Hour Accuracy Testing” on page 6-2 for Kh values):

Peak Spectral wavelength: 574nm

Output timing:



See **“Performing Watt-Hour Accuracy Testing” on page 6-2** for Kh values.

Isolation

All Inputs and Outputs are galvanically isolated to 2500 VAC

Environmental Rating with and without Optional Display DIS3500/DIS5700

Storage:	(-20 to +70)^{o} C/(-4 to +158)^{o} F
Storage with Display:	(-20 to +60)^{o} C/(-4 to +140)^{o} F
Operating:	(-20 to +60)^{o} C/(-4 to +140)^{o} F
Operating with Display:	(0 to +50)^{o} C/(+32 to +122)^{o} F
Humidity:	to 95% RH Non-condensing
Humidity with Display:	to 85% RH Non-condensing; Wet bulb temperature 39°C/ 102.2° F or less

Measurement Methods

Voltage, current:	True RMS
Power:	Sampling at over 400 samples per cycle on each channel simultaneously

Update Rate

All parameters:	Every 60 cycles (e.g., 1 s @ 60 Hz)

Communication

Standard:

1. RS485 port (Com 1)
2. USB port (Com 2)
3. RS485/Display port (Com 3)

4. Energy pulse output LED for meter testing: there are 8 pulses, one for each of the three phase loads of the EPM 4600-T; for the EPM 4600-S, the test pulses are shared, with one pulse for every three loads (see "Using the Metering System's Watt-Hour Test Pulses" on page 6-1 for more details and instructions for using the Test pulses).

Optional:

Ethernet/WiFi port (Com 1): 802.11b Wireless or RJ45 Connection 10/100BaseT Ethernet

Com Specifications

RS485 Ports (Com 1 and Com3):

RS485 Transceiver; meets or exceeds EIA/TIA-485 Standard

Type:	Two-wire, half duplex
Min. input impedance:	96kΩ
Max. output current:	±60mA
Protocol:	Modbus RTU, Modbus ASCII
Com port baud rates:	9600 to 57600 bps
Device address:	001-247
Data format:	8 Bit

WiFi/Ethernet Port (optional Com 1):

Wireless security:	64 or 128 bit WEP; WPA; or WPA2
Protocol:	Modbus TCP
Device address:	001-247

USB Port (Com 2):

Protocol:	Modbus ASCII
Com port baud rate:	57600 bps
Device address:	1

Com Specifications for Optional Displays DIS3500/DIS5700

Serial Interface COM1:

Asynchronous Transmission: RS232C / RS422 / RS485

Data Length:	7 or 8 bits
Stop Bit:	1 or 2 bits
Parity:	None, odd or even
Data Transmission Speed:	2,400 to 115.200 kbps, 187,500 bps
Connector:	D-Sub 9-pin (plug)

Ethernet Interface:

Ethernet (LAN):	IEEE802.3i/ IEEE802.3u, 10BASE-T/100BASE-TX
Connector:	D-Sub 9-pin (plug)

LED:

Green, lit:	Data transmission is available
Green, blinking:	Data transmission is occurring

Relay Output/Digital Input Board Specifications at 25° C

Relay outputs:

Number of outputs: 2

Contact type:	Changeover (SPDT)
Relay type:	Mechanically latching
Switching voltage:	AC 150V / DC 30V
Switching power:	750VA / 150W
Switching current:	5A
Switching rate max.:	10/s
Mechanical life:	5×10^7 switching operations
Electrical life:	10^5 switching operations at rated current
Breakdown voltage:	AC 1000V between open contacts
Isolation:	AC 3000V / 5000V surge system to contacts
Reset/power down state:	No change - last state is retained

Inputs:

Number of inputs:	4
Sensing type:	Wet or dry contact status detection
Wetting voltage:	DC (1-24)V, internally generated
Input current:	2.5mA – constant current regulated
Minimum input voltage:	0V (input shorted to common)
Maximum input voltage:	DC 150V (diode protected against polarity reversal)
Filtering:	De-bouncing with 50ms delay time
Detection scan rate:	100ms
Isolation:	AC 2500V system to inputs
External Connection:	AWG 12-26/(0.129 - 3.31)mm^2
	11 pin, 0.200" pluggable terminal block

Mechanical Parameters

Dimensions:	7.6(L) x 11.28(W) x 4.36(H) in / 19.3(L) x 28.65(W) x 11.07(H) cm
Weight:	7 pounds (3.18kg)

Compliance

- UL Listing: UL61010-1, CAN/CSA C22.2 No. 61010-1, UL file number E250818
- IEC 62053-22 (0.5% Class)
- ANSI C12.20 (0.5% Accuracy)
- ANSI (IEEE) C37.90.1 Surge Withstand
- ANSI C62.41 (Burst)
- EN61000-6-2 Immunity for Industrial Environments
- EN61000-6-4 Emission Standards for Industrial Environments
- EN61326 EMC Requirements

Accuracy

(For full Range specifications see "Specifications" on page 2-8.)

EPM 4600 metering system Clock accuracy:

±3.5ppm max. (±0.3024 second/day) over the rated temperature range

For 23 °C, three phase or single phase 3 wire connected balanced load:

Parameter	Accuracy	Accuracy Input Range
Voltage L-N [V]	0.3% of reading*	(69 to 480)V
Voltage L-L [V]	0.5% of reading	(120 to 600)V
Current Phase [A]	0.3% of reading	(0.15 to 5)A
Current Neutral (calculated) [A]	2.0% of Full Scale	(0.15 to 5)A @ (45 to 65)Hz
Active Power Total [W]	0.5% of reading*	(0.15 to 5)A @ (69 to 480)V @ +/- (0.5 to 1) lag/ lead PF
Active Energy Total [Wh]	0.5% of reading*	(0.15 to 5)A @ (69 to 480)V @ +/- (0.5 to 1) lag/ lead PF
Reactive Power Total [VAR]	1.0% of reading*	(0.15 to 5)A @ (69 to 480)V @ +/- (0 to 0.8) lag/ lead PF
Reactive Energy Total [VARh]	1.0% of reading*	(0.15 to 5)A @ (69 to 480)V @ +/- (0 to 0.8) lag/ lead PF
Apparent Power Total [VA]	1.0% of reading*	(0.15 to 5)A @ (69 to 480)V @ +/- (0.5 to 1) lag/ lead PF
Apparent Energy Total [VAh]	1.0% of reading*	(0.15 to 5)A @ (69 to 480)V @ +/- (0.5 to 1) lag/ lead PF
Power Factor	1.0% of reading*	(0.15 to 5)A @ (69 to 480)V @ +/- (0.5 to 1) lag/ lead PF
Frequency	+/- 0.01Hz	(45 to 65)Hz

* For unbalanced voltage inputs where at least one crosses the 150V auto-scale threshold (for example, 120V/120V/208V system), degrade accuracy by additional 0.4%.

The EPM 4600 metering system's accuracy meets the IEC62053-22 and ANSI C12.20 Accuracy Standards for 0.5% Class Energy meters.

Appendix B.2 Honeywell E-Mon Class 3400 Smart Meter

(Unfortunately, permission has been delayed for reprinting the specification sheet for the Class 3400 Smart Meter, a product of E-Mon D-Mon: Energy Monitoring Products & Systems, Honeywell Corporation. Since the publication of this report cannot be delayed, the report will be published without it.)

The specification sheet for the Class 3400 Smart Meter, as well as other documents for the Class 3400 Smart Meter and other E-Mon meters, can be downloaded from:

http://www.emon.com/en/downloads

A summary of the specification sheet for the Class 3400 Smart Meter can be found on the following two pages.

Class 3400 Smart Meter

Advanced kWh/Demand Meters with Communication

4-line by 20-character backlit LCD display for

- kWh
- Real-time kW load and kW demand with peak data and time
- Power factor, current, and voltage per phase

Onboard optional set-up for

- IP address
- Meter date and time
- Load control settings (optional expanded feature package)
- ID codes for EZ7, Modbus, and BACnet

Onboard installation diagnostics and verification

Split-core current sensors (0-2V output)

Built-in RS-485 communications

- Supports up to 52 Class 3200, 3400, or 5000 meters per channel
- Cables in daisy chain or star configuration, 3-conductor, 18-22 AWG, up to 4,000 feet total per channel

Built-in communication

- RS-485
- Ethernet
- Pulse output
- Optional telephone modem

Protocols

- EZ7
- Modbus RTU or TCP/IP
- BACnet MS/TP or IP
- LonWorks FT-10

Records KWh and kVARh delivered, and kWh and kVARh received in the first four channels

- Data stored in 15-minute intervals for 72 days (or 5-minute intervals for 24 days)
- Data stored in first-in, first-out format

Compatible with E-Mon Energy software using EZ7 protocol for automatic meter reading, billing, and profiling of energy data

Meter appropriate for use on three-phase, 3-wire (delta) or three-phase, 4-wire (wye) circuits

Enclosure

- Standard - Outdoor NEMA 4X polycarbonate enclosure with padlocking hasp and mounting flanges for indoor/outdoor installation (stand alone)
- Optional – Industrial grade JIC steel enclosure with padlocking hasp and mounting flanges for indoor installation (stand alone)

UL/CUL listed. Certified to ANSI C12.20 national accuracy standards

Meters available for three-phase 120/208-240V, 277/480V, and 347/600V systems

Meter ampacity sizes: 100A, 200A, 400A, 800A, 1600A, 3200A

Appendix B.3 Onset Data Loggers for Real Power or Phase RMS Currents

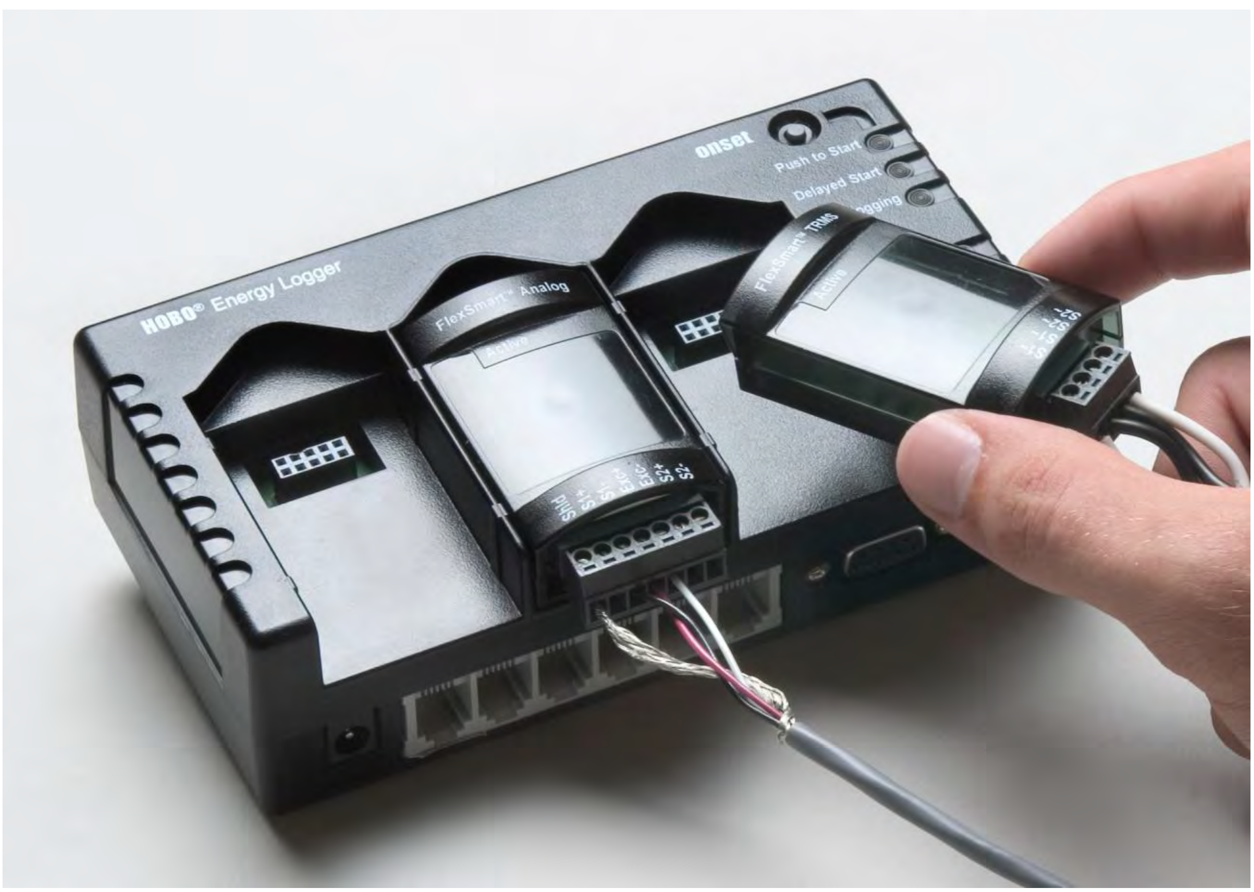
Reference source for the following devices is Onset Corporation / www.onsetcomp.com:

- HOBO Energy Logger
- FlexSmart TRMS Module
- HOBO® State Data Logger (UX90-001x)

Reprint permission granted by Onset Computer Corporation.

Reference source for the WattNode Pulse is WattNode BACnet energy meter manufactured by Continental Control Systems, LLC. Reprint permission granted by Continental Control Systems, LLC.

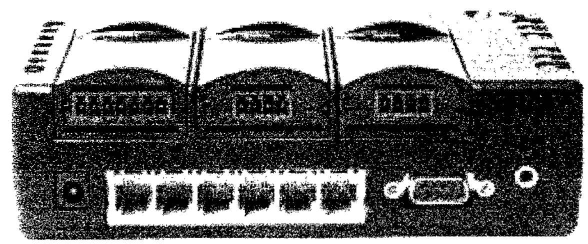

HOBO® FlexSmart™ Data Logger
onset
FlexSmart™ Analog
FlexSmart™ TRMS
FlexSmart™ TRMS
Active
Active
Active
Push to Start
Delayed Start
Logging
Memory Low
Battery Low
Sensor Fail


onset
Push to Start
Delayed Start
HOBO® Energy Logger
FlexSmart™ Analog
Active
FlexSmart™ TRMS
Active
Shld
S1+
S1-
Exc+
S2+
S2-

HOBO® Energy Logger

Multi-channel energy data logging system

The HOBO Energy Logger multi-channel data logger is a modular, reconfigurable data logging system for energy and industrial monitoring applications.



The 15-channel system enables energy and facility management professionals to quickly and easily solve a broad range of monitoring applications without having to purchase a toolbox full of data loggers.

Supported Measurements: Temperature, Relative Humidity, Dew Point, 4-20mA, AC Current, AC Voltage, Air Velocity, Amp Hour, Carbon Dioxide, Compressed Air Flow, DC Current, DC Voltage, Differential Pressure, Gauge Pressure, Kilowatt Hours, Kilowatts, Power Factor, Pulse Input, Volatile Organic Compound, Volt-Amp Reactive, Volt-Amp Reactive Hour, Volt-Amps, Water Flow, Watt Hours, Watts, Wind

Key Advantages:

- Records up to 15 channels
- Provides 12v excitation for third-party sensors
- Pre-configured Smart Sensors for fast setup
- Signal conditioning modules retain configurations until you change them, providing plug-and-play convenience for commonly used sensors
- Flexible power options include battery operation or AC power adapter
- Works with Onset's E50B2 Power & Energy Meter to measure Power Factor, Reactive Power, Watt Hours, and more

Minimum System Requirements:

Software

Interface Cable*

Sensor

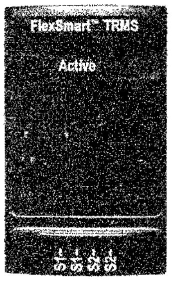
*USB to Serial interface cable, part #CABLE-PC-3.5

Part number	H22-001
Memory	512K nonvolatile flash data storage
Operating Range	-20° to 50°C (-4° to 122°F) with alkaline batteries -40° to 60°C (-40° to 140°F) with lithium batteries
Sensor Inputs	6 RJ-12 Smart Sensor jacks plus 3 FlexSmart module slots
Communication	RS-232 via 3.5 mm serial port*
Logging Interval	1 second to 18 hours, user-specified interval
Sensor Excitation	12 V DC at 200 mA total, with user-programmable warm up time on a per-channel basis
Battery Life	1 year typical
Battery Type	8 standard AA alkaline batteries (included)
External Power	Supports optional 13.6 V DC regulated AC Wall Adapter Connector
Time Accuracy	0 to 2 seconds for the first data point and ± 5 seconds per week at 25°C (77°F)
Dimensions	15.6 cm x 8.4 cm x 4.6 cm (6.13 in x 3.31 in x 1.81 in)
CE Compliant	Yes

*USB to Serial interface cable, part #CABLE-PC-3.5


FlexSmart™ TRMS
Active
S1~
S1~
S2~
S2~

FlexSmart™ TRMS Module
(Part No: S-FS-TRMSA & S-FS-TRMSA-D)



Quick Start Guide

Inside this package:

- FlexSmart TRMS Module
- Detachable screw terminal connector
- Imprintable label
- This guide

Note: Refer to the documentation provided with the Onset HOBO® H22 or U30 series data logger and HOBOware® Pro software for additional information on using and configuring the FlexSmart TRMS Module.

Introduction

Thank you for purchasing an Onset FlexSmart TRMS Module. With proper care, it will give you years of accurate and reliable measurements.

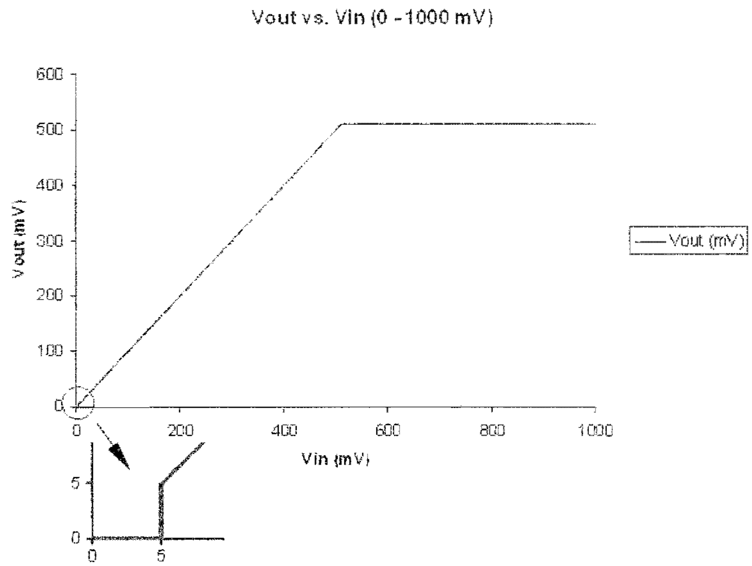
The S-FS-TRMSA and S-FS-TRMSA-D are easy-to-configure, True-RMS input measurement modules. The S-FS-TRMSA is compatible with Onset's HOBO H22 series data loggers. The S-FS-TRMSA-D is compatible with both the HOBO U30 and H22 series loggers. The "-D" variant has a modular connector for connecting to an available smart-sensor port. Both 2-channel modules have an input range of 512 millivolts RMS full-scale. Thus, they are fully compatible with industry-standard voltage and current transformers (PT and CT) which output 333 millivolts RMS full-scale.

The modules feature extremely low-power operation, resulting in long battery life for unattended data logging applications.

Specifications

Input Channels	Two, AC-coupled
Field Wiring	Two-wire via screw terminals on detachable connector, 16-24 AWG Replacement detachable connectors: Part of spares kit, Onset part no: A-FS-TRMSA-4P-1
Input Range	5 to 512 mVRMS
Minimum Input Voltage	5mVRMS; Input voltages < 5mV will be clipped to zero (see graph below)
Maximum Input Voltage	+/- 1V referred to AC- terminals (pins 2 and 4)
Input Frequency	50/60 Hz
Accuracy	+/- 0.3% of reading +/- 0.5% of FSR
ADC Resolution	15 bits
AC Waveform	< 4 Crest Factor
Power Requirements	+3.3V @ 3mA active, 6µA sleep
Transfer Function	$VRMS = \sqrt{\frac{1}{T} \bullet \int_0^T [V(t)^2] dt}$
Measurement Averaging Option	Yes
CE	The CE Marking identifies this product as complying with all relevant directives in the European Union (EU).

Minimum Input Voltage Graph



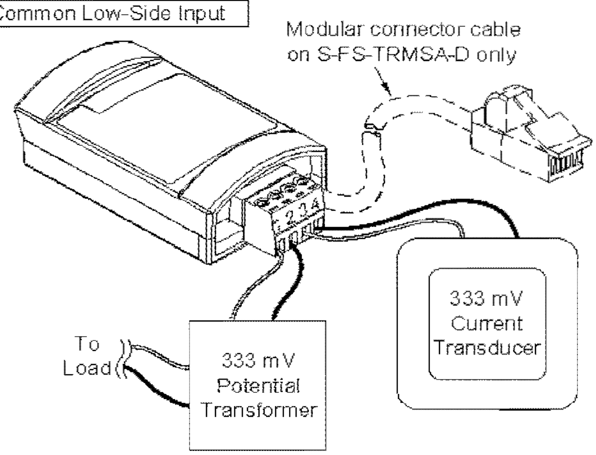
Module Connections

Potential Transformers (PT) and Current Transducers (CT) are connected to the module via a four-pin Phoenix-style detachable screw terminal connector. Once the PTs and/or CTs are connected, the module can then be configured using HOBOware Pro software (with the module installed on the HOBO H22 or U30 series data logger).

The diagram at below illustrates *typical* connections for a PT and CT. For module connection instructions specific to PTs and CTs purchased from Onset, refer to the documentation provided with each PT and CT.

Note: For three-phase monitoring, each of the three modules should be wired so that similar parameters are connected to corresponding pin numbers. For example, voltage inputs pins 1 and 2 on each module; current inputs pins 3 and 4 on each module.

Pin #	Function
1	Channel 1 High-Side Input
2	Common Low-Side Input
3	Channel 2 High-Side Input
4	Common Low-Side Input



Measurement Averaging

This sensor supports measurement averaging. When measurement averaging is enabled, data is sampled more frequently than it is logged. The multiple samples are then averaged together and the average value is stored as the data for the interval. For example, if the logging interval is set at 10 minutes and the sampling interval is set at 1 minute, each recorded data point will be the average of 10 measurements. Measurement averaging is useful for reducing noise in the data.

HOBO® State Data Logger (UX90-001x) Manual

HOBO State Data Logger

Models: UX90-001
UX90-001M

Included Items:

- 2.5 mm input cable
- Command™ strip
- Double-sided tape
- Hook & loop strap
- Magnet with 2 screws

Required Items:

- HOBOware 3.3 or later
- USB cable (included with software)

Accessories:

- Wattnode kWh transducers
- Power & Energy Meter (T-VER-E50B2)
- Water Flow Meter Sensor (T-MINOL-130-NL)
- U-Shuttle (U-DT-1)

The HOBO State/Pulse/Event/Runtime data logger records state changes, electronic pulses and mechanical or electrical contact closures from external sensing devices. Using HOBOware®, you can easily configure the internal magnetic reed switch or the external sensor to monitor and record data in a wide variety of applications, such as energy consumption, mechanical equipment operation, and water and gas flow. This compact data logger also has a built-in LCD screen to monitor logging status, battery use, and memory consumption. There are two models of the HOBO state logger: the UX90-001 has 128 KB of memory while the UX90-001M has 512 KB.

Specifications

Internal Sensor

Maximum State, Event, Runtime Frequency	1 Hz
Preferred Switch State	No magnet present (normally open)

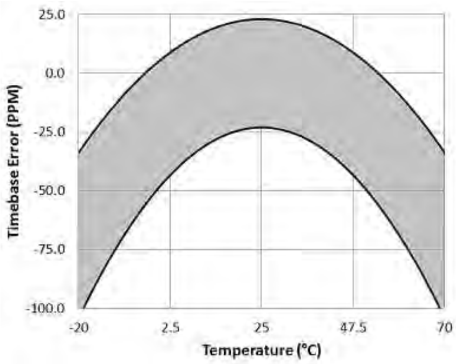
External Input

External Contact Input	Electronic solid state switch closure or logic driven voltage output
Range	0 to 3 V DC (USB powered), 0 to 2.5 V DC (battery powered)
Maximum Pulse Frequency	50 Hz
Maximum State, Event, Runtime Frequency	1 Hz
Pulse, Event Lockout Time	0 to 1 second in 100 ms steps
Solid State Switch Closure	Input Low: < 10 KΩ; Input High: > 500 KΩ
Internal Weak Pull-Up	100 KΩ
Input Impedance	Solid state switch closure: 100 KΩ pull up

Logger

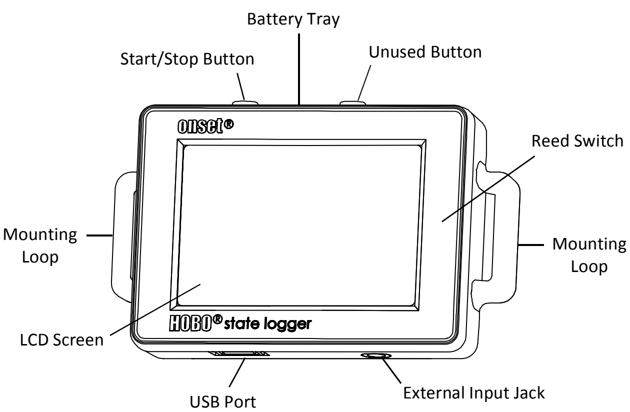
Resolution	Pulse: 1 pulse, Runtime: 1 second, State and Event: 1 State or Event
Logging Rate	1 second to 18 hours, 12 minutes, 15 seconds
Memory Modes	Wrap when full or stop when full
Start Modes	Immediate, push button, date & time, or next interval
Stop Modes	When memory full, push button, or date & time
Time Accuracy	±1 minute per month at 25°C (77°F) (see Plot A)
Power Source	One 3V CR2032 lithium battery and USB cable
Battery Life	1 year, typical with logging intervals greater than 1 minute and normally open contacts
Memory	UX90-001: 128 KB (84,650 measurements, maximum) UX90-001M: 512 KB (346,795 measurements, maximum)
Download Type	USB 2.0 interface
Full Memory Download Time	10 seconds for 128 KB; 30 seconds for 512 KB
Logger Operating Range	Logging: -20° to 70°C (-4° to 158°F); 0 to 95% RH (non-condensing) Launch/Readout: 0° to 50°C (32° to 122°F) per USB specification
LCD	LCD is visible from: 0° to 50°C (32° to 122°F); the LCD may react slowly or go blank in temperatures outside this range
Size	3.66 x 5.94 x 1.52 cm (1.44 x 2.34 x 0.6 in.)
Weight	23 g (0.81 oz)
Environmental Rating	IP50
CE	The CE Marking identifies this product as complying with all relevant directives in the European Union (EU).

Specifications (continued)



Plot A: Time Accuracy

Logger Components and Operation



Start/Stop Button: Press this button for 3 seconds to start or stop logging data. This requires configuring the logger in HOBOware with a push button start or stop (see *Setting up the Logger*). You can also press this button for 1 second to record an internal event (see *Recording Internal Logger Events*) or to turn the LCD screen on if the option to turn off the LCD has been enabled (see *Setting up the Logger*). Note that the other button on the top of the logger is not functional for this model.

Battery Tray: Remove the battery tray (not visible in the diagram) on the top of the logger to access the logger battery (see *Battery Information*).

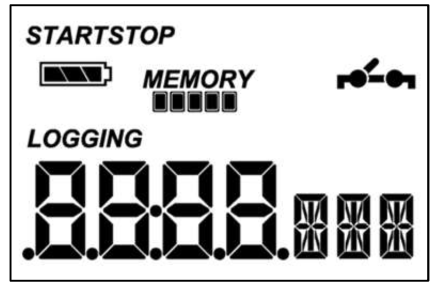
Reed Switch: The internal reed switch (not visible in the diagram) inside the logger housing allows for monitoring when windows and doors are open or closed (see *Using the Magnet*).

Mounting Loops: Use the two mounting loops to mount the logger with the hook-and-loop strap (see *Mounting the Logger*).

External Input Jack: Use this jack to attach the 2.5 mm input cable to an external sensing device (see *Using the Input Cable*).

USB Port: Use this port to connect the logger to the computer or the HOBO U-Shuttle via USB cable (see *Setting up the Logger* and *Reading Out the Logger*).

LCD Screen: This logger is equipped with an LCD screen that displays details about the current status. This example shows all symbols illuminated on the LCD screen followed by definitions of each symbol in the following table.



LCD Symbol	Description
START	The logger is waiting to be launched. Press and hold the Start/Stop button for 3 seconds to launch the logger.
STOP	The logger has been launched with a push button stop enabled; press and hold the Start/Stop button for 3 seconds to stop the logger. **Note**: If you also launched the logger with a push button start, this symbol will not appear on the display for 5 minutes.
	The battery indicator shows the approximate battery power remaining.
MEMORY	If the logger has been configured to stop logging when memory fills, the memory bar indicates the approximate space remaining in the logger to record data. In this example, the logger memory is almost full.
MEMORY	If the logger has been configured to never stop logging (wrapping enabled), then a single block will blink starting at the left and moving right over time. Each block represents a segment of memory where the data is being recorded. In this example, the middle block is blinking.
	The switch is open or off.
	The switch is closed or on.
	The logger is configured to record pulse or event data.
LOGGING	The logger is currently logging.
05:38 M-S	**Time display when logger is logging:** This shows the total amount of time the switch has been closed or on since logging began, ranging from seconds to days. This example indicates the switch has been closed or on for a total of 5 minutes and 38 seconds. The logger must be launched with the LCD set to show "Time" for this symbol to display. **Time display when logger is stopped:** This indicates the logger has been configured to start logging on a particular date/time. The display will count down to the start date/time until logging begins. In this example, 5 minutes and 38 seconds remain until logging will begin.
24 %	This shows the percentage of time the switch has been closed or on since logging began. This example indicates the switch has been closed or on for a total of 24% of the time since logging began. The logger must be launched with the LCD set to show "%" for this symbol to display.
StoP	The logger has been stopped.

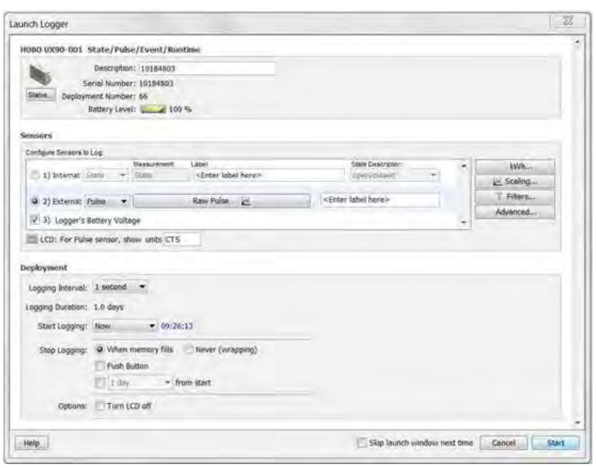
Notes:

- You can disable the LCD screen when logging. Select "Turn LCD Off" when setting up the logger as described in the next section. When this option is enabled, you can still temporarily view the LCD screen by pushing the Start/Stop button for 1 second. The LCD will then remain on for 10 minutes.
- When the logger has stopped logging, the LCD will remain on until the logger is offloaded to a computer or HOBO U-Shuttle (unless launched with the "Turn LCD Off" option). Once the logger has been offloaded and disconnected from the computer, the LCD will turn off automatically after 2 hours. The LCD will turn back on the next time the logger is connected to the computer.
- If the pulse count exceeds 9,999 or -999, a second decimal point will be illuminated on the LCD to indicate the count has surpassed the 4-digit display.

Setting up the Logger

Use HOBOware to set up the logger, including selecting the start and stop logging options, configuring the sensors, and entering scaling factors as necessary. It may be helpful to set up the logger to start at a specific date/time or with a push button stop and then bring it to the location where you will mount it to connect any external devices and test the connections before logging begins.

1. **Connect the logger and open the Launch Logger window**. To connect the logger to a computer, plug the small end of the USB cable into the side of the logger and the large end into a USB port on the computer. Click the Launch icon on the HOBOware toolbar or select Launch from the Device menu.



> **Important:** USB 2.0 specifications do not guarantee operation outside the range of 0°C (32°F) to 50°C (122°F).

2. **Configure the sensor.** Choose either the internal or external sensor. Enter the name and select the state description as necessary or select the sensor type. Type a label for the sensor if desired.

   The internal sensor can be configured to log:

   - **State.** This records how long an event lasts by storing the date and time when the state or switch changes (logic state high to low or low to high). The logger checks every second for a state change, but will only record a time-stamped value when the state change occurs. One state change to the next represents the event duration.
   - **Runtime.** The logger checks the state of the switch once every second. At the end of each logging interval, the logger records how many seconds the line was in the logic low state.

   The external channel can be configured to log state or runtime as described above or the following:

   - **Pulse.** This records the number of pulse signals per logging interval (the logger records a pulse signal when the input transitions to the logic low). There are built-in scaling factors you can select for supported devices and sensors, or you can set your own scaling when you select raw pulse counts. Click the Advanced button to adjust the maximum pulse frequency and lockout time as needed (see *Setting the Maximum Pulse Frequency and Lockout Time* for more details). **Note:** Setting maximum pulse frequency to 50 Hz will reduce battery life.
   - **Event.** This records the date and time when a connected relay switch or logic low transition occurs (the logger records an event when the input transitions to the logic low). This is useful if you need to know when a switch closes, but the duration of the closure is not important. Click the Advanced button to adjust the lockout time to debounce switches as needed.

3. **Configure optional filters as necessary.** Click the Filters button to create additional filtered data series based on the sensor configuration. Any filtered series will be automatically available upon reading out the logger.

4. **Set the units to display on the LCD screen.** For State and Runtime sensors, select either Time or %. For external sensors, you can either use the default units or enter your own units up to three characters.

5. **If the logger is configured to record pulse or runtime, choose a logging interval from 1 second to a maximum of 18 hours, 12 minutes, and 15 seconds.**

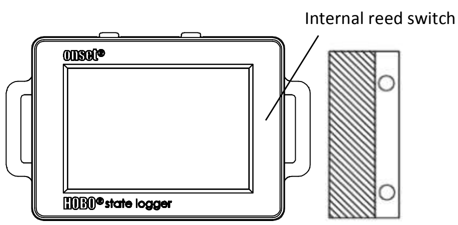
6. **Choose when to start logging:**
   - **Now.** Logging begins immediately.
   - **At Interval.** Logging will begin at the next even interval (available when logging pulse or runtime).
   - **On Date/Time.** Logging will begin at a date and time you specify.
   - **Push Button.** Logging will begin once you press the Start/Stop logging button for 3 seconds.

7. **Choose when to stop logging:**
   - **When Memory Fills.** Logging will end once the logger memory is full.
   - **Never (Wrapping).** The logger will continue recording data indefinitely, with newest data overwriting the oldest.
   - **Push Button.** Logging will end once you press the Start/Stop logging button for 3 seconds. Note that if you also choose Push Button to start logging, then you will not be able to stop logging until 5 minutes after logging begins.
   - **Specific Stop Time.** Logging will end at a date and time you specify.

8. **Choose whether to keep the LCD on or off.** By default, the LCD will always remain on while logging. If you select the “Turn LCD off” checkbox, the LCD will not show the current readings, status, or other information while the logger is logging. You will, however, be able to temporarily turn the LCD screen on by pressing the Start/Stop button for 1 second if you select this option.
9. **Click the Start button to launch the logger.** Disconnect the logger from the computer and deploy it using the mounting materials (see *Mounting the Logger*). After logging begins, you can read out the logger at any time (see *Reading Out the Logger* for details).

Using the Magnet (Internal Sensor)

The logger contains an internal reed switch that can be used with the included magnet as the input to the logger. This configuration can be used to determine when a door or window is open or closed. The magnet must be oriented as shown below, positioned to the right side of the logger when the LCD screen is facing up.



Using the Input Cable (External Sensor)

The 2.5 mm input cable included with the logger can be used to measure contact closures and allows the logger to be mounted remotely from the contacts. Connect the contacts to the black and white wires, and plug the other end of the cable into the external input jack on the bottom of the logger. Do not connect the contacts to any other devices or cables.

If the external sensor was configured to record raw pulse counts or events in HOBOware, there is also an option to specify lockout time. This can prevent false readings from mechanical contact closure bouncing. For more details on setting lockout time, see the HOBOware Help.

Determining Logging Duration Data

The logger’s storage capacity and logging duration depends on the interval between state changes and events. The longer the interval between state changes, the more memory is needed to store each data point.

The following table shows how memory capacity is affected by the amount of time between events:

Time Between Events	Approximate Total Data Points	Approximate Logging Duration (1 Year Battery Life)	Logger Part Number
1 to 15 seconds	84,650	23.51 hours to 14.7 days	UX90-001
	346,795	4.01 to 60.21 days	UX90-001M
16 seconds to 4.25 minutes	63,488	11.76 to 187.38 days	UX90-001
	260,096	48.17 days to 2.1 years	UX90-001M
4.26 to 68.25 minutes	50,790	150.49 days to 6.6 years	UX90-001
	208,077	1.69 years to 2.7 decades	UX90-001M
68.26 minutes to 18.2 hours	42,325	5.5 years to 8.8 decades	UX90-001
	173,397	2.25 to 36.03 decades	UX90-001M

Notes:

- Typical battery life is 1 year when state or event changes are at 1 minute or greater intervals.
- The logger can record battery voltage data in an additional channel. This is disabled by default. Recording battery voltage reduces storage capacity and is generally not used except for troubleshooting.

Setting Maximum Pulse Frequency and Lockout Time

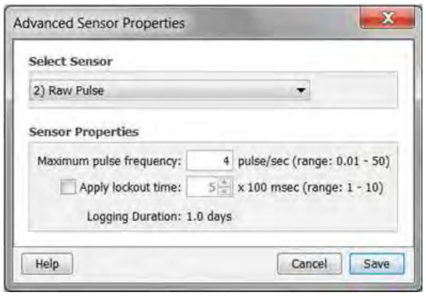
When recording raw pulse counts, the logger dynamically adjusts its memory use from 4 to 32 bits instead of a typical fixed width. This results in the ability to store more data using less space, which in turn extends logging duration. The default pulse rate is 4 Hz; the maximum pulse frequency is 50 Hz. Decreasing the rate will increase logging duration. The following table shows examples of how pulse rate and logging interval affect logging duration.

Logging Interval	Pulse Rate (Hz)	Number Bits Required	Approx. Total Data Points	Approx. Logging Duration	Logger Part Number
1 min	4	8	126,976	88 days	UX90-001
			520,192	361 days	UX90-001M
1 min	50	12	84,650	58 days	UX90-001
			346,795	240 days	UX90-001M

You can change the maximum pulse frequency in HOBOware. In addition, you can also set a lockout time for raw pulse and event channels to prevent false readings from mechanical sensors as their relay state changes. To change the maximum pulse frequency or lockout time:

1. Click the Advanced button from the Launch Logger window in HOBOware.
2. Select the sensor that corresponds with the pulse channel you wish to configure.
3. Set the maximum pulse frequency (on raw pulse channels only) keeping in mind that the larger the pulse frequency, the shorter the logging duration will be.
4. Click the “Apply lockout time” checkbox if you wish to specify a time period when pulses will be ignored (only available for raw pulse channels and event channels). Select the lockout time value from 1 to 10. On sensors with both

pulse frequency and lockout time settings, lockout time will affect the maximum pulse frequency: the higher the lockout time, the lower the maximum pulse frequency will be.
Note: When lockout time is enabled, you can specify a value from 1 to 10 (with a default of 5), which is then multiplied by 100 milliseconds for a range of 0.1 to 1 second. The available range for the maximum pulse frequency is automatically recalculated based on the lockout time. For example, if the lockout time is set to 2, the maximum pulse frequency range changes to 0.01 to 5 Hz.



5. Click Save. Note that the selections will not take effect in the logger until you launch it.

Reading Out the Logger

There are two options for reading out the logger: connect it to the computer with a USB cable and read out it with HOBOware, or connect it to a HOBO U-Shuttle (U-DT-1, firmware version 1.15m030 or higher) and then offload the data files from the U-Shuttle to HOBOware. Refer to the HOBOware Help for more details.

Recording Internal Logger Events

The logger records the following internal events (different from state/event changes) to help track logger operation and status:

Internal Event Name	Definition
Host Connected	The logger was connected to the computer.
Started	The Start/Stop button was pressed to begin logging.
Stopped	The logger received a command to stop recording data (from HOBOware or by pushing the Start/Stop button).
Button Up/Button Down	The Start/Stop button was pressed for 1 second.
Safe Shutdown	The battery level dropped below 2.5 V; the logger performs a safe shutdown.

Mounting the Logger

There are several ways to mount the logger using the materials included:

- Attach the Command strip to the back of the logger to mount it a wall or other flat surface.
- Use the double-sided tape to affix the logger to a surface.
- Insert the hook-and-loop strap through the mounting loops on both sides of the logger to mount it to a curved surface, such as a pipe or tubing.

Protecting the Logger

The logger is designed for indoor use and can be permanently damaged by corrosion if it gets wet. Protect it from condensation. If the message FAIL CLK appears on the LCD screen, there was a failure with the internal logger clock possibly due to condensation. Remove the battery immediately and dry the circuit board.

Note: Static electricity may cause the logger to stop logging. The logger has been tested to 8 KV, but avoid electrostatic discharge by grounding yourself to protect the logger. For more information, search for “static discharge” in the FAQ section on onsetcomp.com.

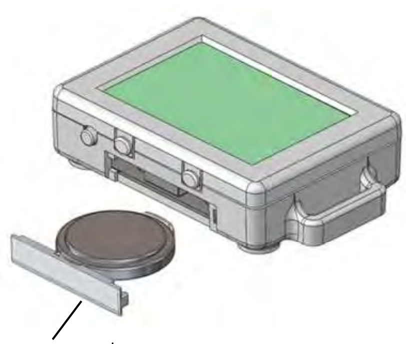
Battery Information

The logger is installed with a 3V CR2032 battery (HRB-TEMP). Expected battery life varies based on the ambient temperature where the logger is deployed, the logging interval, the rate of state changes and/or events, the frequency of offloading to the computer, and battery performance. A new battery typically lasts 1 year with logging intervals greater than 1 minute and when the input signals are normally open or in the high logic state. Deployments in extremely cold or hot temperatures, logging intervals faster than 1 minute, or continuously closed contacts may reduce battery life. Estimates are not guaranteed due to uncertainties in initial battery conditions and operating environment.

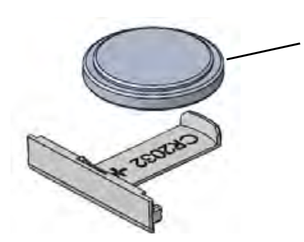
The logger can also be powered by the USB cable when the remaining battery voltage is too low for it to continue logging. Connect the logger to the computer, click the Readout button on the toolbar, and save the data as prompted. Replace the battery before launching the logger again.

To replace the battery:

1. Holding the logger with the LCD screen facing up, pull the battery tray out of the logger housing.



2. Remove the old battery from the tray.
3. Place the new battery in the tray with the positive side facing down.



4. With the LCD screen still facing up, slide the tray back into the logger. The LCD should display "HOBO" briefly after correctly installing the battery.

> ⚠ **WARNING:** Do not cut open, incinerate, heat above 85°C (185°F), or recharge the lithium battery. The battery may explode if the logger is exposed to extreme heat or conditions that could damage or destroy the battery case. Do not dispose of the logger or battery in fire. Do not expose the contents of the battery to water. Dispose of the battery according to local regulations for lithium batteries.

HOBOware provides the option of recording the current battery voltage at each logging interval, which is disabled by default. Recording battery life at each logging interval takes up memory and therefore reduces logging duration. It is recommended you only record battery voltage for diagnostic purposes.


Continental Control Systems LLC
WATTNODE® BACNET
A–
B+
C
X
MS/TP
Com
WNC-3Y-208-BN
120V~ 50-60Hz 3W
SN 117096
Ver 1.13
2013-05-15
N
ΦA CT 0.333V~
Status
ΦB CT 0.333V~
Status
ΦC CT 0.333V~
Status
Φ-N 120V~
Φ-Φ 240V~
240V CAT III
ΦA
ΦB
ΦC
1
0
Watthour Meter
US LISTED 3KNN
Boulder, CO USA

Overview

Congratulations on your purchase of the WattNode® BACnet® watt/watt-hour transducer (meter). The WattNode meter offers precision energy and power measurements in a compact package. It enables you to make power and energy measurements within existing electric service panels avoiding the costly installation of subpanels and associated wiring. It is designed for use in demand side management (DSM), sub-metering, and energy monitoring applications. The WattNode meter communicates on an EIA RS-485 two-wire bus using the BACnet protocol. Models are available for single-phase, three-phase wye, and three-phase delta configurations for voltages from 120 Vac to 600 Vac at 50 and 60 Hz.

Measurements

The WattNode BACnet meter measures the following:

- True RMS Power - Watts (Phase A, Phase B, Phase C, Sum)
- Reactive Power - VARs (Phase A, Phase B, Phase C, Sum)
- Power Factor (Phase A, Phase B, Phase C, Average)
- True RMS Energy - Watthours (Phase A, Phase B, Phase C, Sum)
- Reactive Energy - VAR-hours (Sum)
- AC Frequency
- RMS Voltage (Phase A, Phase B, Phase C)
- RMS Current (Phase A, Phase B, Phase C)
- Demand and Peak Demand

One WattNode BACnet meter can measure up to three different “single-phase two-wire with neutral” branch circuits from the same service by separately monitoring the phase A, B, and C values. If necessary, you can use different CTs on the different circuits.

Communication

The WattNode meter uses a half-duplex EIA RS-485 interface for communication. The standard baud rates are 9,600, 19,200, 38,400, and 76,800 baud. The meter uses the industry standard BACnet MS/TP communication protocol, allowing up to 64 devices per RS-485 subnet.

Diagnostic LEDs

The meter includes three power diagnostic LEDs—one per phase. During normal operation, these LEDs flash on and off, with the speed of flashing roughly proportional to the power on each phase. The LEDs flash green for positive power and red for negative power. Other conditions are signaled with different LED patterns. See **Installation LED Diagnostics (p. 22)** for details.

The BACnet WattNode meter includes a communication LED that lights green, yellow, or red to diagnose the RS-485 network. See **BACnet Communication Diagnostics (p. 27)** for details.

Options

The WattNode BACnet meter can be ordered with options. For more details and documentation, see article WattNode BACnet - Options on our website.

General Options

- ***Option CT=xxx*** - Pre-assign xxx as the ***CtAmpsA, B, and C*** values.
- ***Option CT=xxx/yyy/zzz*** - Pre-assign xxx to ***CtAmpsA***, yyy to ***CtAmpsB***, and zzz to ***CtAmpsC***.

Current Transformers

The WattNode meter may use split-core (opening), solid-core (toroidal), and flexible Rogowski current transformers (CTs), with a full-scale voltage output of 333.33 mVac and opening widths ranging from 0.3 in (7.6 mm) up to 12 in (305 mm) or Rogowski lengths up to 48 in (1220 mm). Split-core and Rogowski CTs are easier to install without disconnecting the circuit being measured. Solid-core CTs installation requires that you disconnect the circuit to install the CTs.

Additional Literature

These additional documents are available on the Continental Control Systems, LLC website or BACnet.org website.

- WattNode BACnet Object List (Excel format): WNC-BACnet-Object-List
- Continental Control Systems, LLC website
  - http://www.ccontrolsys.com/w/WattNode_BACnet - main page.
  - http://www.ccontrolsys.com/w/Category:WattNode_BACnet - support articles.
- http://www.bacnet.org
  - BACnet Standard: ASHRAE/ANSI Standard 135-2010

Front Label

This section describes the connections, information, and symbols on the front label.

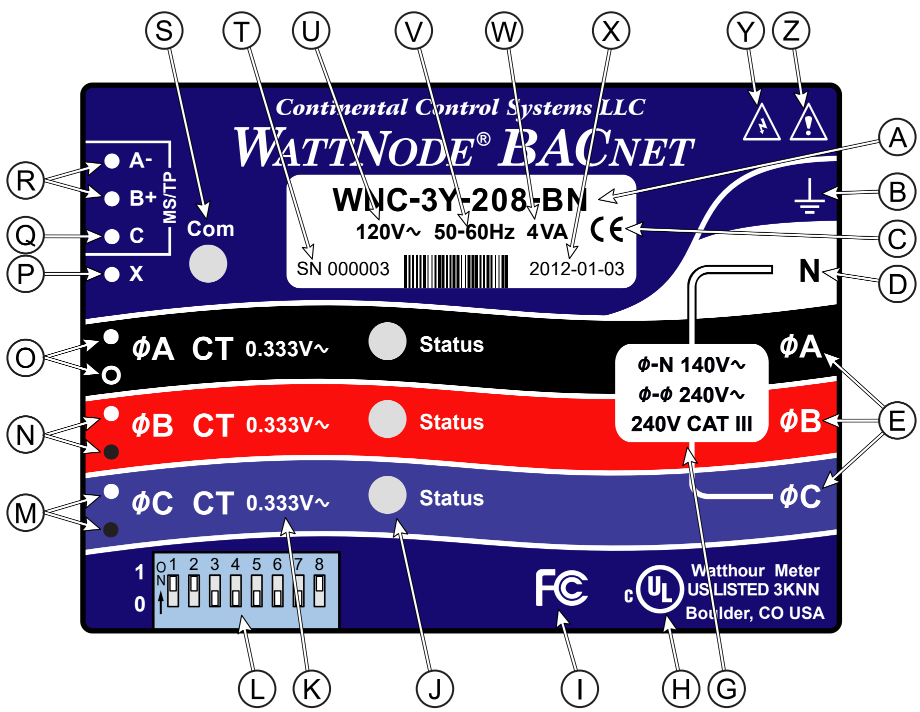


Figure 1: Front Label Diagram

A: WattNode model number. The "**WNC**" indicates a third generation WattNode meter. The "**3**" indicates a three-phase model. The "**Y**" or "**D**" indicates wye or delta models, although delta models can measure wye circuits (the difference is in the power supply). The "**208**" (or other value) indicates the nominal line-to-line voltage. Finally, the "**BN**" indicates BACnet output.

B: Functional ground. This terminal should be connected to earth ground if possible. It is not required for safety grounding, but ensures maximum meter accuracy.

C: CE Mark. This logo indicates that the meter complies with the regulations of the European Union for Product Safety and Electro-Magnetic Compatibility.

D: Neutral. This terminal "**N**" should be connected to neutral for circuits where neutral is present.

E: Line voltage inputs. These terminals connect to the ***ϕ*A** (phase A), ***ϕ*B** (phase B), and ***ϕ*C** (phase C) electric mains. On wye models the meter is powered from the ***ϕ*A** and **N** terminals. On delta models, the meter is powered from the ***ϕ*A** and ***ϕ*B** terminals.

G: Line voltage measurement ratings. This block lists the nominal line-to-neutral "***ϕ*-N 120V~**" voltage, line-to-line "***ϕ*-*ϕ* 240V~**" voltage, and the rated measurement voltage and category "**240V CAT III**" for this WattNode model. See the **Specifications (p. 50)** for more information about the measurement voltage and category.

H: UL Listing mark. This shows the UL and cUL (Canadian) listing mark and number "**3KNN**".

I: FCC Mark. This logo indicates that the meter complies with part 15 of the FCC rules.

J: Status LEDs. These are status LEDs used to verify and diagnose meter operation. See **Installation LED Diagnostics (p. 22)** for details.

K: Current transformer (CT) voltage rating. These markings "**0.333V~**" indicate that the meter must be used with CTs that generate a full-scale output of 0.333 Vac (333 millivolts).

L: DIP switch. This DIP switch block is used to set the BACnet MAC (network) address and baud rate. See **Setting the BACnet Address (p. 19)**.

M, N, O: Current transformer (CT) inputs. These indicate CT screw terminals. Note the white and black circles at the left edge of the label: these indicate the color of the CT wire that should be inserted into the corresponding screw terminal. The terminals marked with black circles are connected together internally.

P: Auxiliary output terminal. This screw terminal is used for the X terminal options.

Q: BACnet common terminal. This is the common or ground terminal for BACnet EIA RS-485 communication wiring. It is also the common for the X terminal options if they are installed.

R: BACnet signal terminals. These are the RS-485 A– and B+ signals (half-duplex, two-wire). There are several names for these terminals:

- **Inverting pin**: A–, A, –, TxD–, RxD–, D0, and on rare devices "B"
- **Non-inverting pin**: B+, B, +, TxD+, RxD+, D1, and on rare devices "A"

S: Communication status. This LED indicates communication status. See **BACnet Communication Diagnostics (p. 27)** for details.

T: Serial number. This is the meter serial number. The barcode contains the serial number in Code 128C format.

U: Mains supply rated voltage. This is the rated supply voltage for this model. The **V~** indicates AC voltage. For wye models, this voltage should appear between the **N** and ***ϕ*A** terminals. For delta models, this voltage should appear between the ***ϕ*A** and ***ϕ*B** terminals.

V: Mains frequencies. This indicates the rated mains frequencies for the meter.

W: Maximum rated volt-amps. This is the maximum apparent power consumption (volt-amps) for this model.

X: Manufacture date. This is the date of manufacture for this WattNode meter.

Y: Caution, risk of electrical shock. This symbol indicates that there is a risk of electric shock when installing and operating the meter if the installation instructions are not followed correctly.

Z: Attention - consult Manual. This symbol indicates that there can be danger when installing and operating the meter if the installation instructions are not followed correctly.

Symbols

	Attention - Consult Installation and Operation Manual	Read, understand, and follow all instructions in this Installation and Operation Manual including all warnings, cautions, and precautions before installing and using the product.
	Caution – Risk of Electrical Shock	Potential Shock Hazard from Dangerous High Voltage.
	CE Marking	Complies with the regulations of the European Union for Product Safety and Electro-Magnetic Compatibility. ● Low Voltage Directive – EN 61010-1: 2001 ● EMC Directive – EN 61327: 1997 + A1/1998 + A2/2001

Installation

Precautions

DANGER — HAZARDOUS VOLTAGES
WARNING - These installation/servicing instructions are for use by qualified personnel only. To avoid electrical shock, do not perform any servicing other than that contained in the operating instructions unless you are qualified to do so.

Always adhere to the following checklist:

1) Only qualified personnel or **licensed electricians** should install the WattNode meter. The mains voltages of 120 Vac to 600 Vac can be lethal!
2) Follow all applicable local and national electrical and safety codes.
3) Install the meter in an electrical enclosure (panel or junction box) or in a limited access electrical room.
4) Verify that circuit voltages and currents are within the proper range for the meter model.
5) Use only UL listed or UL recognized current transformers (CTs) with built-in burden resistors, that generate 0.333 Vac (333 millivolts AC) at rated current. **Do not use current output (ratio) CTs such as 1 amp or 5 amp output CTs: they will destroy the meter and may create a shock hazard.** See **Current Transformers (p. 55)** for CT maximum ratings.
6) Ensure that the line voltage input leads to the meter are protected by fuses or circuit breakers (not needed for the neutral wire). See **Circuit Protection (p. 18)** for details.
7) Equipment must be disconnected from the HAZARDOUS LIVE voltages before access.
8) The terminal block screws are **not** insulated. Do not contact metal tools to the screw terminals if the circuit is energized!
9) Do not place more than one line voltage wire in a screw terminal; use wire nuts instead. You may use more than one CT wire or communication interface wire per screw terminal.
10) Before applying power, check that all the wires are securely installed by tugging on each wire.
11) Do not install the meter where it may be exposed to temperatures below –30°C or above 55°C, excessive moisture, dust, salt spray, or other contamination. The meter requires an environment no worse than pollution degree 2 (normally only non-conductive pollution; occasionally, a temporary conductivity caused by condensation must be expected).
12) Do not drill mounting holes using the meter as a guide; the drill chuck can damage the screw terminals and metal shavings can fall into the connectors, causing an arc risk.
13) If the meter is installed incorrectly, the safety protections may be impaired.

Appendix B.4 GE ASPMETER Metering Panelboard

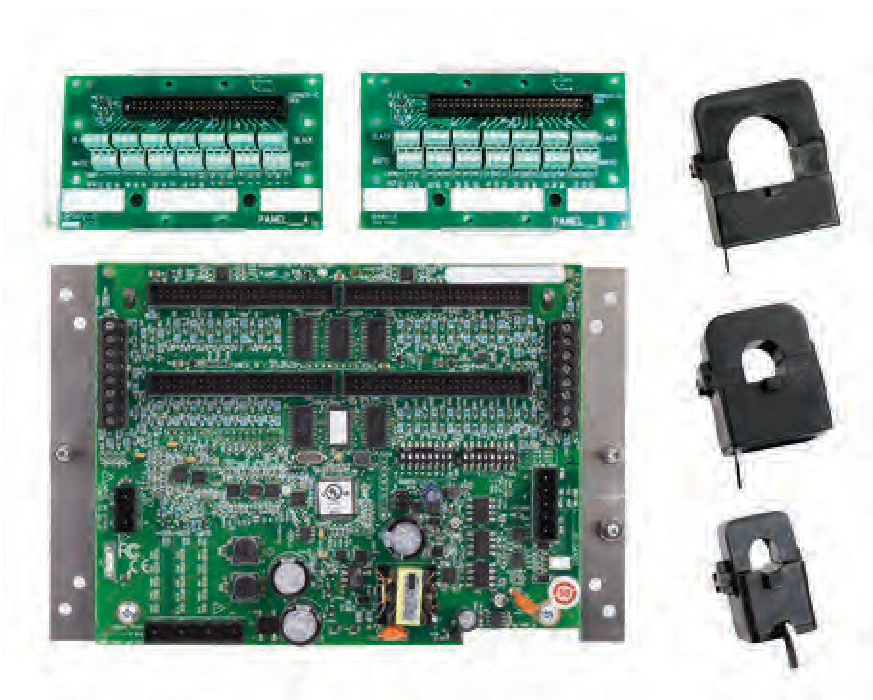
(Reference source for DEH-40700 ASPMETER Panelboard Monitoring System is GE Energy Connections. Reprint permission granted by General Electric.)

GE
Industrial Solutions

DEH-40700 Installation Instructions

ASPMETER Panelboard Monitoring System

Split Core



Safety

FCC PART 15 INFORMATION NOTE: This equipment has been tested by the manufacturer and found to comply with the limits for a class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a residential environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. This device complies with part 15 of the FCC Rules.

Operation is subject to the following two conditions:
(1) This device may not cause harmful interference, and
(2) This device must accept any interference received, including interference that may cause undesired operation.

Modifications to this product without the express authorization of the manufacturer nullify this statement.

A qualified person is one who has skills and knowledge related to the construction and operation of this electrical equipment and the installation, and has received safety training to recognize and avoid the hazards involved.

NEC2011 Article 100: No responsibility is assumed by manufacturer for any consequences arising out of the use of this material.

Control system design must consider the potential failure modes of control paths and, for certain critical control functions, provide a means to achieve a safe state during and after a path failure. Examples of critical control functions are emergency stop and over-travel stop.

⚡	This symbol indicates an electrical shock hazard exists.
⚠	Documentation must be consulted where this symbol is used on the product.

DANGER: Hazard of Electric Shock, Explosion or Arc Flash
Failure to follow these instructions will result in death or serious injury.

- Follow safe electrical work practices. See NFPA 70E in the USA, or applicable local codes.
- This equipment must only be installed and serviced by qualified electrical personnel.
- Read, understand and follow the instructions before installing this product.
- Turn off all power supplying equipment before working on or inside the equipment.
- Use a properly rated voltage sensing device to confirm power is off. DO NOT DEPEND ON THIS PRODUCT FOR VOLTAGE INDICATION
- Only install this product on insulated conductors.

NOTICE:

- This product is not intended for life or safety applications.
- Do not install this product in hazardous or classified locations.
- The installer is responsible for conformance to all applicable codes
- Mount this product inside a suitable fire and electrical enclosure.

WARNING: Loss of Control
Failure to follow these instructions may cause injury, death or equipment damage.

- Assure that the system will reach a safe state during and after a control path failure.
- Separate or redundant control paths must be provided for critical control functions.
- Test the effect of transmission delays or failures of communication links.
- Each implementation of equipment using communication links must be individually and thoroughly tested for proper operation before placing it in service.

For troubleshooting or service related questions, contact GE at 1-800-GE-1-STOP (1-800-431-7867).

Save These Instructions

Specifications

Inputs	
Input Power	90-277 VAC, 50/60 Hz
Accuracy	
Power/Energy	IEC 62053-21 Class 1, ANSI C12.1-2008
Voltage	±0.5% of reading 90-277 V line-to-neutral
Operation	
Sampling Frequency	2560 Hz
Update Rate	1.8 seconds (both panels)
Overload Capability	22 kAIC
Outputs	
Type	Modbus RTU™
Connection	DIP switch-selectable 2-wire or 4-wire, RS-485
Address	DIP switch-selectable address 1 to 247 (in pairs of 2)[1]
Baud Rate	DIP switch-selectable 9600, 19200, 38400
Parity	DIP switch-selectable NONE, ODD, EVEN
Communication Format	8-data-bits, 1-start-bit, 1-stop-bit
Termination	5-position depluggable connector (TX+ TX- SHIELD TX+/RX+ TX-/RX-)
Terminal Block Torque	4.4 to 5.3 in-lb (0.5 to 0.6 N-m)
Mechanical	
Ribbon Cable Support	4 ft. (0.9m) flat ribbon cable ships standard; up to 20 ft. (6m) available
Operating Conditions	
Operating Temp Range	0° to 60°C (32° to 140°F); <95% RH, non-condensing
Storage Temp Range	-40° to 70°C (-40° to 158°F)
Altitude of Operation	3000m
Compliance	
Agency Approvals	UL508 open type device, EN61010-1
Installation Category	Cat III, pollution degree 2

[1] See Configuration Section for details.

Notes:
- If ASPMETER products are used in installations with circuits higher than the product ratings, the circuits must be kept segregated per UL508A Sec. 17.5.
- 277/480VAC Wye connected (center grounded) power systems operate within the 300VAC line to neutral safety rating of the ASPMETER series, and the operational voltage limit (single-phase connection) as the line to neutral voltage is 277VAC in such power systems. Corner-grounded delta 480VAC systems would not qualify, as the actual line to earth voltage is 480VAC on each leg, exceeding the ASPMETER ratings.
- ASPMETER internal circuitry (cables and CTs) are not circuits as defined by UL508A, as they do not extend beyond the ASPMETER itself without further safety/fire isolation.

Product Overview

The ASPMETER Panelboard Monitoring System is designed to measure the current, voltage, and energy consumption of up to 92 circuits (84 branch circuits, 2 3-phase mains, 2 neutrals) on a single board. One ASPMETER can monitor up to two panels.

The ASPMETER consists of a data acquisition board and up to 84 split-core current sensors (50A, 100A, or 200A), with eight auxiliary inputs. Each conductor passes through a current sensor and terminates at the breaker. Each sensor transmits the current data to the data acquisition board. Data is transmitted using an RS-485 Modbus protocol. Each data acquisition board requires two addresses, one for each set of 42 current sensors and four auxiliary inputs. Data is updated roughly every two seconds. As a circuit approaches the user-defined threshold, the ASPMETER activates the alarm indicators.

The ASPMETER-A measures both current and power for the mains and branch circuits. The ASPMETER-B measures both current and power for the mains, and current only in each circuit. The ASPMETER-C measures current only for the mains and branch circuits.

Product Identification

ASPMETER

Description

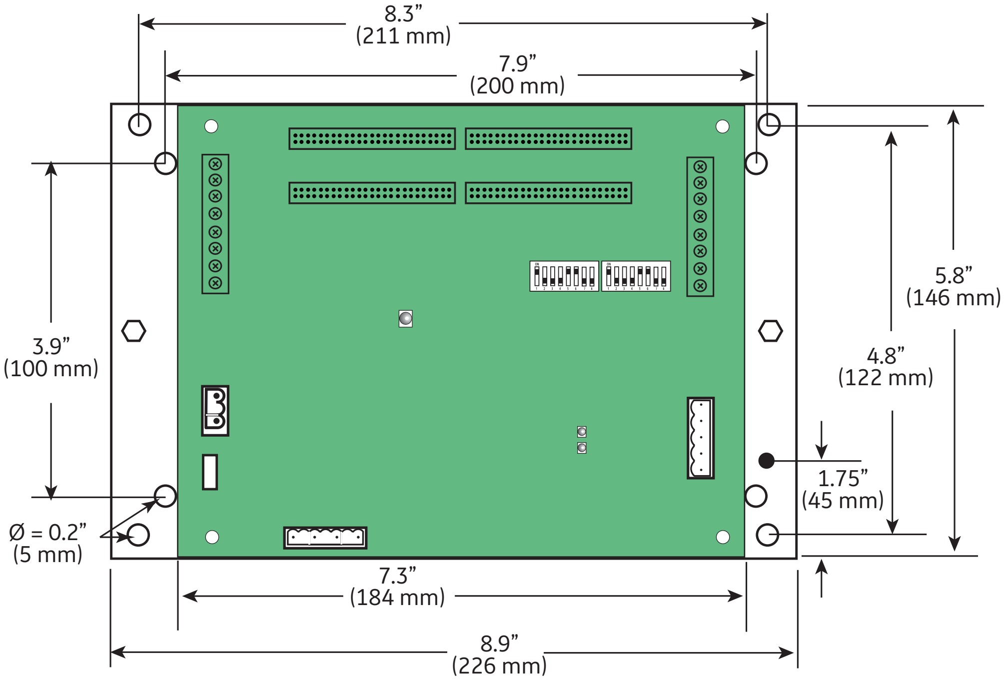
A = Advanced board
B = Intermediate board
C = Basic board

# of CTs

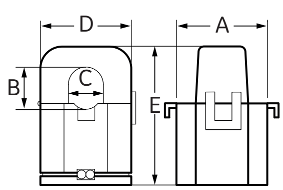
002 = 2 adapter boards, no CTs, no cables
004 = 4 adapter boards, no CTs, no cables
42 = 2 adapter boards, (42) 50A CTs, (2) 4 ft. round ribbon cables
84 = 4 adapter boards, (84) 50A CTs, (4) 4 ft. round ribbon cables

Dimensions

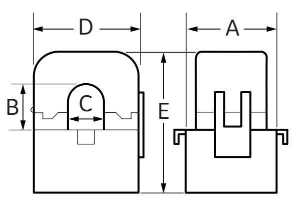
Circuit Board and Mounting Bracket



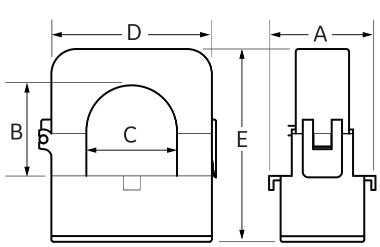
Current Sensors



ASPCT0 50 Amp
A = 1.0" (26 mm)
B = 0.5" (11 mm)
C = 0.4" (10 mm)
D = 0.9" (23 mm)
E = 1.6" (40 mm)

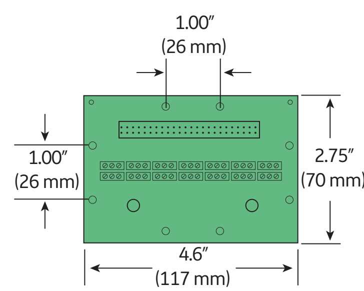


ASPCT1 100 Amp
A = 1.5" (37.5 mm)
B = 0.6" (16 mm)
C = 0.6" (16 mm)
D = 1.85" (47 mm)
E = 2.1" (53 mm)

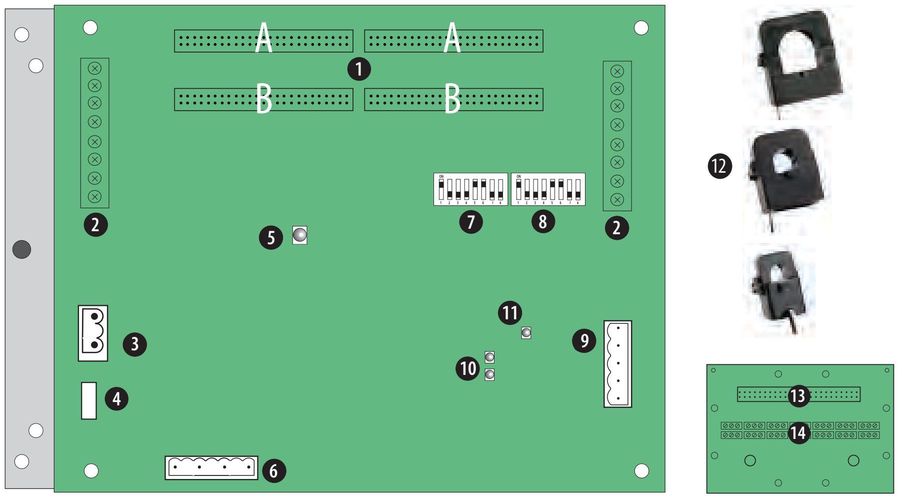


ASPCT3 200 Amp
A = 1.5" (39 mm)
B = 1.25" (32 mm)
C = 1.25" (32 mm)
D = 2.5" (64 mm)
E = 2.8” (71 mm)

Adapter Board



Product Diagrams



1. **50-Pin Ribbon Cable Connectors:** Ribbon cables attach here for easy connection of adapter boards to the data acquisition board. The two connectors on the left are for panelboard 1; the two on the right are for panelboard 2.

   NOTE: Connect Adapter Boards A and B to the correct ribbon cable connectors for each panel. The top connector is for Adapter Board A, and the bottom connector is for Adapter Board B.

   NOTE: Ribbon Cable is not included with all ASPMETER models. For ribbon cable options, see Recommended Accessories on page 14.

2. **Auxiliary Inputs:** These 0.333 VAC inputs are used for monitoring the main breaker or other high amperage source. Inputs on the left are for panelboard 1; inputs on the right are for panelboard 2.
3. **Control (Mains) Power Connection:** Easy 2-wire 90-277 VAC 50/60 Hz connection.
4. **Control Power Fuse:** 600 VAC, 500 mA time lag, factory-replaceable.
5. **Alive LED:** Red/green/amber LEDs. Blink codes are on page 5.
6. **Voltage Taps:** 1, 2, or 3 phase plus neutral connections. For voltage sensing and power calculations (no voltage taps on the ASPMETER-C). Voltage taps are shared by both panels.
7. **Communications Address DIP Switches:** Each Modbus device must have a unique address. Switches are binary weighted. Left-most switch has a value of 1; right-most switch has a value of 128.

   NOTE: Switches set the address for panel 1; panel 2 is automatically set to (Panel 1 address + 1).
   See Configuration section for details.

8. **Communications Settings DIP Switch:** Configures baud rate, parity, 2/4 wire communications.
9. **RS-485 Connection:** Used for Modbus serial communications. The Universal plug accommodates 2 or 4 wire connections.
10. **RS-485 LEDs:** The RX LED (closest to DIP switches) indicates the RS-485 is receiving information; the TX LED (farthest from DIP switches) indicates transmission of information.
11. **Power LED:** Indicates power to main board .
12. **Branch Current Sensors:** Each split-core current sensor is capable of monitoring conductors rated up to a maximum of 50, 100, or 200 amps. Up to 84 sensors can be purchased with the ASPMETER (see Recommended Accessories on page 14). One of each style is pictured here.
13. **Ribbon Cable Connectors**
14. **CT Terminal Connectors**

Data Output

Monitoring at Mains	ASPMETER-A	ASPMETER-B	ASPMETER-C
Current per phase	✓	✓	✓
Max. current per phase	✓	✓	✓
Current demand per phase	✓	✓	✓
Max. current demand per phase	✓	✓	✓
Energy (kWh) per phase	✓	✓	
Real Power (kW) per phase	✓	✓	
Apparent Power (kVA)	✓	✓	
Power factor total *	✓	✓	
Power factor per phase	✓	✓	
Voltage - L-L and average of 3 phases	✓	✓	
Voltage - L-N and average of 3 phases	✓	✓	
Voltage - L-N and per phase	✓	✓	
Frequency (phase A)	✓	✓	
Monitoring at Branch Circuit			
Current	✓	✓	✓
Max. current	✓	✓	✓
Current demand	✓	✓	✓
Max. current demand	✓	✓	✓
Real power (kW)	✓		
Real power (kW) demand	✓		
Real power (kW) demand max.	✓		
Energy (kWh) per circuit	✓		
Power factor	✓		
Apparent Power (kVA)	✓		
Modbus Alarms			
Voltage over/under	✓	✓	
Current over/under	✓	✓	✓

* Based on a 3-phase breaker rotation.

Blink Code for Status LED

Color and Pattern	Status Description
Green, once per second	Normal operation
Amber, once per second	Volts or Amps clipping
Amber, twice per second	Invalid firmware image
Red, solid or blink	Diagnostic event detected

Split-Core CT Accuracy

Description	Split-Core CT		
	50A	100A	200A
Voltage rating	300 VAC	300 VAC (CE), 600 VAC (UL)	300 VAC (CE), 600 VAC (UL)
Accuracy	±1%	±0.5%	±1%
Temperature	0° to 60°C		
Agency	UL508 recognized, EN61010-1		

Commissioning

1. Install according to instructions in Mechanical Installation.
2. Provide control power to panel.
3. Configure installation mode using Modbus Register 6.
4. Configure CT scaling.
5. Configure alarms.
6. Configure demand.

Download the free Configuration Tool “NetConfig” from www.veris.com/modbus_downloads.aspx to commission the E3x for operation.

Wiring

⚠	Power must be disconnected and locked out before making any wiring connections.

Connect 2-wire or 4-wire Modbus RS-485 daisy chain network (Figures 1 and 2).

Figure 1.

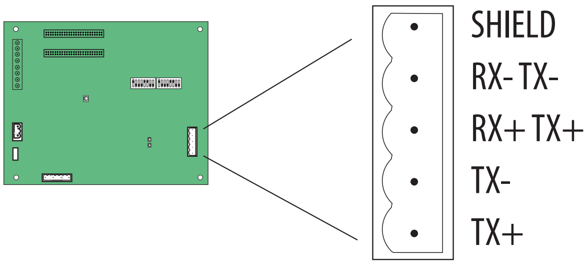
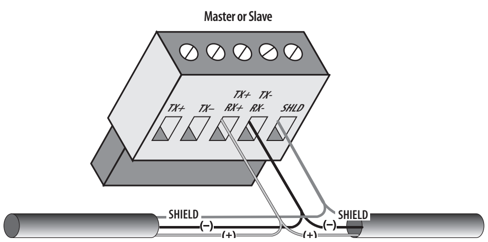
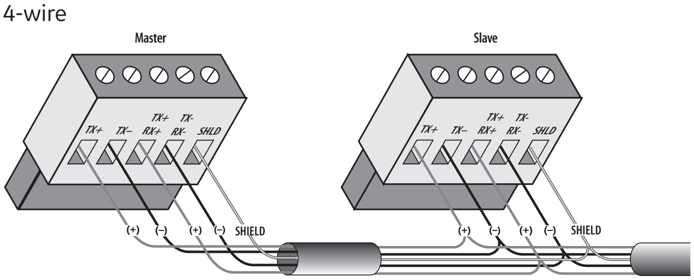


Figure 2.

2-wire



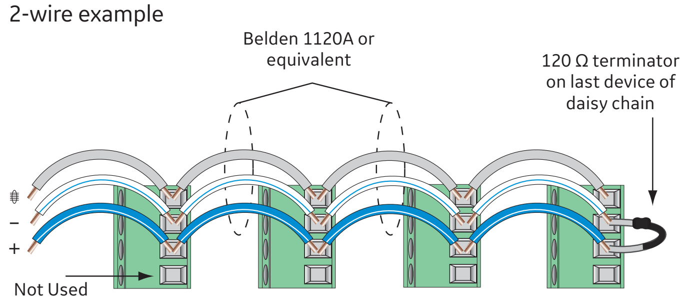
4-wire



1. Mechanically secure the RS-485 cable where it enters the electrical panel.
2. Connect all RS-485 devices in a daisy-chain fashion, and properly terminate the chain (Figure 3).

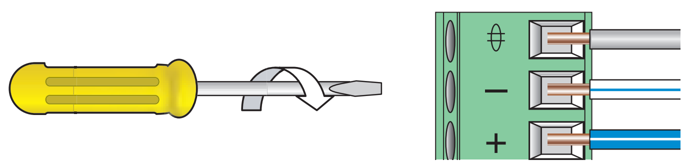
Figure 3.

2-wire example



3. Shield the RS-485 cable using twisted-pair wire, such as Belden 1120A. The cable must be voltage-rated for the installation.
4. When tightening terminals, ensure that the correct torque is applied: 0.5 to 0.6 N·m (0.37 to 0.44 ft·lb) for connectors on main board, 0.22 to 0.26 N·m (0.16 to 0.19 ft·lb) for connectors on adapter boards (Figure 4).

Figure 4.

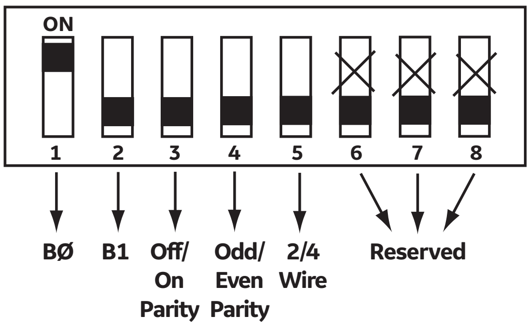


⚠	**WARNING**: After wiring the RS-485 cable, remove all scraps of wire or foil shield from the electrical panel. Wire scraps coming into contact with high voltage conductors could be DANGEROUS!

Configuration

1. **Communications Configuration:** Communications parameters for the ASPMETER series are field selectable for your convenience. Please see the Product Diagrams section (page 5) for selector location. The following parameters are configurable:
   - Baud Rate: 9600, 19200, 38400
   - Parity On or Off
   - Parity: odd or even
   - Wiring: two or four

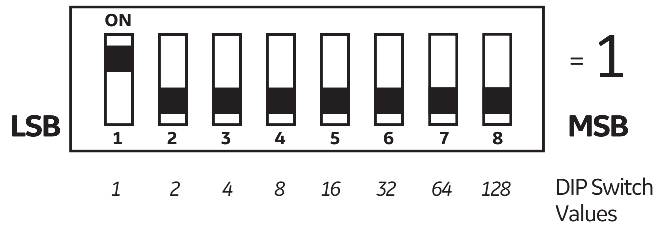
Example: 2-wire 19200 Baud, no parity (default only)



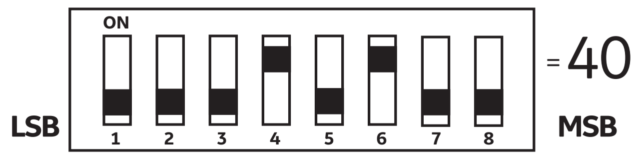
1	2	3	4	5	6	7	8	
Off	Off				X	X	X	**9600**
On	Off				X	X	X	**19200**
Off	On				X	X	X	**38400**
On	On				X	X	X	**Reserved**
		Off	Off		X	X	X	**No Parity**
		On	Off		X	X	X	**Odd Parity**
		Off	On		X	X	X	**No Parity**
		On	On		X	X	X	**Even Parity**
				On	X	X	X	**4-wire RS-485**
				Off	X	X	X	**2-wire RS-485**

2. **Address Configuration:** Each Modbus device on a single network must have a unique address. Set the switch block to assign a unique address before the device is connected to the Modbus RS-485 network. If an address is selected which conflicts with another device, neither device will be able to communicate.

3. The ASPMETER uses two logical addresses. Panel 1 uses the base address as set on the DIP switches, and Panel 2 uses this base address + 1. Address the ASPMETER as any whole number between and including 1-246. Each unit is equipped with a set of 8 DIP switches for addressing. See below.



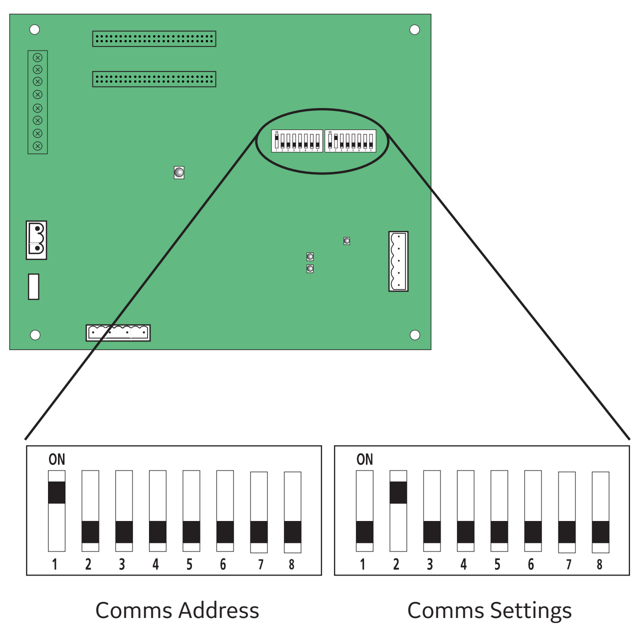
4. T o determine an address, simply add the values of any switch that is on. For example:



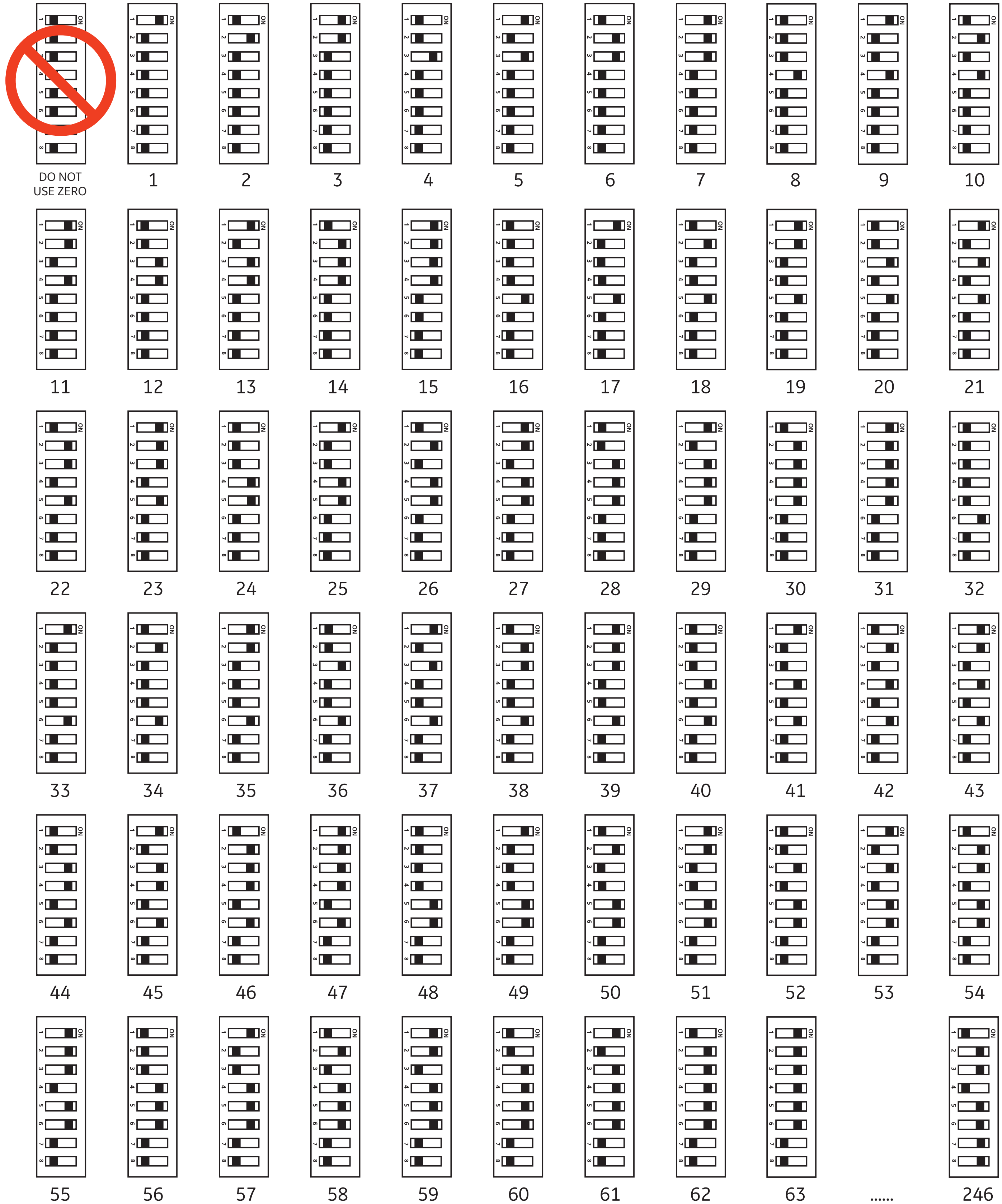
Switch number 4 has an ON Value of 8 and switch number 6 has an ON Value of 32. (8 + 32 = 40). Therefore, the address for Panel 1 is 40 and the address for Panel 2 is 41. See the Address Setup section (page 9) for a pictorial listing of the first 63 switch positions.

Default DIP Switch Settings

The ASPMETER includes two DIP switches, as shown below. Switches are shown in their default positions.



Address Setup



Mechanical Installation

Observe precautions for handling static sensitive devices to avoid damage to the circuitry that is not covered under the factory warranty.

Disconnect power to the electrical panel and lock it out.

1. Install the acquisition board mounting bracket in the panel using screws and bolts provided. Panels can be oriented side-by-side (Figure 5A) or vertically (Figure 5B). A grounding connection is located on the mounting bracket, near the lower right corner. Use this stud to ground the bracket when mounting on a non-conductive surface.

Figure 5A.
Side-by-side

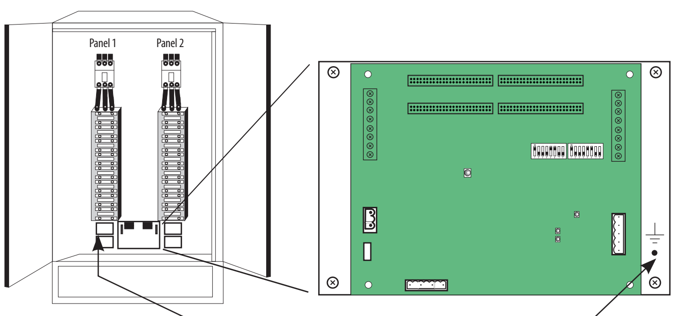
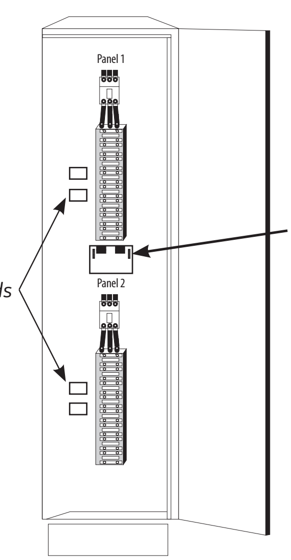


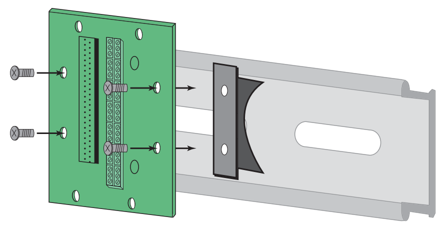
Figure 5B.
Vertically



2. Mount the adapter boards to either DIN rail or SNAPTRACK.
   — **DIN Rail:** Use the supplied screws to secure the plastic DIN clip to the adapter board. Affix the clip to the DIN rail (Figure 6).

   — **SNAPTRACK:** Secure the SNAPTRACK to the mounting surface. Click the adapter board into place (Figure 7).

Figure 6.
DIN Option – Vertical Mount



DIN Option – Horizontal Mount

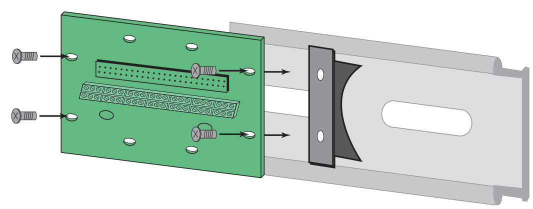
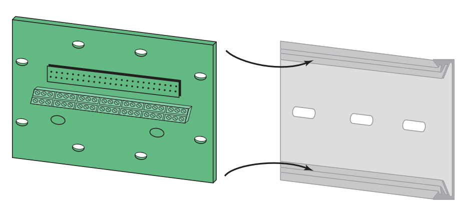


Figure 7.
SNAPTRACK



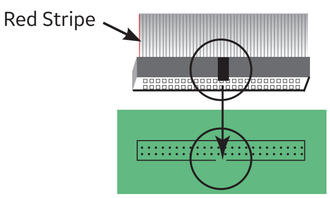
3. Connect adapter boards to the main board using ribbon cable (Figure 8). Ribbon cables are keyed to ensure proper installation.

   Orient cables so that the red stripe is on the left.

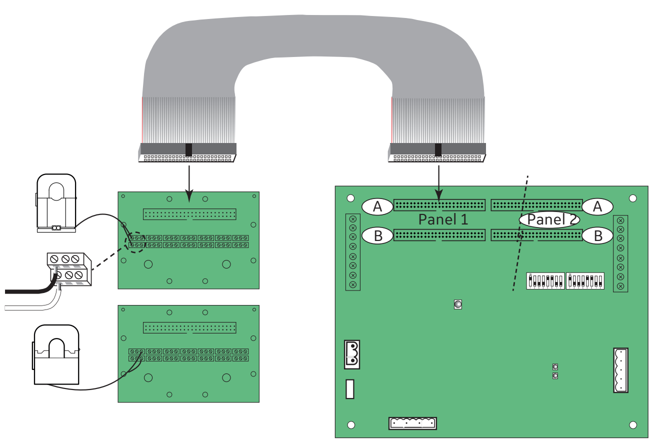
   NOTE: Flat and round ribbon cable are available. See Recommended Accessories.

4. Connect current sensors to the terminals on the adapter boards (Figure 8).

Figure 8.



Align ribbon cable key with connector keyhole. Orient ribbon cable so that the red stripe is on the left side of the connector.

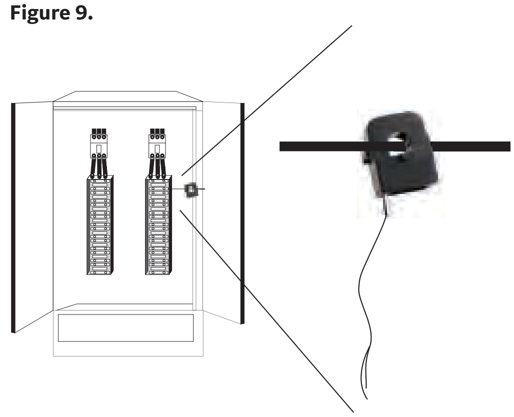


If the signed power factor feature is NOT enabled, then the current sensor orientation does not affect meter behavior. If this feature IS enabled, orient the current sensors so that the arrow points toward the load for proper operation.

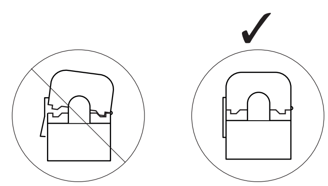
5. Install the current sensors onto the conductors to be monitored (Figure 9). Sensors can be mounted facing either direction; orientation does not affect meter accuracy.

   NOTE: Clean split-core contacts before closing. The hinge can detach, allowing the base and the top to separate for easier cleaning and installation

Figure 9.



The 50 A CT accepts a maximum #2 AWG (0.384" O.D.) wire with THHN insulation. The 100A CT accepts a maximum 3/0 AWG (0.584" O.D.) wire with THHN insulation. The 200A CT accepts a maximum of 350 MCM wire with THHN insulation. Use this gauge wire or smaller for each circuit.



Close CTs until the clasp clicks into place to ensure that contact surfaces are firmly seated.

6. Plastic cable ties are included with the product for strain relief. Insert the strain relief device into one of the available holes on the adapter board (Figure 10A). Gather all current sensor wires connected to that adapter board and secure the cable tie around them (Figure 10B).

Figure 10A.

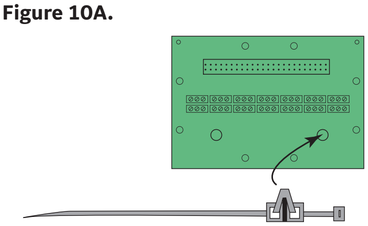
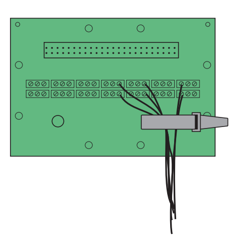
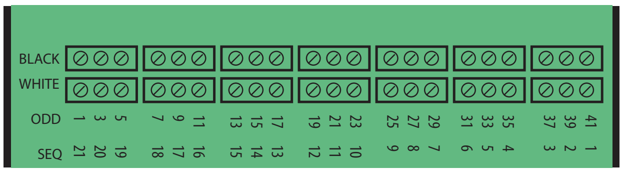


Figure 10B.



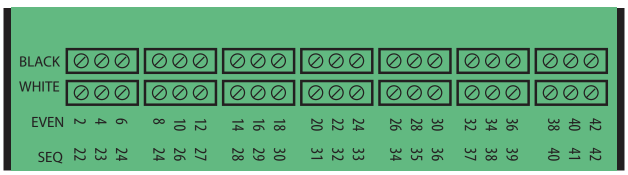
7. The adapter boards are silk screened with two rows of numbers. For applications that require odd/even branch circuit numbering, use the row designated ODD or EVEN. For applications that require sequential numbering, use the number row marked SEQ (Figures 11 and 12).

Figure 11.



Numbering – Adapter Board A:

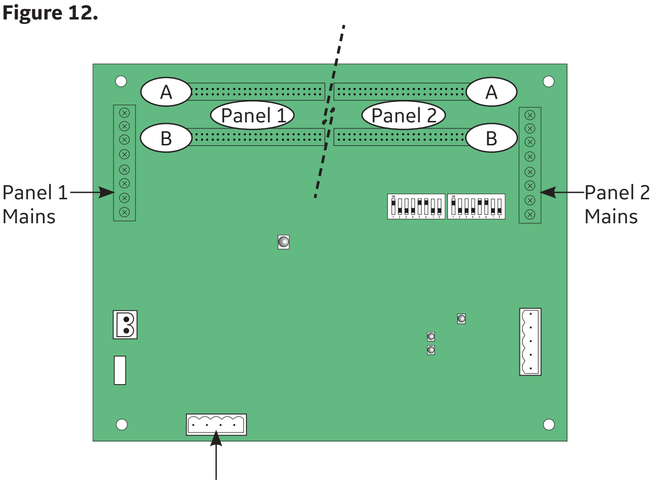
ODD	1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41
SEQ	21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1



Numbering – Adapter Board B:

EVEN	2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42
SEQ	22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42

Figure 12.



Voltage taps are shared by both panels

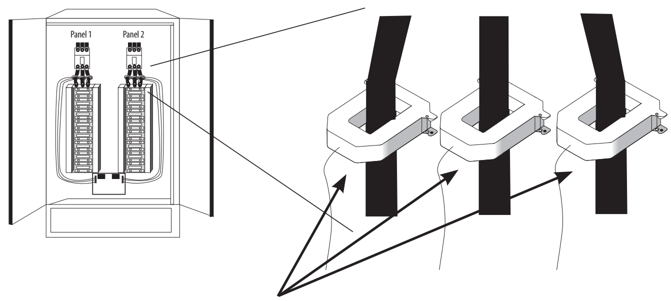
Panel 1 uses base Modbus address as set by DIP switches.
Panel 2 uses base + 1 Modbus address as set by DIP switches.

8. Configure communication and addressing parameters using DIP switches. The ASPMETER requires two addresses, one for each set of 42 current sensors and four auxiliary inputs. See the Configuration section for more information.

9. Wire RS-485 communications (see diagrams in Wiring section).

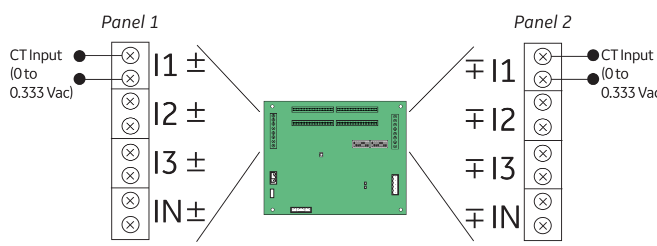
10. Connect 0.333VAC current transducers (CTs) to the main conductors by snapping CTs around lines, observing local codes regarding bending radius (optional; Figures 13 and 14).

Figure 13.



Recommended CT: AMP1 Series available in 100A max. to 2000A max. Contact your local GE sales rep for recommended CTs amperages or if higher amperages are required.

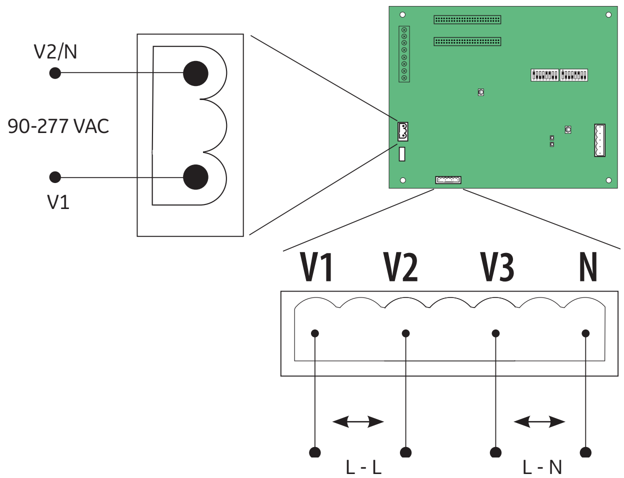
Figure 14.



Set up Modbus registers 115-118 for CT scaling.
Use base + 1 address for Panel 2 setup.
NOTE: (+) represents black, (-) represents white

11. Connect 2-wire 90-277VAC power to main power terminals. Observe polarity. For the ASPMETER-A and ASPMETER-B, connect voltage lines to the voltage taps (Figure 15). Equip voltage lines with fuses.

Figure 15.



Line to Line (L-L) Voltage: 150 to 480 VAC
Line to Neutral (L-N) voltage: 90 to 277 VAC

Recommended Accessories

Catalog Number	Description
ASPCT0	Six-pack 50 A CT, 6 ft. (1.8 m) lead
ASPCT1	Six-pack 100 A CT, 6 ft. (1.8 m) lead
ASPCT2	Single 200A CT, 6ft (1.8m) lead

Troubleshooting

Problem	Solution
Product is not communicating over Modbus daisy chain	• Check the unit Modbus address to ensure that each device on the daisy chain has a unique address. • Check Parity. • Check the communications wiring. • Check that the daisy chain is properly terminated.
RX LED is solid	• Check for reversed polarity on Modbus comms. • Check for sufficient biasing on the Modbus bus. Modbus physical specification calls for 450-650 Ω biasing. This is usually provided by the master.
The main board has a fast flashing amber light	• Verify ribbon cable connectors are inserted in the correct orientation. • If cables are correct, reset main board to re-initialize product.
The main board has a slow flashing amber light	• One or more channels is clipping. This can be caused by a signal greater than 100 A or 277 V L-N, or by a signal with high THD near the gain stage switching points (1.5 A and 10 A).
The main board has a flashing green light	• Everything is wired properly and the main board has power.
The main board is a flashing or solid red light	• Light may be red briefly while device powers up. • If light is red for more the 60 sec. device has encountered a diagnostic event. Contact technical support.
Split-core product is reading zero for some values	• Device was unable to read split-core adapter boards on power up. Verify adapter boards are connected. • Verify ribbon cable connectors are inserted in the correct orientation. • Reset main board to re-initialize product.
Power factor reading is not as expected	• Verify voltage taps are connected in appropriate phase rotation. • Verify phase rotation of breakers (firmware rev. 1.012 or higher allows for custom rotation if needed).
Current reading is not as expected, or reading is on different CT number than expected	• Verify ribbon cable is fully seated and in the correct orientation.
Current is reading zero, even when small currents are still flowing through circuit	• The product cuts off at 50 mA, and will set the reporting register to 0 mA for currents near or below this range.
Configuration Tool “NetConfig” returns Modbus error on read/write	• Verify using the latest release of Configuration Tool “NetConfig” as older versions may not support all features in current product firmware. Latest version is available on the website http://www.veris.com/modbus_downloads.aspx

For troubleshooting or service related questions, contact GE at 1-800-GE-1-STOP (1-800-431-7867).

Imagination at work

GE
41 Woodford Avenue
Plainville, CT 06062
www.geindustrial.com

DEH-40700 0516

Public Input No. 3628-NFPA 70-2017 [Section No. 220.87]

220.87 Determining Existing Loads.

The calculation of a feeder or service load for existing installations shall be permitted to use actual maximum demand to determine the existing load under all of the following conditions:

Exception: If the feeder or service has any renewable energy system (i.e. Solar Photovoltaic Systems or Wind Electric Systems) or employs any form of Peak Load Shaving, this calculation method shall not be used.

(1) The maximum demand data is available for a 1-year period.

Exception: If the maximum demand data for a 1-year period is not available, the calculated load shall be permitted to be based on the maximum demand (the highest average kilowatts reached and maintained for a 15-minute interval) continuously recorded over a minimum 30-day period using a recording ammeter or power meter connected to the highest loaded phase of the feeder or service, based on the initial loading at the start of the recording. The recording shall reflect the maximum demand of the feeder or service by being taken when the building or space is occupied and shall include by measurement or calculation the larger of the heating or cooling equipment load, and other loads that may be periodic in nature due to seasonal or similar conditions.

(2) The maximum demand at 125 percent plus the new load does not exceed the ampacity of the feeder or rating of the service.

(3) The feeder has overcurrent protection in accordance with 240.4, and the service has overload protection in accordance with 230.90.

Statement of Problem and Substantiation for Public Input

Any feeder or service that includes any form of renewable energy system or peak load shaving system has effectively altered the actual peak demand load seen by a meter such that the maximum demand data available does not reflect the actual peak demand for the feeder or service. Additionally:
- There is no effective way to determine the contribution from these systems so the peak demand could be calculated.
- There is no easy way to describe a metering scenario that could be used to obtain the actual peak demand.
Therefore, I recommend not allowing the methods described in 220.87 for feeders and services under these conditions.

Submitter Information Verification

Submitter Full Name:	Phillip Whisenhunt
Organization:	Harris Consulting Engineers
Affilliation:	I am not affiliated with any organiziation other than Harris Consulting Engineers in Las Vegas, Nevada
Street Address:	
City:	

State:

Zip:

Submittal Date: Wed Sep 06 15:27:43 EDT 2017

Copyright Assignment

I, Phillip Whisenhunt, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Phillip Whisenhunt, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature