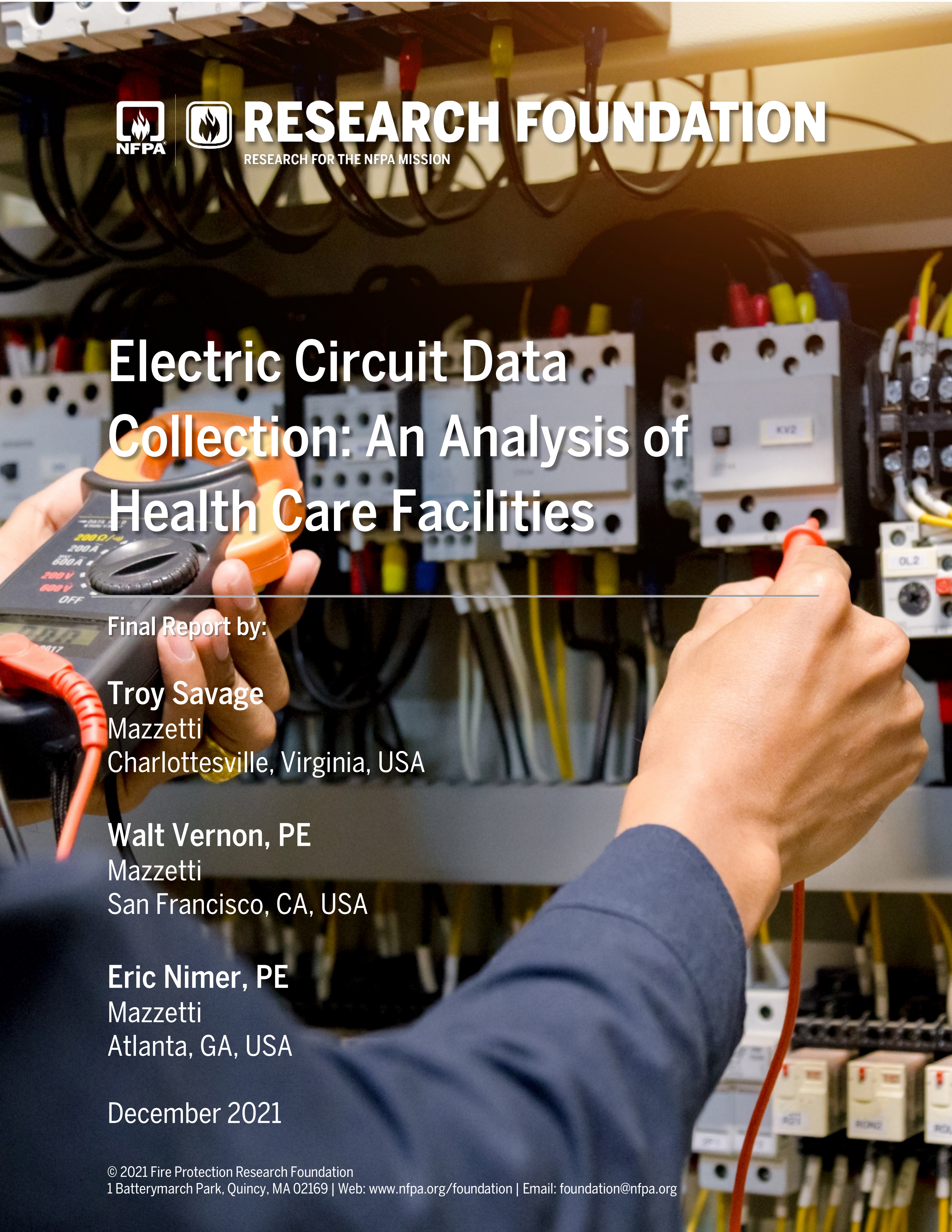


NFPA
RESEARCH FOUNDATION
RESEARCH FOR THE NFPA MISSION

Electric Circuit Data Collection: An Analysis of Health Care Facilities

Final Report by:

Troy Savage
Mazzetti
Charlottesville, Virginia, USA

Walt Vernon, PE
Mazzetti
San Francisco, CA, USA

Eric Nimer, PE
Mazzetti
Atlanta, GA, USA

December 2021

1 Batterymarch Park, Quincy, MA 02169 | Web: www.nfpa.org/foundation | Email: foundation@nfpa.org

Foreword

Over the last few decades, there has been significant technological innovation along the entire span of the electrical power chain. Factors such as today's Energy Codes are driving down the electrical load presented by end use equipment. Thus, the service, feeder, and branch circuit load design requirements in NFPA 70, National Electrical Code® (NEC®) such as the load growth assumptions that justify "spare capacity", have been called into question.

The changing landscape of building operations and corresponding technological advances has also resulted in data rich environments. While electrical data collection or the availability of relevant data has historically been lacking, insights from validated electrical data has become more prevalent today and are being utilized in the code development process to assess existing regulations or substantiate code changes.

Recognizing the need for data to inform the service, feeder, and branch circuit load design requirements in the NEC, the Fire Protection Research Foundation (FPRF) initiated a research program to gather electrical circuit data. A prior phase I project titled "*Evaluation of Electrical Feeder in Branch Circuit Loading*" of the electrical data research program focused on general commercial occupancies and entailed a literature review that helped to clarify key elements of a data collection plan to support a Phase II effort. This Phase II, "*Electrical Circuit Data Collection: An Analysis on Healthcare Facilities"* project implemented the data collection plan outlined in the Phase I study, with a focus on health care facilities electrical loads in patient care areas during the Covid-19 pandemic.

The Fire Protection Research Foundation expresses gratitude to the report authors Troy Savage, Walt Vernon and Eric Nimer who are with Mazzetti, Inc. located in San Francisco, CA, 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.

The content, opinions and conclusions contained in this report are solely those of the authors and do not necessarily represent the views of the Fire Protection Research Foundation, NFPA, Technical Panel or Sponsors. The Foundation makes no guaranty or warranty as to the accuracy or completeness of any information published herein.

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 65,000 individuals around the world.

Keywords: electrical circuits, electrical panels, demand factors, electrical load, calculated load, NEC, NFPA 70, healthcare, pandemic

Report number: FPRF-2021-##

Project Manager: Victoria Hutchison and Sreeni Ranganathan

Project Technical Panel

Mike Anthony, Standards Michigan

Larry Ayer, Biz Com Electric & IEC

Kevin Carr, NFPA

Thomas Domitrovich, Eaton Corporation

Lou Galante, University of Iowa and APPA

Alan Manche, Schneider Electric

Roger McDaniel, Georgia Power Company

Robert Osbourne, UL LLC

Brian Liebel, Illuminating Engineering Society of North America

Jeff Sargent, NFPA

Billie Zidek, APPA (Alternate)

Sponsor Representatives

Chad Beebe, ASHE-AHA

Kara Brooks, ASHE-AHA

Chad Duffy, NFPA

Project Sponsors

ASHE™
Optimizing health care facilities

NFPA®

Electric Circuit Data Collection: An Analysis of Healthcare Facilities

MAZZETTI
DECEMBER 2021

PREPARED FOR THE FIRE PROTECTION RESEARCH FOUNDATION

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Since Samuel Insull applied the principles of diversity and demand factors to the creation of the first electrical grids, these ideas have been fundamental to the creation of reliable and cost-effective electrical systems. The determination of demand factors has long been something of an art, especially at the building level, due to the difficulty of obtaining quality data on which to base them. As a result, code-minimums for demand factors have historically resulted in systems that are generally larger than the loads they serve; building designers tell stories of utility engineers perplexed at the service sizes they request, because the utility engineers know, from their data, that the building design "minimums" will prescribe systems that are much larger than the actual loads the building will produce.

There are a range of theories regarding what exacerbates the general problem of insufficient, many of which make intuitive sense, about how people actually use electrical systems in varying circumstances, but which have little to no actual evidence for their truth.

The Fire Protection Research Foundation, with generous support from the American Society of Healthcare Engineering (ASHE), National Fire Protection Association (NFPA), and the generous donations of electrical metering equipment from Pacific Gas and Electric and the Smart Buildings Center was able to use the recent pandemic to deploy hundreds of meters into operating hospitals across the country. These meters allow us, for the first time, to truly see the behavior of hospital electrical systems at circuit level and at the level, in the context of the calculated connected loads and the National Electrical Code (NEC®) calculated loads. The resulting data highlights the true over-sizing of systems that the current codes create. The results of this study demonstrate that the hospital demand factors contained in the current (2021) edition of the National Electrical Code result in electrical systems that are between 100% and 700% larger than the actual loads.

1 INTRODUCTION

The conditions under which buildings operate are constantly changing given the rapid pace of technological innovation. As a result, it is a challenge for the building codes and regulatory bodies to keep pace. The changing landscape of building operations has also resulted in data rich environments. It is important to utilize the insights provided by the data, to inform the codes and standards process.

Load requirements in the NEC® have largely been in effect since at least 1968, with few modifications over the last 50 years. Factors such as today's Energy Codes are driving down the electrical load presented by end use equipment. *As a result, questions have been raised about whether the design requirements for feeder and branch circuit loads in the NEC have kept pace with technological advancements and the reduction in energy loads that are being seen in facilities today.* Specifically, load growth assumptions that justify "spare capacity" are being re-examined. Further, larger than necessary transformers that supply power to service, feeder and branch circuits may expose unnecessary flash hazards to electricians working on live equipment. *The 2020 edition of NEC® did introduce significant changes to lighting load requirements, which shows some progress toward calculated loads that reflect current usage and technology. For example, health care lighting loads went from 2 volt-amps per square foot (VA/ft^2) to 1.6 VA/ft^2.*

1.1 TYPES OF HEALTHCARE PLUG LOADS

By "plug loads", we mean those loads that are cord-connected to an electrical outlet. Most frequently, these loads are 120-volt single phase, though they may be 2- or 3- phase, and they may be as high as 208 volts.

Healthcare facilities include virtually every type of space – from residential spaces for housing patients, to offices, retail spaces, religious spaces, educational spaces, workshops, laboratories, data centers, and all types of procedure rooms.

From a licensing perspective, healthcare buildings fall into two categories; in-patient buildings, in which patients stay for 24 hours or more, and outpatient buildings, in which patients stay for fewer than 24 hours. In general, the range of procedures and the condition of patients in the former are more intense than those in the latter.

Within all of these spaces, there are two kinds of plug loads. For the purpose of this report, we will define them as "General receptacles[1]" and "Dedicated receptacles[2]."

By general receptacles, we refer to the ubiquitous single-pole, 15- or 20- amp wire device. By dedicated receptacles, we refer to those receptacles that are designed to serve a single piece of equipment and that are on dedicated circuits.

1.2 NEED FOR DEMAND FACTORS

Many electrical loads are either on and operating at 100% of rated load, or off, and operating at 0% of rated load. Many loads vary over time in response to automatic or manual controls. The probability that any one particular load may be fully on is certainly less than one, but the wiring serving one load needs to be capable of serving 100% of that load because sometimes, the device will need to be fully "on".

But, when a circuit serves more than one receptacle, that circuit is likely to experience a load range from 0 to 100% of all the connected loads and on at full power, simultaneously.

At higher levels of a system, such as at a panel, transformer or other distribution equipment, the likelihood of all devices being on at full power at the same time is less

Demand factors allow components of the system to be sized at some fraction of the potential sum of all connected loads. This gives system designers the ability to design systems that recognize the decreasing likelihood of all dedicated and connected loads being "on" at the same time. Without the use of demand factors, all elements of an electrical system would be designed to serve 100% of the connected load, and systems would be oversized, more expensive, and generally unused.

This over-sizing results in wasted materials, space, money, and increased risk of arc-flash hazards.

1.3 HISTORY OF PLUG LOAD DEMAND FACTORS

Research through the NFPA library shows that the first instance of the use of the term "demand factor" in the NEC ® occurred in 1928. The Report of the Electrical Committee indicates that demand factors were included to avoid wasting "copper" that would never be used since the system would never be called upon to carry all of the connected load at any one time.[3][4] Article

---

[1] May also be referred to as general outlets

[2] These outlets are referred to as dedicated receptacles, dedicated outlets, specific equipment receptacles, specific equipment outlets, throughout the report

[3] Report of Electrical Committee. Pg. 142. Obtained from the NFPA librarian.

[4] The full quote is illustrative. It reads "There are a number of what we might class as major accomplishments in the next which we now recommend. For a great many years, installations of electric wiring in buildings was

6 of the 1928 code indicates that hospitals (except in the operating suite and X-ray department) should be calculated at ¾ watt per square foot. It then states that for areas of 25,000 square feet or less per feeder, the demand is 100(%)[5]. For the excess area above 25,000 square feet per feeder, the demand is 60(%). The demand factors have changed since 1928. To the author's knowledge, there is no record for the derivation of these demand factors. Previous changes to healthcare demand factors, have not been based on a comprehensive study of healthcare plug loads.

Today, the requirements for calculating receptacle loads are as follows:

Dedicated outlets. NFPA 70, Section 220.14(A) requires circuits serving outlets dedicated to a specific appliance[6] to be calculated based on the ampere rating of the appliance or load served.[7]

General outlets. NFPA 70, Section 220.14(L) requires that other receptacle outlets be calculated at not less than 180 volt-amperes (VA) per receptacle.

NFPA 70, Section 220.44 applies a demand factor of 100% to the first 10kVA of calculated load and a demand factor of 50% to receptacle load above 10kVA, for the 220.14(L) outlets.[8]

By today's code, the permissible ways to calculate demand factor for plug loads in any building, including a healthcare building, are:

- Based on the service and calculated load based on 180 VA per receptacle for general receptacles and using the nameplate (ampere rating) for dedicated receptacles as described above.
- Based on the largest load, NEC 220.60 indicates that where two or more non-coincident loads will be used simultaneously, it is permissible to use only the largest load that will

---

satisfactorily accomplished from the point of view of all concerned, when the copper from the service switch to the final outlet was put in on the basis of the current value given in what used to be table 610 in the Code. But with the increase in the size of buildings and with the increase in the uses of electricity in premises, there has grown up to be what is known in electrical circles as a demand or a diversity factor, so that it has become uneconomic to install copper from the service witch throughout the installation on the theory that every bit of that copper will be called upon to carry all the connected load at any one time. Perhaps, therefore, one of the most important economic changes which is recommended in this edition of the Code is the values for a so-called demand factor for calculating the sizes of copper for risers and feeders in buildings. It has been explained to me that this may result in a very substantial saving in investment in copper which remains in the building permanently and which, under previous conditions of the Code, if that Code were complied with, would represent a frozen investment with no economic return."

[5] The text itself indicates a demand factor of 100, not 100%. The percentage is implied.

[6] These outlets are referred to as specific equipment receptacles, specific equipment outlets, throughout the report

[7] See NEC70.220.14(A). In NEC 70.220 Branch-Circuit, Feeder, and Service Load Calculations. NEC 70: National Electrical Code, 2020 Edition. NFPA (© 2019)

[8] See NEC70. 220.44. In NEC 70.220 Branch-Circuit, Feeder, and Service Load Calculations. NEC 70: National Electrical Code, 2020 Edition. NFPA (© 2019)

be used at one time to calculate the total load of a feeder or service.[9] In theory, this means that a calculation could consider a demand factor of 100% for the largest load and 0 for everything else.

- Based on a prudent demand factor (in healthcare). Section 517.31(D) of the code allows sizing of the alternate power source to be based on (1) prudent demand factors and historical data, (2) connected load, (3) feeder calculation procedures from article 220 or any combination of (1), (2) and (3).[10] This section of the code recognizes that historical data and prudent demand factors are acceptable ways to do demand calculations.

The loads now experienced by electrical systems in general, and particularly by healthcare electrical systems, are significantly different from those calculated in NFPA 70. Yet, these demand factors have not changed.

Many trends have changed the kinds, magnitudes, and behaviors of the loads that today's electrical systems need to serve. Among these factors are:

- an increasing number of electronic devices and needs for charging of these devices
- a decreasing load per device, in general.

In addition, other factors specific to healthcare occupancies have driven changes to electrical systems in these buildings:

- requirements from other codes, including NFPA 99 and the Facilities Guidelines Institute's (FGI) FGI Guidelines for Design and Construction, for more and more outlets in various spaces
- needs of healthcare facilities to plan for unexpected events, thus increasing the number of devices.

Despite these changes, code-makers have had no data on which to base revisions. A conservative mindset, especially in the case of healthcare buildings, have caused code-writers, and generations of design engineers, cautious about changing the code provisions without substantial data.

1.4 SUMMARY OF PREVIOUS WORK

There is history of work and study on plug loads in general and plug loads, particularly in healthcare. This section highlights key portions of that history.

---

[9] See NEC70.220.60. In NEC 70.220 Branch-Circuit, Feeder, and Service Load Calculations. NEC 70: National Electrical Code, 2020 Edition. NFPA (© 2019)

[10] See NEC70.517.31D. In NEC 70.517 Health Care Facilities. NEC 70: National Electrical Code, 2020 Edition. NFPA (© 2019)

1.4.1 IEEE Standard P241, "Gray Book", (1990)

The Institute of Electrical and Electronics Engineers (IEEE) published IEEE Std 241-1990, *IEEE Recommended Practice for Electric Power Systems in Commercial Buildings*, commonly known as the "gray book". IEEE 241-1990 notes that the 1 VA/ ft^2 of net demand is adequate for appliance loads. It notes that loads for large computers, plug-in type air conditions, cooking and laundry equipment should be considered separately. Table 5 in chapter 2 of this book notes typical appliance/general purpose receptacle loads (excluding plug-in type A/C and heating equipment). Hospitals are listed as having a load of between 0.5(low) and 1.5 VA/ ft^2 (high).

1.4.2 IEEE Standard P602, "White Book", (2007)

IEEE also published IEEE Std 602-2007, "*IEEE Recommended Practice for Electric Systems in Health Care Facilities.* Standard 602-2007 provides guidance for health facility electrical design. It notes that "*generally speaking, the actual loads that any given portion of an electrical system will experience will be less than the sum of the connected loads on that portion of the electrical system, and less than the connected loads adjusted by the code's specifically enumerated demand factors… the explicit code-specified demand factors will result in actual demands, especially at the service or the generator, that are considerably higher than the maximum demand that point in the system will experience.*"[11]

Thus, the standard for electrical system health care design acknowledges discrepancy between likely actual demands and code-specified demands.

1.4.3 LBNL, "Evaluation of Miscellaneous and Electronic Device Energy Use in Hospitals" (2012)

Lawrence Berkely National Laboratory published a study entitled *Evaluation of Miscellaneous and Electronic Device Energy Use in Hospitals.* The study, funded by the California Energy Commission Public Interest Energy Research Program looked at several hospitals in California.

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 study concluded that metering for a two-month period would have provided a reasonably 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 study found the average power densities for the

---

[11] IEEE Std 602-2007, pg 18.

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.[12]

1.4.4 Targeting 100 (2012-14)

“Targeting 100!”, an initiative of the University of Washington and others to reduce energy use in hospitals performed a detailed study of energy use at Legacy Salmon Creek Medical Center in Vancouver Washington. The study, entitled *Energy Use and Model Calibration Study: Legacy Salmon Creek Medical Center Vancouver, Washington, found* an average 0.98 W/ ft^2 for miscellaneous equipment.

1.4.5 Plug and Process Loads in Medical Office Buildings CEC Study (2013) (ASHRAE Paper).

A study entitled *Plug and Process Loads in Medical Office* Buildings, published in ASHRAE transactions, specifically considered loads in medical office buildings.[13] This study measured plug and process loads at five medical office buildings (MOB) sites (total 519,646 ft^2) in the San Francisco Bay Area. The report finds that plug loads are overdesigned by 160% to 260%.

The peak plug and process load power density (by room type) recorded was 4.67 W/ft^2 in “Prep Area, Pre-Op space. This space had an average density 2.93 W/ ft^2. The peak W/ ft^2 across the entire building occurred was 1.04 W/ ft^2.[14]

This study looked at outpatient medical facilities and provides an opportunity to compare to plug loads in acute care facilities.

1.4.6 Quantifying Hospital Cord-Connected Plug Loads in Inpatient Areas ASHE Monograph (2014)

The American Society for Healthcare Engineering (ASHE) of the American Hospital Association (AHA) published a monograph entitled *Quantifying Hospital Cord-Connected Plug Loads in Inpatient Areas.* This monograph presented a six-month case study that trended the emergency and normal power 120 V cord-connected plug loads at two inpatient care facilities located in Boston, Massachusetts, each part of a tertiary care academic medical center.

---

[12] Black, Douglas R., Steven M. Lanzisera, Judy Lai, Richard E. Brown, and Brett C. Singer. "Evaluation of Miscellaneous and Electronic Device Energy Use in Hospitals." (2012).

[13] The authors of this article were employees of Mazzetti at the time of its publication.

[14] Ruecker, Ross, Arash Guity, and Jun Timbang. "Plug and Process Loads in Medical Office Buildings." *ASHRAE Transactions 121*, no. 2 (2015): 63-71.

The study noted that plug loads are oversized. It is, however, clear that all of the distribution systems in all of the areas monitored as part of this study were quite oversized in comparison to the recorded demand loading over the six-month study period.

All of the suites monitored had 120 V plug load systems with design capacities between 9 and 10 W/ ft^2. The highest plug load demand data from the most plug load–intensive suite peaked at only 1.95 W/ ft^2 and averaged closer to 1.3 W/ ft^2. This means that the plug load systems examined were at a minimum six times the capacity of the peak demand load recorded in the six-month study.

The results indicate that a system capacity of 2 W/ ft^2 of normal and 2 W/ ft^2 of emergency (total plug load system capacity of 4 W/ ft^2) could have easily accommodated the plug loads of even the most clinically intense areas surveyed as part of this study.

This study also quantified some cost implications. Downsizing the distribution transformation from 9 to 10 W/ ft^2 to 4 to 6 W/ ft^2 would result in a nest transformation reduction of 1200 kVA across all of the areas surveyed. This reduction would have resulted in over $315,000 in equipment savings. This figure only takes into account the cost savings associated with smaller transformers and does not include savings from reductions in raceway, wiring, other distribution equipment (such as switchboards and circuit breakers), or installation labor. These factors would only add to the calculated savings.[15]

1.4.7 NREL. “Healthcare Energy End-Use Monitoring” (2014)

The National Renewable Energy Laboratory (NREL) partnered with two hospitals to collect data on multiple thermal and electrical end-use categories including large medical equipment loads. The NREL study also used data from Rucker et al., 2015.

The study monitored three computed tomography (CT) scan units and two Magnetic Resonance Imagining (MRI) units for one (1) year and found these devices used, on average, between 3 kW and 13 kW. There were sporadic instances of higher power with the maximum power recorded ranging from 33 kW to 111 kW. [16]

1.4.8 Partners/TCI Plug Load Study

Mass General Brigham (formerly Partners HealthCare) and Thompson Consultants Inc. (TCI) measured plug loads for six (6) months at two acute care inpatient hospitals (totaling 214

---

[15] D’Antona, Jason and Messervy, John. 2014. *Quantifying Hospital Cord-Connected Plug Loads in Inpatient Areas.* Chicago, The American Society for Healthcare Engineer (ASHE) of the American Hospital Association.

[16] Sheppy, Michael, Shanti Pless, and Feitau Kung. *Healthcare energy end-use monitoring*. No. NREL/TP-5500-61064. National Renewable Energy Lab.(NREL), Golden, CO (United States), 2014.

general and 57 ICU beds) in Massachusetts. The highest average plug load was 1.47 VA/ ft^2 in the Nero Intensive Care Unit (28 beds) This area also saw the highest maximum at 1.88 VA/ ft^2. This data was presented to the healthcare engineering community at the 2018 ASHE PDC Summit in Nashville, Tennessee

1.4.9 ASHE Study (2018)

In 2018 Mazzetti monitored receptacle loads in Kaiser Permanente Westside Hospital in Portland Oregon. Over the course of six (6) months and eight (8) individual phases, Panoramic Power amperage meters were installed on 37 panels and over 1,000 individual circuits. For each phase, one minute interval data was collected for two weeks, then removed and installed on new panels for the next phase. Circuits and panels were mapped to floor plans, to determine the room type, department, and square footage they respectively served.
This study reported a peak measured load of 1.98 VA/ ft^2 in the imaging department
The results of this work, including the raw data, have been shared with the NEC® Code Making Panels but no formal report was published. The results are included in this report for comparison purposes. Data from this study is available upon request.

1.4.10 Overall Summary

The above studies from different facilities in different jurisdictions generally point to average plug load power usage of approximately 1 W/ ft^2 with peak loads in the range of 2.0 W/ ft^2. These studies and general engineering guidance from the IEEE and others support these expected levels of plug load demand in healthcare facilities.

1.5 INTUITIVE CONCERNS

Despite the growing evidence of the need to evolve the current demand factors, code making panels have been reluctant to modify demand factors for healthcare facilities based on of the following intuitions:

a. ***The one-year of data problem***. Some believe that measuring loads over one year would be necessary to determine accurate behavior of loads.
b. ***The red outlet problem***. Some have expressed a concern that, during an extended power outage, clinicians would unplug many devices from white receptacles (which do not have redundant power sources) and plug them into red receptacles (which do have redundant power sources)
c. ***The all-branch problem***. All the connected loads in hospitals are either connected to an essential or non-essential system. However, there have been some concerns with the research studies not addressing all branches.
d. ***The up-stream problem***. The literature studies generally measure loads at the branch circuit level and at the panel level. Without fully understanding how probabilities

accumulate and how demand factors can take advantage of this, concerns have been raised that more aggressive demand factors will cause some kind of harm at other levels of an electrical system.

e. ***The "representative hospital" problem***. There are different kinds of hospitals. Some are behavioral health; some are community hospitals; some are academic medical centers. There have been concerns that the loads may vary, and therefore, the appropriate demand factors might be different in various types of hospitals. This concern sometimes manifests in terms of size of facility, geographic location, or other variables.
f. ***The "all department" problem.*** There have been concerns that loads will vary widely between departments, so that, unless all department types are measured in many instances, it is impossible to determine appropriate demand factors.
g. ***The "census" problem***. There have been concerns that, if readings are taken while a hospital is empty, the load readings would be inaccurate.
h. ***The "statistical significance" problem***. Some have expressed that there was no way to do a study without measuring EVERY circuit in EVERY hospital in the country, to show that any potential set of demand factors was correct.
i. ***The "surge" problem***. Some people believed that, during some kind of surge, such as a pandemic, the loads in a hospital would sky-rocket, such that load readings taken during normal times would not accurately reflect the electrical demand during a pandemic.
j. ***The "spare capacity" problem***. Some think that because the codes force a system to be significantly larger than needed to serve a design load is preferable, from the perspective of future expansion. That is, a hugely over-sized electrical system makes it much easier to overcome future changes and additions of loads to the system.

2 STUDY METHODOLOGY

2.1 ORIGINAL PROJECT SCOPE

Recognizing the need for data to inform evolving electrical codes, the Fire Protection Research Foundation (FPRF) initiated a research program to gather electrical circuit data. A prior Phase I project titled "*Evaluation of electrical feeder in branch circuit loading*" of the electrical data research program focused on general commercial (office) occupancies and entailed a literature review that helped to clarify key elements of a data collection plan to support this Phase II Electrical Circuit Data Collection project.

The goal of this Phase II project was to implement a data collection plan to provide statistically significant load data for a variety of occupancies and loading types. This information will provide a technical basis to NEC® code making panels about feeder and branch circuit design requirements.[17,18,19]

The original scope of this phase II project focused on three occupancy types: (A) business, (B) education, and (C) healthcare. Within those occupancies, four baseline comparable targeted spaces were identified for data collection: (1) breakrooms, (2) general office areas, (3) conference room, and (4) cubicles.

2.2 COVID-19 PANDEMIC

The sizing of electrical systems is an important issue in healthcare electrical design. As previously noted, data from an event that might cause atypical high electrical usage in a hospital, like a pandemic, is of particular interest to the electrical community.

In March 2020, the world faced an unprecedented global pandemic, sparked by the SARS-CoV2 virus. This virus causes the disease COVID-19. Hospitals quickly prepared to treat patients suffering from COVID-19. The use of ventilators (a high electricity usage piece of medical equipment) was predicted to increase, as would the number of patients being treated at hospitals. A pandemic of this magnitude required hospitals to respond and therefore operate in unique ways that might, it was believed, stress the hospital electrical system in unique ways.

---

[17] Ranganathan, Sreenivasan, and Victoria Hutchison. "Balancing safety and efficiency. Research project builds database of information to help in development of health care electrical standards." Health Facilities Management. Available online: https://www.hfmmagazine.com/articles/4072-balancing-safety-and-efficiency

[18] The original request focused on office spaces in healthcare, education and business occupancies.

[19] Excerpt from the Request for Proposal by the Fire Protection Research Foundation

2.3 REVISED APPROACH

The COVID-19 pandemic created an opportunity to collect electrical load data from hospitals and, specifically, hospital spaces that might experience abnormal (and potentially historic peak) demands. At the same time, it was not appropriate to collect data from education and business occupancies since most of these facilities saw little to no demand during the pandemic; in many cases they were closed or explicitly operating well below capacity. The data collected for education and business uses during this time would not be reflective of demands under normal operating conditions. Therefore, it was decided to adjust the focus of this project's scope on collecting hospital data during the COVID-19 pandemic.

The rare opportunity to collect hospital load data during a pandemic warranted shifting the focus entirely on metering hospitals during the pandemic. As the focus of the study shifted, so did the duration of data collection. The electrical load data was now decided to be collected for an extended duration of one year as opposed to the originally planned duration of one month. Therefore, this study focuses on hospital patient care areas, specifically on key departments that may see a surge because of COVID-19 (e.g., ICUs, patient care areas or other departments that serve as overflow, etc.).

Anticipating this, the project focused its resources to allow deployment of as many meters as possible, in many different kinds, sizes and geographical locations of hospitals, for more than one year. The purpose of this study was to gather sufficient data to answer the intuitive concerns described above, and to provide adequate data to code making panels that could inform potential revisions in the NEC® demand factors.

2.4 SURVEY OF HOSPITAL CONDITIONS

During the COVID-19 pandemic, hospitals went from being totally unoccupied (as hospitals cancelled most procedures in anticipation of floods of patients) in the spring of 2020, to being filled with COVID-19 patients in varying degrees in the summer. Occupancy was somewhat back to normal in the fall but then elevated due to a second surge of COVID-19 in the winter of 2020.

There were a number of limitations with electric circuit data collection in hospitals including the availability of meters to deploy, availability of hospital plans and panel schedules and census data. As a result, the types of data collected for this analysis varied. However, in all cases, the study period was longer than one year, either the COVID hospitalization data or *County-level Covid Case* rate is available, and meaningful comparisons can be made to corroborate the more detailed findings of the hospital where circuit-level data was available.

2.5 HOSPITALS MEASURED

For this study, the research team approached several hospitals. Hospitals were selected based on the likelihood (at the time of meter installation) that they might experience a surge of COVID-19 patients and their willingness to have meters installed and comfort sharing the data with the research team. The hospitals that participated in the study overcame this barrier by requesting to be anonymous. To protect the confidentiality of the participating hospitals, all data within this report is presented generically by region. Table 1 summarizes the characteristics of the hospitals that participated in the study.

Table 1: Approximate beds, square footage, and description of studied hospitals

Name	**Location**	**Beds**	**Description**
Westcoast Hospital 1	Northern California	523	Urban high-rise trauma center
Westcoast Hospital 2	Oregon[20]	128	Urban/suburban general medical center
Southeast Hospital 1	Georgia	134	Urban/suburban level II trauma center
Southeast Hospital 2	Georgia	451	Urban Academic Medical Center
Southeast Hospital 3	Alabama	345	Urban level II trauma Center
Southeast Hospital 4	Alabama	399	
Southeast Hospital 5	Georgia	961	Urban high-rise Level 1 Trauma Center
Northeast Hospital	Mass.	999	Urban high-rise academic medical center, level 1 trauma center

Requests for metering were made during March and April of 2020, just as hospitals were preparing for an influx of patients due to the COVID-19 pandemic. During this incredibly difficult time, these hospitals graciously agreed to have meters installed while the regions were experiencing a surge in COVID-19 cases, to assess the impact of the pandemic on their systems. All hospitals identified in Table 1 permitted metering of their electrical panels and/or circuits. General information about the metering at each participating hospital is provided in Table 2.

Table 2: Data collection period, panels metered and information availability for studied hospitals

Name	**Data Collection Period**	**# Panels Metered**	**Metering and Scheduling Details**
Westcoast Hospital 1	Mar 2020 - May 2021	11[21]	Circuit level and panel level metering. Plans and panel schedules available
Westcoast Hospital 2	~July 2017- January 2018[22]	37	Circuit level and panel level metering. Plans and panel schedules available
Southeast Hospital 1	April 2020 – May 2021	5	Panel level metering. Plans and panel schedules available
Southeast Hospital 2	April 2020 – May 2021	8	Panel level metering. No plans or panel schedules available

---

[20] Data collection and analysis of the second west coast hospital in Oregon was not performed during this study but was conducted previously by Mazzetti. Data from this previous study is provided in this report as an appendix. In general, this data is not used in this report, but it is consistent with the results of this study.

[21] A total of 11 panel sections (42 circuits per panel sections). Some panels consisted of panel section 1 and panel section 2.

[22] The data for Westcoast Hospital 2 was collected independently through a separate study.

Southeast Hospital 3	April 2020 – May 2021	4	Panel level metering. No plans or panel schedules available
Southeast Hospital 4	April 2020 – May 2021	4	Panel level metering. No plans or panel schedules available
Southeast Hospital 5	April 2020 – May 2021	30	Panel level metering. Limited plans and panel schedules available
Northeast Hospital	April 2020 – May 2021	(1 floor)	Panel/floor level metering. Plans available. General and specific receptacles cannot be distinguished.

Each hospital developed a COVID-19 Response plan. Some of the hospitals included in this study were part of a health system and were designated to be the system-wide COVID-19 facility. We worked with staff within each hospital to determine those locations most likely to experience surges in demand. Generally speaking, these locations included Emergency Departments, ICUs, converted patient wings, and surgical suites (these latter spaces, including prep and recovery, were well-suited to conversion to ICU functions). Given the limitation on metering, we deployed the meters where we anticipated the surge to manifest, so that we could, literally, “catch the wave.”

2.6 METERS

Electric circuit metering devices were installed in the data providers’ hospitals when they appeared to be experiencing a surge in COVID-19 patients. In California, circuit-level metering was installed on select circuits that were anticipated to be impacted by pandemic-related surges. Panel-level meters were also installed for areas highly impacted by the pandemic at the California, Georgia, and Alabama hospitals. Meters in the northeast hospital are integrated in the electrical system and thus permanently installed. The northeast hospital simply provided data from these meters.

The study used 366 Panoramic Power wireless sensors to collect information at the California hospital. The Panoramic Power System consists of wireless, self-powered sensors attached to individual circuits in an electrical panel. These sensors transmit current information to a wireless bridge, which then transfers data to the cloud where it can be retrieved. These meters measured loads continuously for individual circuits. Panoramic Power System was installed at Westcoast Hospital 1.

Additionally, the study used Fluke 1736 and 1738 three-phase power loggers (Fluke meters) at various sites. These meters measure all three phases and neutral through four current probes that are connected separately. These meters measured panel loads continuously, requiring periodic downloading of data.

The study also used Dent Elitepro SC power meters at various sites. These meters feature four analog input channels configurable for voltage or current. These meters measured panel loads continuously, requiring downloading of data once every six months.

The Northeast hospital includes panel/floor meters that are permanently installed in the electrical system. This hospital works with an online meter data acquisition and reporting service to monitor data from these integrated meters. Floor level data from the meters were provided as part of this study. These meters measured panel loads continuously.

2.7 DATA COLLECTION

The methodology for data collection differed depending on the facility and condition. As mentioned above, floor plans and panel schedules were not available for all the hospital sites included in this study. In some cases, floor plans for some floors were obtained. For many of the Southeast hospital sites, limited floor plans and panel schedules were available.

The study had four typologies:

A. Westcoast Hospital 1
    a. Circuit level meters (not all circuits on any panel; only measured receptacle circuits)
    b. Panel level meters (panel level data necessarily did not align with circuit level data because not all circuits were measured).
    c. Plans and panel schedules available
B. Southeast Hospitals with Drawings
    a. Panel level meters
    b. Plans and panel schedules available
C. Southeast Hospitals without Drawings[23]
    a. Panel level meters
    b. Plans and panel schedules NOT available
D. Northeast Hospital
    a. Data from integrated meters available at panel level.
    b. Plans available but no panel schedules.
    c. The plans did not indicate loads for dedicated circuits. This study then simply imputed a value of 180VA per each receptacle.

<u>For all hospitals, the following steps were taken:</u>

- Identify hospitals that may experience a surge due to the pandemic.
- Contact hospital staff to obtain permission to install meters.

---

[23] The distinction in the southeast hospitals occurs at the panel level. In some cases, the facility was able to find some floor plans and panel schedules and an analysis indicating the specific receptacles could be performed. Otherwise, such a receptacle specific analysis could not be performed.

- Where permission was granted, meet with facility staff to identify areas that may have unusual uses due to the surge (e.g. A facility anticipating converting recovery rooms into COVID-19 beds).

The remaining steps differed depending on the site:

For Westcoast Hospital 1[24]:

- Install circuit-level meters on circuits that serve general receptacles or dedicated equipment on panels that may have unusual use.
- Install panel level meters on the panels associated with these meters.
- Check, identify, and correct any metering issues as they arose.
    - A number of meter issues arose over the year, so not all circuits were 100% continuous.[25]
- Work with facility staff to identify extended power outages. (None were identified.)

For the Southeast Hospitals
- Install panel level meters on panels that may have unusual use.
- Pull data routinely, when needed.
- Check, identify, and correct any metering issues as they arose.
- Identify extended power outages. (None were identified)

For the Northeast Hospital
- Meter data is integrated into the electrical system.
- The hospital provided floor/panel level data it was collecting.
- Identify extended power outages. (None were identified)

The study attempted to gather building area served by a particular panel and census data for each unit served by a particular panel. However, census data for any particular unit or hospital was unavailable. In most cases, COVID-19 hospitalization rates were available for the facility. Where specific hospitalization rates are not available, general county level COVID rates are used. These are displayed as graphs in the data set. They are presented alongside electrical load data so that the user can graphically see any significant correlation.

2.8 METHOD OF ANALYSIS

The calculations for plug loads on a particular circuit, panel, feeder, distribution panel, service, etc. are based on the number of general receptacles times 180VA per receptacle plus the amperage rating for each piece of dedicated equipment. The NEC calculated load also includes

---

[24] Panoramic Power circuit level meters were used at Westcoast Hospital 1. This was the first hospital to permit meters to be installed. All available circuit level meters were installed at this site.

[25] Some of the circuits at the west coast hospital lost connectivity in the early stages of data collection and therefore gaps exist in the data. For the southeast hospitals

a demand factor for general receptacles after the first 10,000VA. These calculations are summarized as follows:

Connected load[26]:

$$\sum_{1}^{m} R_m * 180VA + \sum_{1}^{n} S_n * S_{R_n}$$

Where
m = number of general receptacles on each general receptacle circuit
R_m = The number of general receptacles on circuit m
V = Volts
A = Amperes
n = number of specified equipment receptacles
S = number of specified equipment pieces on receptacle n (typically 1)
S_{R_n} = the total amperage (nameplate) on circuit n in VA

The NEC Calculated load:

$$\sum_{1}^{m} R_m * 180VA + \sum_{1}^{n} S_n * S_{R_n};\ where \sum_{1}^{m} R_m * 180VA < 10{,}000VA$$

$$10{,}000VA + \left(\left(\sum_{1}^{m} R_m * 180VA\right) - 10{,}000VA\right) * 0.5 + \sum_{1}^{n} S_n$$
$$* S_{R_n};\ where \sum_{1}^{m} R_m * 180VA => 10{,}000VA$$

The study was able to compare the “Connected load” and the “NEC Calculated load”, and the “Actual Load.”

In this study, the calculated load consists of each general receptacle at 100% of 180 VA, and each dedicated receptacle at 100% of its nameplate rating, as required by NFPA 70.

In this study, the NEC Demand load consists of the connected load, with demand factors described in NFPA 70, Section 220.44 applied.

For locations with neither floor plans nor panel schedules, calculating the connected load or demand load was not feasible. Thus, the data from these sites is useful only to corroborate the general magnitude of loads seen in other locations and to test the variance of loads under differing conditions.

---

[26] Sometimes referred to as the calculated load.

In this study, for panel-level readings, the “actual load” consists of the peak load experienced over the course of all readings for one year for the particular panel. Note, in cases where circuit-level and panel-level readings were obtained, “apples to apples” comparisons are impossible, because, due to limitations on the number of circuit-level measurement devices available, the study focused ONLY on circuits serving either general- or dedicated receptacles. In many instances, the panels also served other loads, primarily various lighting circuits.

In this study, for circuit-level readings, the “actual load” for each circuit consists of the peak load experienced over the course of all readings while the devices were deployed.

For this analysis, this data was simplified in a way that is crucial to understand. The loads on any one circuit vary over time. Rarely did two circuits experience a peak at the same moment. And never did ALL of the circuits on one panel peak at the same time. But, because the measurements did not include any method for aggregating the loads at any one time, this study simplified the situation by taking the sum of the peak loads of each circuit, even though they never occurred at the same time. Thus, the numbers given in the “Actual load” for circuits overstates the true peak load for these groups of circuits. That is, they already include a certain amount of “safety factor” due to the method of analysis. The amount of this safety factor is difficult to determine, and, so, the study relied upon this “sum of peaks” methodology.

The study groups all of the dedicated receptacles for each panel where circuit level data was available, and it compares the connected load, the NEC Demand load, and the conservative actual load in the aggregate for each panel. The study notes the magnitude of the difference between the demand load and the actual load, as a “safety factor.”

The study groups all of the general receptacle circuits for each panel where circuit level data was available, and it compares the connected load, the NEC Demand load, and the conservative actual load in the aggregate for each panel. The study notes the magnitude of the difference between the demand load and the actual load, as a “safety factor.”

To mimic the effect of accumulating demand factors at various levels of a system, the over-stated actual loads are summed and compared to connected load and demand loads applying the NFPA 70 demand factors as if these were the only loads on the aggregated load centers.

The study examines the peak readings of panels without circuit-level data over the course of the study period, to identify the magnitude of variance and to identify, where possible, causes for variance. The study also examines the magnitude of panel level loads for these facilities to provide substantiation for the loads experienced in the facilities with circuit-level data available.

More details for the methodology are described in Appendix 1.

3 RESULTS

3.1 METERED DATA

During this project, a large quantity of metered data was collected from hospital electrical circuits and panels. This data is available upon request from the Fire Protection Research Foundation, via email at foundation@nfpa.org.

3.2 WESTCOAST HOSPITAL 1

3.2.1 Westcoast Hospital 1 Panel Level Analysis

Table 3 below summarizes the calculated and peak panel-level data measured at Westcoast Hospital 1. The lowest safety factor over measured for an individual panel was 207%; the highest being 1196%. This indicates that for the course of one year, the highest load ever measured on the panels was at least two times smaller than the minimum load the NEC requires.

When looking at the cumulative load for panels aggregated together, the safety factor ranges from 207% to 327%. Even considering the larger effect of the demand factor with additional panels, the system is sized between 207 - 327% over the peak measured value.

Table 3: Connected load and metered load at Westcoast Hospital 1.

Panel	Site/Panel Information (kVA)						Calculated Load Information (kVA)			CUMULATIVE LOADS					
	Department Served	**Metered Peak Load (kVA)**	**# of General Receptacles**	**General Receptacle Load (kVA)**	**# Dedicated receptacles**	**Sum of Nameplate of Dedicated Receptacles (kVA)**	**Total Connected Load**[27]	**NEC Calculated Load (w eqp at nameplate)**	**Safety Factor Above Measured**	**Measured Peak Demand (kVA)**	**General Receptacle Load (kVA)**	**Dedicated Receptacle Load (kVA)**	**Total Load (w/ eqp at nameplate) (kVA)**	**NEC Calculated Load (eqp at nameplate) (kVA)**	**Cumulative Safety Factor**
W4CL2 Pnl Sec 1 & 2	ICU	14.36	293	**52.74**	12	11.64	**64.38**	**43.01**	**199%**	**14.365**	**52.74**	**11.64**	**64.38**	**43.01**	**199%**
W4L1	ICU/Core/ Nurse Station	7.46	153	**27.54**	4	4.12	**31.66**	**22.89**	**207%**	**21.823**	**80.28**	**15.76**	**96.04**	**60.9**	**179%**
W4LC1 Sec 1 & 2	ICU patient rooms	12.77	346	**62.28**	5	6.18	**68.46**	**42.32**	**231%**	**34.594**	**142.56**	**21.94**	**164.5**	**98.22**	**184%**
W4LC3 Sec 1 & 2	ICU patient Rooms	12.03	319	**57.42**	9	9.64	**67.06**	**43.35**	**260%**	**46.625**	**199.98**	**31.58**	**231.56**	**136.57**	**193%**
3LC7 pnl	PACU/Cath/ FSD/ Brain Suite	11.28	239	**43.02**	21	25.38	**68.4**	**51.89**	**360%**	**57.906**	**243**	**56.96**	**299.96**	**183.46**	**217%**
3LC6 pnl sec 1& 2	IT Room/OR supply/Cryo /PACU/ Equip	9.23	192	**34.56**	27	26.11	**60.67**	**48.39**	**425%**	**67.131**	**277.56**	**83.07**	**360.63**	**226.85**	**238%**
W4LC4 Sec 1	ICU patient beds	6.85	336	**60.48**	1	0.96	**61.44**	**36.2**	**428%**	**73.986**	**338.04**	**84.03**	**422.07**	**258.05**	**249%**
3L3 pnl sec 1& 2	PACU/Office /Printer/ Cath	7.00	394	**70.92**	3	2.72	**73.64**	**43.18**	**517%**	**80.986**	**408.96**	**86.75**	**495.71**	**296.23**	**266%**
3LC3 pnl sec 1& 2	PACU/Cath	11.52	398	**71.64**	20	45.88	**117.52**	**86.7**	**653%**	**92.506**	**480.6**	**132.63**	**613.23**	**377.93**	**309%**
W4L2	ICU/Core/Nurse Station	2.71	145	**26.1**	5	6.72	**32.82**	**24.77**	**815%**	**95.215**	**506.7**	**139.35**	**646.05**	**397.7**	**318%**
3L7 pnl	Consult/ Corridor/ Cath	1.55	110	**19.8**	3	5.25	**25.05**	**20.15**	**1198%**	**96.767**	**526.5**	**144.6**	**671.1**	**412.85**	**327%**

---

[27] **(0.18kVA per receptacle + equipment at nameplate)**

The cumulative analysis is best depicted in chart form. Figure 1, below, depicts the cumulative kVA as additional panels are added to the analysis. The actual load, the NEC calculated load, and several other calculations are depicted.   Increasing the number of panels, increases the gap between the peak load and the calculated load.

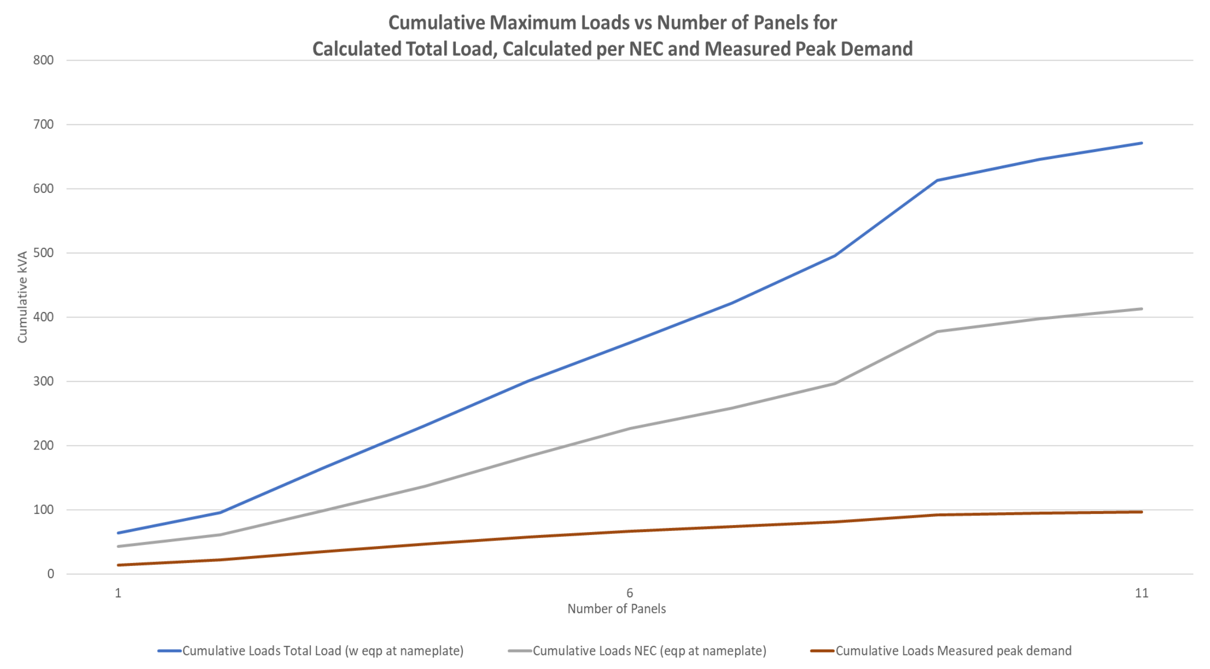


Figure 1: Comparison of panel level calculated and actual load values at Westcoast Hospital 1

3.2.2 Westcoast Hospital 1 Circuit Level Analysis – General Receptacles

Circuit level data is available for the Westcoast Hospital. This data is useful because it allows separation of general receptacles and dedicated receptacles.

Figure 2, below, depicts the comparison of the calculated load to the actual load for the general receptacle circuits (only). The data represents the demand at each circuit at the moment the panel experiences its peak load. That is, the hour the peak load on the panel occurred was identified. Then the load on each measured circuit on that panel was identified. The chart shows this load. Since, at the circuit level, peak loads will never occur simultaneously, this method better depicts the loading on these panels.

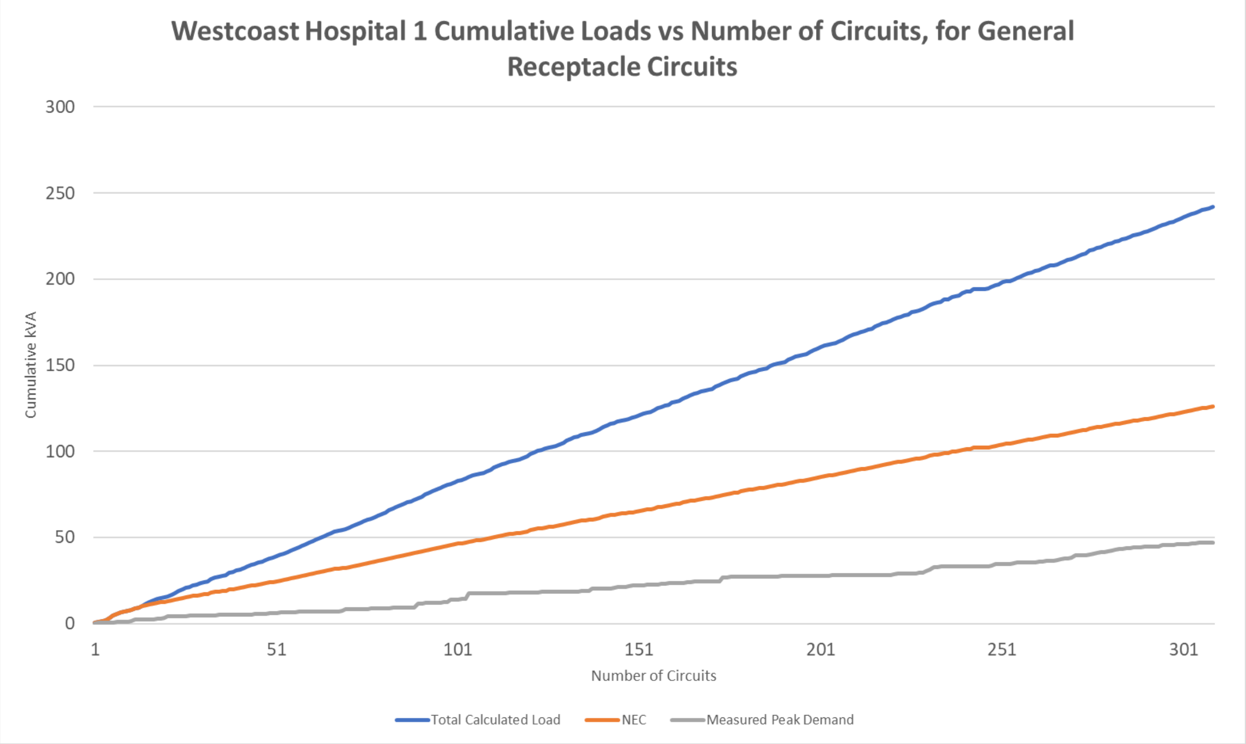


Figure 2: Cumulative Calculated vs Metered Load at the Circuit level for general receptacles. The load on each circuit is captured at the point of peak demand on that circuit's panel.

3.2.3 Westcoast Hospital 1 Circuit Level Analysis – Dedicated Receptacles

Similarly, Figure 3 below depicts the comparison of the calculated load to actual load for the dedicated equipment receptacle circuits (only) at the moment of peak demand. Together, these figures give a sense of what is happening between the general and dedicated receptacles at peak power moments. It should be noted that not all circuits on each panel were monitored, so the data shown here is for the monitored circuits at the point the panel reached a peak. As per the graphs in Figures 2 and 3, for the circuits monitored at the point of peak demand, the safety factor between measured peak and the calculated total load is greater for the dedicated equipment receptacles than it is for the general receptacles.

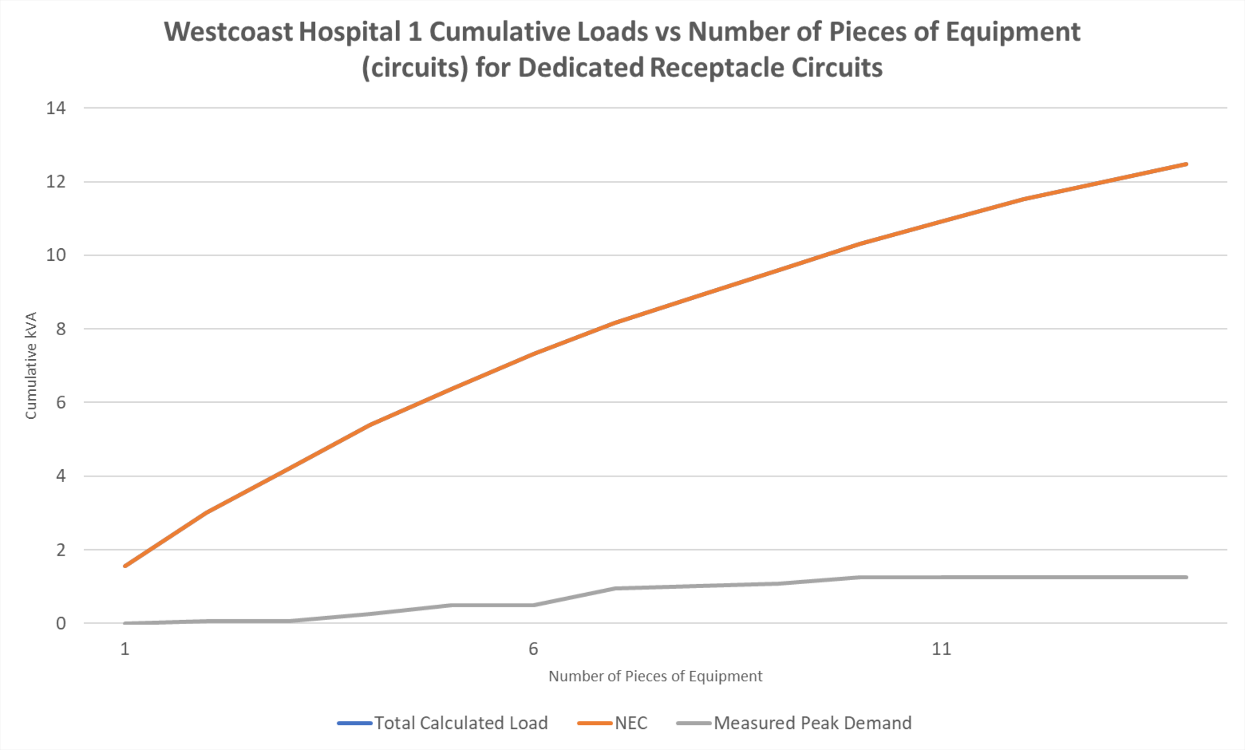


Figure 3: Cumulative Calculated vs Metered Load at the Circuit level for specific equipment receptacle circuits captured at the point of peak demand on each panel

3.3 SOUTHEAST HOSPITALS WITH DRAWINGS AVAILABLE

The analysis of the Southeast hospitals with drawings available was conducted in a similar manner to the Westcoast Hospital 1 panel level analysis.

Table 4, below, provides a summary of the calculated and measured load at Southeast Hospital 1 for panels where the number of general receptacles and dedicated equipment receptacles could be determined from floor plans. The safety factor on each panel is between 46% and 334%. The cumulative safety factor is 136%.

Figure 4, below represents the calculated loads and the maximum metered load in graphical form for Southeast Hospital 1.

Table 4: Connected load and metered load at Southeast Hospital 1.

	Site/Panel Information (kVA)						Calculated Load Information (kVA)			CUMULATIVE LOADS		
Panel	**Department Served**	**Max Power KVA (metered) Peak Load**	**# of Receptacles (non-dedicated)**	**Receptacle Load (non-dedicated) (KVA)**	**# Cord Connected (dedicated) Equipment circuits**	**Nameplate Dedicated Equipment - KVA**	**Total Load (0.18kVA per recep + equipment at nameplate)**	**NEC Demand Load (w eqp at nameplate)**	**Safety Factor Above Measured**	**Total Load (w/ eqp at nameplate)**	**NEC (eqp at nameplate)**	**Cumulative Safety Factor**
2CLB	ICU	21.45	224	40.32	7	6.06	46.38	**31.22**	**46%**	**46.38**	**31.22**	**46%**
2CLA	Patient room	14.08	239	43.02	13	10.8	53.82	**37.31**	**165%**	**100.2**	**68.53**	**93%**
2NLB		7.62	246	44.28	5	5.97	50.25	**33.11**	**334%**	**150.45**	**101.64**	**136%**

Table 5: Connected load and metered load at Southeast Hospital 5.

	Site/Panel Information (kVA)						Calculated Load Information (kVA)			CUMULATIVE LOADS		
Panel	**Department Served**	**Max Power KVA (metered) Peak Load**	**# of Receptacles (non-dedicated)**	**Receptacle Load (non-dedicated) (KVA)**	**# Cord Connected (dedicated) Equipment circuits**	**Nameplate Dedicated Equipment - KVA**	**Total Load 0.18kVA per recep + equipment at nameplate**	**NEC Demand Load w eqp at nameplate**	**Safety Factor Above Measured**	**Total Load (w/ eqp at nameplate)**	**NEC (eqp at nameplate**	**Cumulative Safety Factor**
11BCBA	Patient Room	**16.65**	231	41.58	16	13.27	**54.85**	**39.06**	**135%**	**54.85**	**39.06**	**135%**
7BNBB	ICU	**11.58**	144	25.92	18	9.99	**35.91**	**27.95**	**141%**	**90.76**	**67.01**	**137%**
7BCBA	ICU	**13.39**	274	49.32	12	9.82	**59.14**	**39.48**	**195%**	**149.9**	**106.49**	**156%**
7BCBB	ICU	**14.85**	235	42.3	20	18.9	**61.2**	**45.05**	**203%**	**211.1**	**151.54**	**168%**

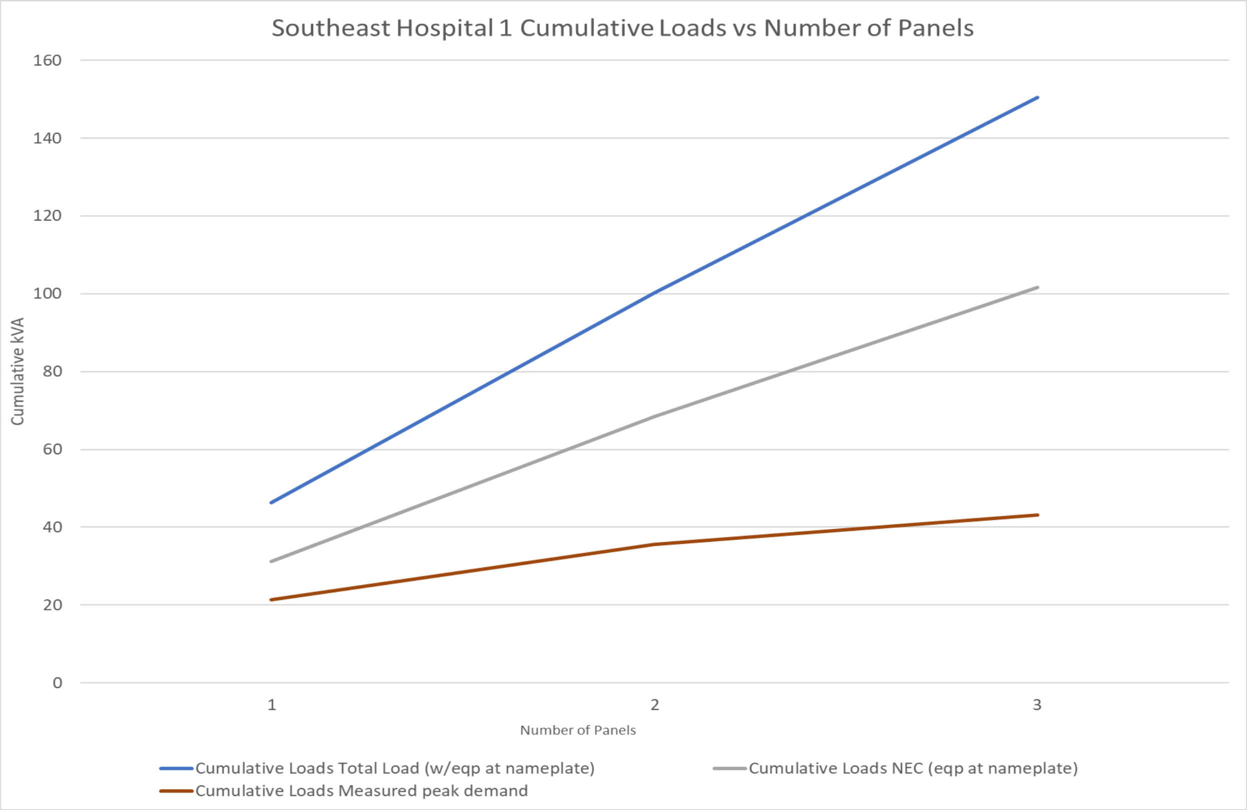


Figure 4: Comparison of cumulative connected, NEC calculated and peak measured demand for panels at Southeast Hospital 1

Similarly, Table 5 above and Figure 5 below represent the same information for Southeast Hospital 5. The safety factor for individual panels is between 135% and 195%. The cumulative safety factor across panels with information is 195%. In all cases, the calculated load is greater than the metered load. This creates a gap between the calculated load and the metered load. The magnitude of the gap, as well as its variance over time, is remarkably similar to loads in the Westcoast Hospital's panel level monitoring.

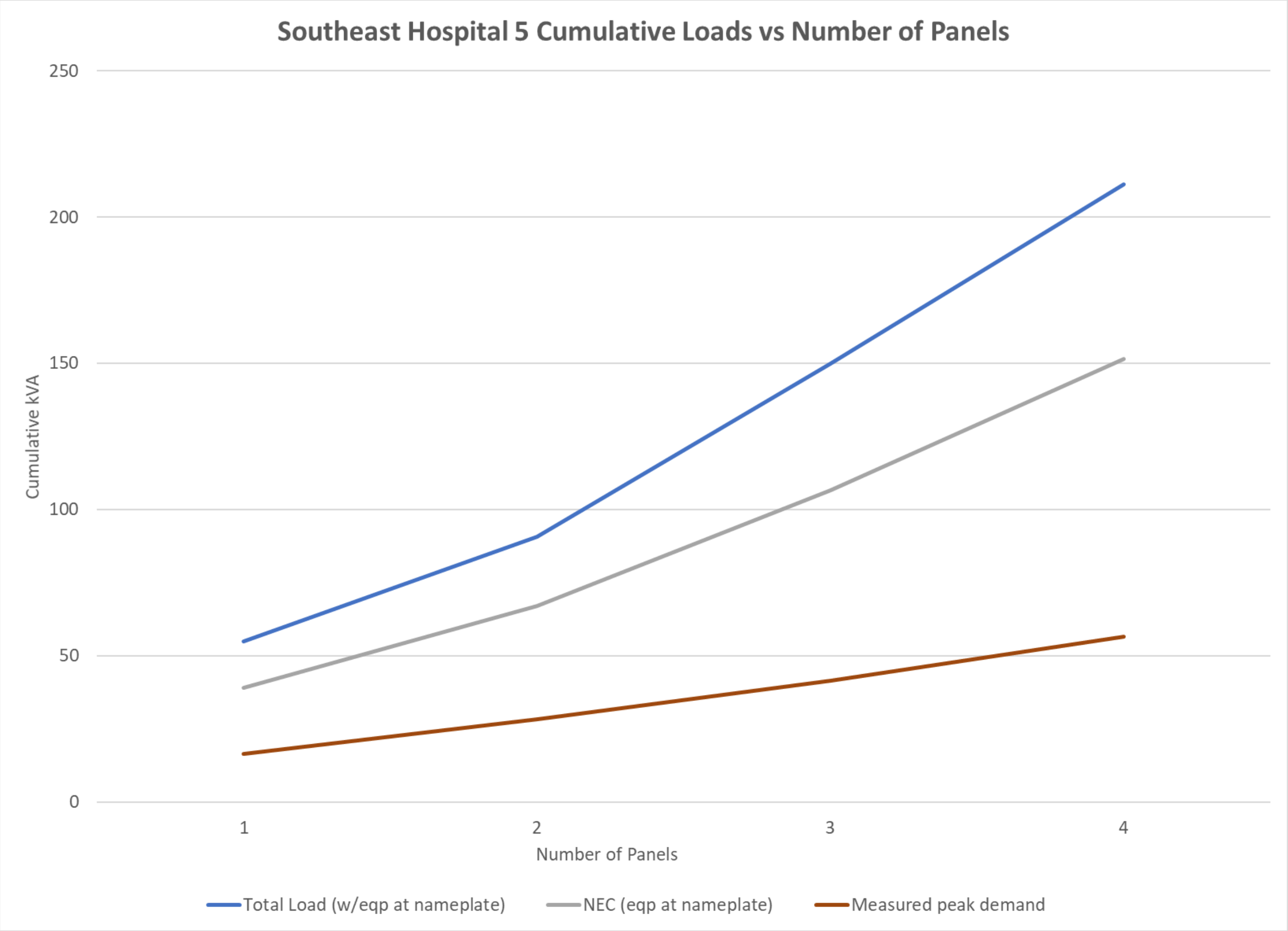


Figure 5: Southeast Hospital 5 Cumulative Loads vs Number of Panels

3.4 SOUTHEAST HOSPITALS WITHOUT DRAWINGS

As indicated above, electrical floor plans nor panel schedules were available for most of the panels monitored in the Southeast hospitals. A rich data set is provided for these hospitals; it is believed this data will be beneficial for researchers in the future. However, since electrical floor plans associated with these panels are unavailable, performing the same analysis and comparison (as completed for data with floor plans) is impossible. Therefore, for these panels, time series graphs, as presented below (max kVA vs date), were created. The graphs show the peak kVA for each day.[28]

The time-series graphs are useful for understanding the maximum load on an electrical panel over time. These graphs depict the maximum kVA per day, regardless of how long that

---

[28] The raw data provides the peak kVA over a much smaller time interval (5-minutes to 1-hour) however that level of resolution makes it difficult to understand the graphs. Therefore, a graph depicting the daily maximum is presented here.

maximum kVA occurs, including if it occurs for fractions of a second. These data points were not "cleaned" from the raw data sets. Instead, the data for any particular day can be reviewed to determine whether the maximum is a momentary spike or represents a longer time period of relatively high usage.

Some representative graphs are provided in Figures 6 and 7. The remainder of these graphs can be viewed/examined in the full dataset, which is available from the Foundation upon request.

The data for these panel-level readings showed no significant load variation over the course of the year. The data for the panel level readings were similar to the loads experienced by the West Coast Hospital 1 and the Southeast hospitals with floor plans, thus providing further corroboration for these readings.

Figure 6 below depicts an example of such a time series graph. It depicts fairly consistent peak loads on each day except when a spike in the peak load occurred on January 5, 2021. Since the daily graphs are created from the available interval data, the respective underlying data for this spike is available. Figure 7 below depicts the electrical load ratings on panel 11ANBC at Southeast Hospital 5 on January 5, 2021. Reviewing this graph, we see that the spike here was momentary and occurred sometime between 7:35 am and 7:40 am on that day. The data around this time period (including the average load data over this interval and the max load data at the adjacent intervals) suggest that the peak depicted here was momentary.[29]

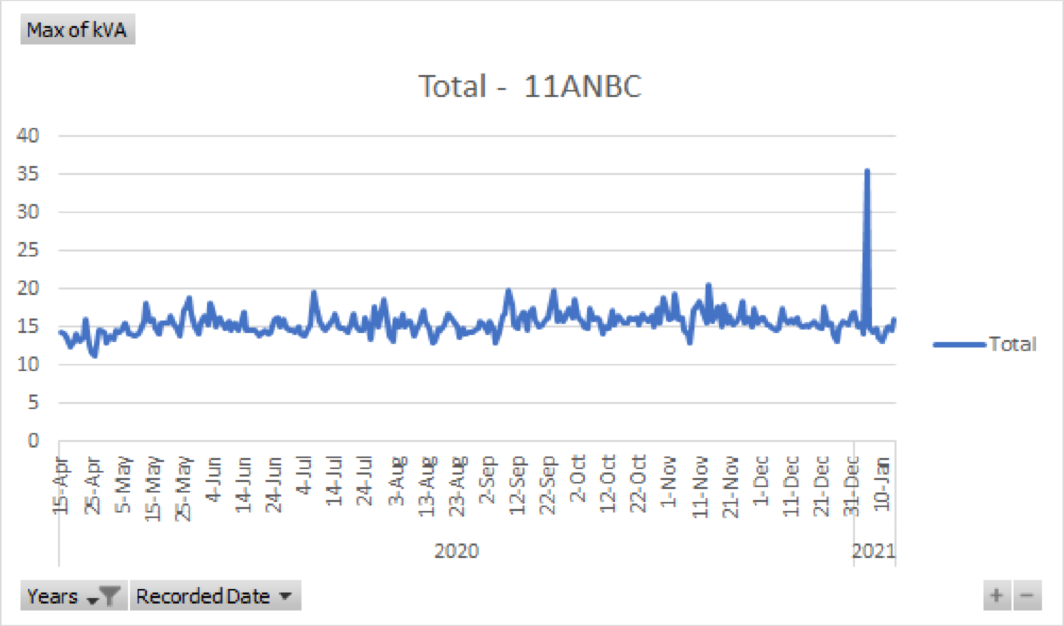


Figure 6: Time series graph showing peak load for each day in the series

---

[29] The data sets have not been cleaned. That is no data points in the data set have been removed. Instead, those interested are invited to review and interpret the raw data and to use the data to understand trends and any deviations from those trends.

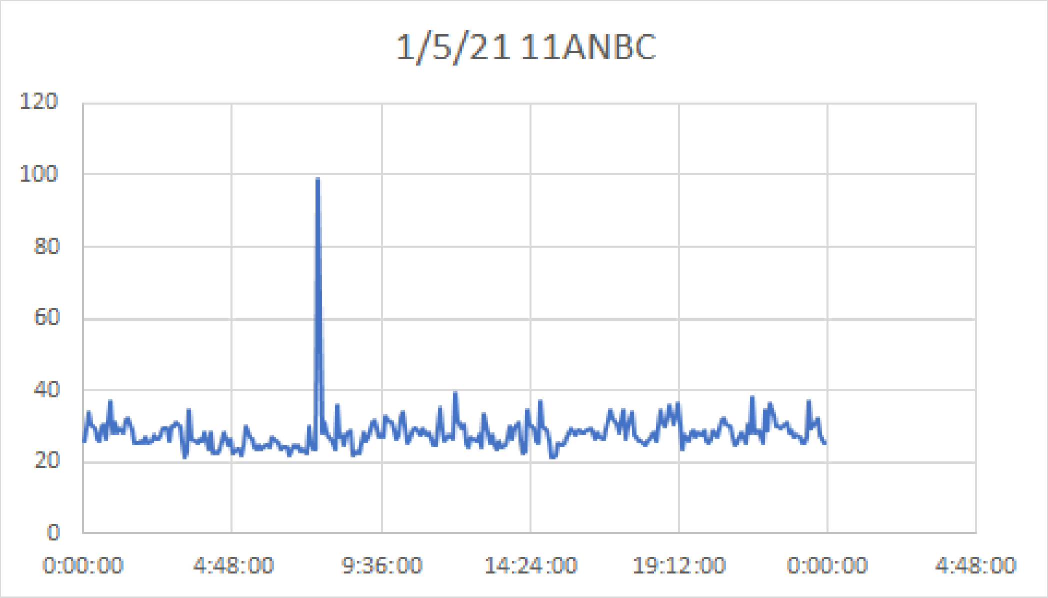


Figure 7: Data from panel 11ANBC during on January 5th, 2021

3.5 NORTHEAST HOSPITAL

The Northeast hospital provided data from meters permanently integrated into the system and floor plans for the associated floors. However, the available floor plans do not distinguish between general and dedicated receptacles. Panel schedules were not available. Therefore, the provided calculations assume all receptacles are general use receptacles, thus each receptacle is calculated at 180 VA. In addition, it should be noted that the meters installed at this location provided the average electrical load during a time interval as opposed to a peak during a time interval.[30]

Table 6 below provides the number of receptacles, connected load, calculated loads and maximum metered load for the Northeast Hospital.

Table 6: Connected, calculated and maximum metered loads for the northeast hospital

Panel	**# of receptacles**	**Connected Load (kVA)**	**NEC Calculated Load (kVA)**	**Maximum metered load (kVA)**
CB7 1-2 (E)	132	23.76	16.88	3
CB7-2-2 (B)	144	25.92	17.96	7
Total:	**276**	**49.68**	**34.84**	**10**

---

[30] The meters at the Northeast Hospital are integrated into the electrical panels. Meters were not specifically installed by Mazzetti for this study. These meters measure average electrical load instead of peak loads.

Figure 8 below provides the same information in graphical form. Since the analysis at the Northeast Hospital was performed at floor/area level as opposed to the panel level (given the format of the information provided), the graph showing the cumulative effect of adding additional panels is not provided. Instead, a simple bar graph is provided as a graphical depiction of the information in Table 6. The information and comparison for this hospital is provided in the below chart:

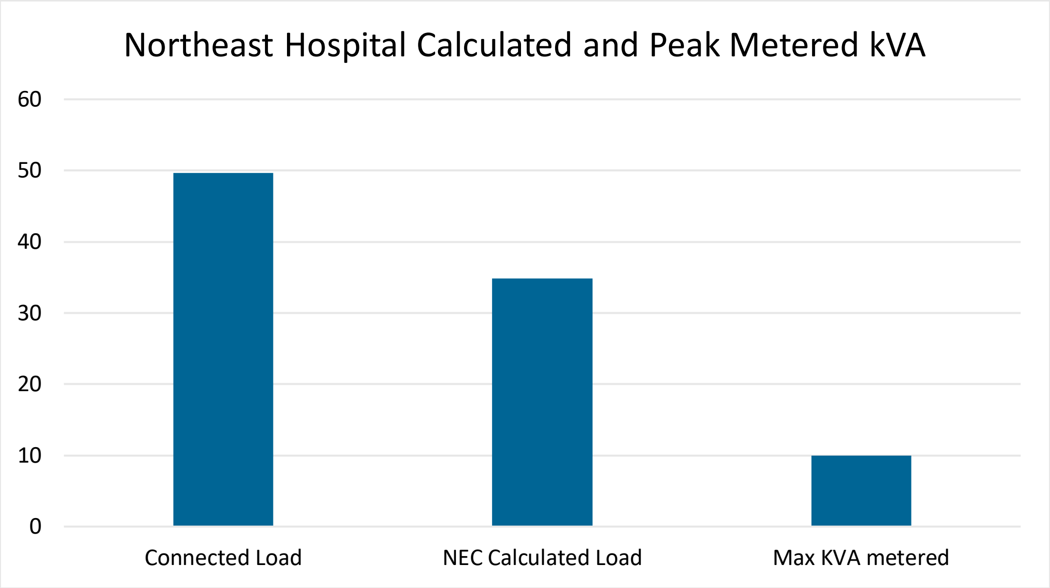


Figure 8: Graphical depiction of the connected, calculated, and maximum metered loads for the northeast hospital.

3.6 COMPARISON OF COVID-19 CASE LOAD TO MEASURED ELECTRICAL LOADS

To provide further insight into the impact of a pandemic on hospital electrical loads, graphs comparing the maximum daily electrical load on a panel with the COVID-19 rates are provided. For example, Figure 9 below provides the 7-day average new COVID-19 case load for the county in which the Southeast Hospital 5 with panel 11ANBC is located. A quick review of the graph shows that, for panel 11ANBC, COVID-19 rates in that county are not driving electrical use rates. More data and additional comparative graphs are available from the full data set.

In no case did the data suggest a correlation between the measured electrical loads and the specific Covid hospitalization rates (or the *County Case* rates where specific hospitalization rates were not available).

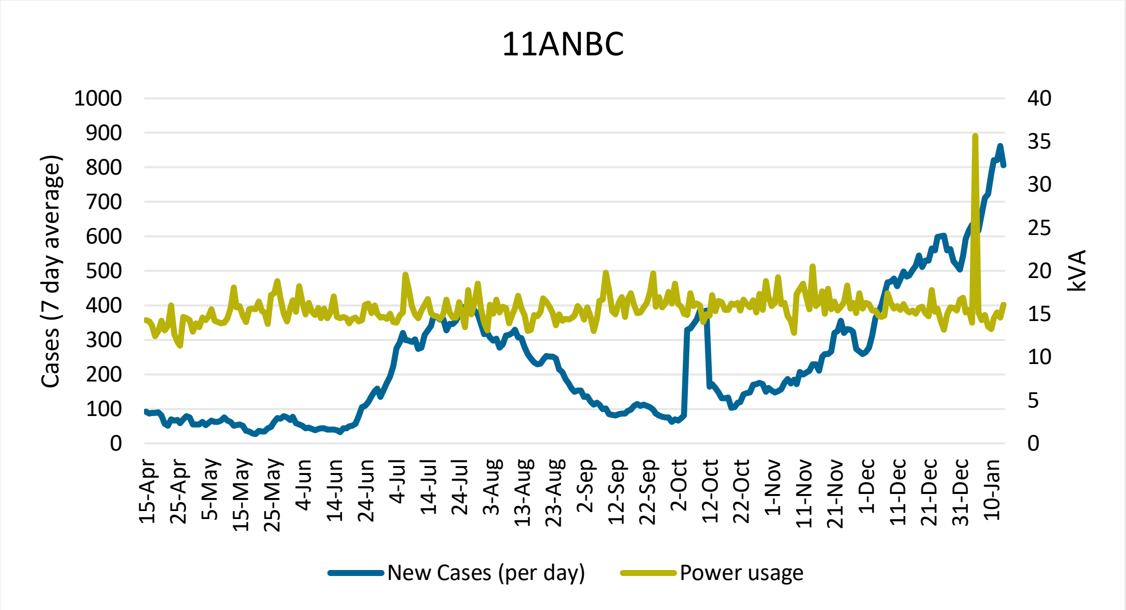


Figure 9: Time-Series graph depicting (a) maximum load per day on panel 11ANBC and, the 7-day average new COVID cases from Southeast Hospital 5

4 DISCUSSION

4.1 MAJOR FINDINGS

The data analysis resulted in the following summary observations:

1. Current NFPA 70 demand factors for patient care areas in a hospital result in systems that are at least twice as large as needed for all receptacle loads. The over-sizing increases at higher levels in the distribution system.
2. The oversizing is a much bigger problem for dedicated receptacles than it is for general receptacles.
3. These results are consistent across geographies, sizes of hospitals, age of hospitals, and types of hospitals.
4. The receptacle loads for a hospital patient care area do not vary over a year.
5. The receptacle loads for a hospital appear to not substantially increase do not substantially increase even during a pandemic.

4.2 POSSIBLE PROBLEMS WITH METHODOLOGY AND DATA

The limitations on the data collection process and the methodology utilized for data analysis are summarized herein.

Because of the wide variance in the numbers and kinds of meters (circuit level vs panel level), and the wide variance in available design documents (drawings and panel schedules), the granularity of analysis across different sites necessarily varies.

The lack of detailed census data for most facilities adds difficultly to draw precise conclusions about the relationship between census and electrical loads.

The study only examined the patient care areas of the various hospitals. Therefore, at this time, sufficient data to make recommendations with respect to other, non-patient care areas within the hospital does not exist. Note that the patient care areas often contain offices, nourishment stations, and other support spaces, and these receptacles are included in the various studies, including the historical ones. Therefore, there is at least some data available for these spaces, especially those within a clinical department.

Since a way to measure the aggregate peak loads for a group of receptacles is lacking, the use of the ‘sum of peaks’ methodology was used for this analysis. A true measurement of aggregate peak loads would likely provide an even larger opportunity for demand factor adjustments, than those suggested by this study.

It is important to note that no hospital, included in this study, experienced an extensive power outage during the time monitored.

In some cases, access to meters varied so data was downloaded at different intervals. Different meters were used in different locations as enumerated above. Because of these differences, the output data is different depending on the site and methodology used. This has a negligible effect on the actual data; however, it does yield different columns, time frames, and characteristics depending on the meter used and its setup.

Lastly, different staff installed meters and downloaded information from meters. This was necessary due to the speed at which meters were installed and the distance between hospitals. The effect of different people being involved in installation and data downloads is negligible.

4.3 COMPARISON OF RESULTS TO PREVIOUS STUDIES

All of the previous studies suggested that the NFPA 70 demand factors, especially if applied to levels of an electrical system beyond the branch circuit panel, result in electrical systems much larger than the loads the systems will actually experience. This study further validates these findings.

The past research also suggested that using nameplate data, without modification for dedicated receptacles in a hospital, especially if applied to levels of an electrical system beyond the branch circuit panel, result in electrical systems much larger than the loads the systems will actually experience. The previous studies speculate that this problem is likely a bigger issue than the issue for general receptacles. This study further validates these findings.

All the previous studies measured loads over a limited duration, with a maximum duration of two weeks. This study corroborated these findings and provided clear indication that receptacle loads for patient care spaces in hospitals remain constant throughout the year. This study validates that a shorter monitoring period is adequate to understand the behavior of electrical loads.

4.4 IMPLICATIONS OF FINDINGS

NFPA Codes and Standards prescribe the minimum requirements to ensure safety. The availability good quality data of a sufficient quantity will help code making bodies to make more informed decisions.

Based on the analysis above, the following should be noted:

- In all cases where receptacle information was available, there is significant spare capacity above the peak load experienced by the system over the metered period of one year.
- This finding is generally consistent with other studies and/or analysis of healthcare plug loads.

- The data in this study shows that the current demand factors for general receptacles in patient care areas can be reduced by half in general, and even more at higher levels of the system.
- The data in this study shows that the current demand factors for dedicated receptacles in patient care areas can be reduced, especially at higher levels of the system.

The data confirms what has generally been assumed by hospital electrical engineers – the current demand factors systematically cause oversizing of equipment in hospitals. The data strongly suggests this remains true even in pandemic situations.

Ultimately, it is believed the data from this study may be used to consider revisions to the NEC demand factors. Recommendations and determination of appropriate demand factors based on this information is left to the consensus process of NFPA Codes and Standards.

The study also provided decisive responses to many of the intuitive concerns noted in earlier sections of this paper.

a. **The One-year problem**. This project extended past one year for all hospitals measured. The project demonstrated that a one-year minimum requirement for receptacle load measurements may not be necessary.
b. **The Red outlet problem.** This study did not include a hospital that endured an extended utility outage.
c. **The all-branch problem.** All receptacles in hospital patient care areas are on the critical branch or the non-essential system. This study included all critical branch panels and all non-essential panels serving a particular area. Therefore, no further work is needed in this regard.
d. **The up-stream problem.** This study did not measure loads upstream from the branch circuit panels. However, the summary figures above show the cumulative effect of adding additional panels. These figures (for example see Figure 1) show that the demand factors for distribution equipment upstream (away from the loads and towards the sources) from the branch circuit panels should require even lower capacities than the demand factors for the branch circuit panels.
e. **The "representative hospital" problem**. This study included community hospitals, urban hospitals, academic medical centers. This study demonstrates no difference between these kinds of hospitals. The aforementioned *Plug and Process Loads in Medical Office* Buildings study (see section 1.4.5 above) shows similar results in outpatient facilities, indicating the applicability of these demand factors to all healthcare systems.
f. **The "all department" problem.** This study, together with previous studies cited, include the vast majority of clinical spaces within any hospital. The results are similar across all departments, indicating applicability of the results to receptacles in all patient care areas of all hospitals.
g. **The "census" problem.** The hospitals in this study went through various phases of occupancy. When patient care areas are empty, the loads on the receptacles are low. As occupancy rises, loads go up. However, most of the load readings taken, including those

in earlier studies, occurred during high-occupancy states. This study focused on peak loads over a year time-period and used the sum of peaks methodology, so that the results measured are reliable.

h. **The "statistical significance" problem**. All references cited suggest results similar to the ones found in this study. All hospitals measured in this study, for more than one year, showed similar results. The results of all of this cumulative work are definitive.
i. **The "surge" problem.** During a hospitalization surge, as expected during a pandemic, the electrical loads did not skyrocket as feared. This is largely due to the way that hospitals are managed – cancelling elective procedures, diverting patients to other sites, setting up surge facilities, and even turning away patients. It is also due to limitations of other systems in the hospital, primarily staff, and equipment. Since healthcare systems are rate-limited, the data suggests that the potential benefit of installing oversized electrical systems is limited if these other systems are incapable of serving the surge.
j. **The "spare capacity" problem**. The purpose of a code is to describe the minimum requirements for safety. It is explicitly not for future expansion of electrical use. NEC section 90.1(B) says, "This Code contains provisions that are considered necessary for safety. Compliance therewith and proper maintenance result in an installation that is essentially free from hazard but not necessarily efficient, convenient, or adequate for good service or future expansion of electrical use."[31]

This study corroborates other previous studies showing that the current NFPA 70 demand factors for sizing electrical systems with respect to receptacle loads in healthcare facilities, especially when applied to distribution elements upstream from the branch circuit panels, result in systems that are much larger than the loads they will likely ever experience.

4.5 SUGGESTED FURTHER RESEARCH

Suggested further receptacle load research is categorized (below) as (a) Healthcare and (b) Business and education occupancies.

4.5.1 Healthcare Occupancies

This study provides significant insight into receptacle loads at hospitals. Additional study on this important topic will be helpful, specifically related to the following areas:

- Higher levels

Explicit study of higher levels of the distribution system may be helpful in developing a complete understanding of electrical loads. While the circuit and panel level data reviewed in this study provides a sufficient basis to understand higher levels of the system generally, there may be some interest in having direct measurements of these levels.

- Dedicated circuits

---

[31] See NEC 70.90.1(B). In NEC 70.90 Branch-Circuit, Feeder, and Service Load Calculations. NEC 70: National Electrical Code, 2020 Edition. NFPA (© 2019)

Additional study of dedicated receptacles is warranted. Research suggests that many pieces of equipment will not operate at their rated amperage ever, and only rarely operate at their actual peak load. A greater understanding of dedicated circuit loads may be beneficial.

- Non-patient spaces

The focus of this study was on patient spaces. Studying hospital, non-patient spaces would be beneficial, especially if these spaces are compared to metering results from similar spaces in non-healthcare settings. Study of non-patient areas and different space categories may be helpful in confirming how the findings in this and previous studies should be interpreted for non-patient care spaces.

- Extended power outage

No significant power outages occurred during the study period. When an opportunity arises, understanding what occurs to electrical loads during an extended power outage will be helpful.

In general, this study is a significant step towards obtaining a deeper understanding of hospital plug loads. The implications of changes in medical equipment and other trends could be better understood. It may be prudent to perform additional work to conclusively understand plug loads in hospitals.

4.5.2 Business and Education Occupancies

The Research Foundation originally commissioned a study on healthcare, business, and education occupancies before the COVID-19 pandemic caused a change in direction (See section 2). The original study focused on office spaces across three occupancy types.

If electrical engineers design a building type and each space type (e.g., office space, patient care area, etc.) has a different demand factor, the calculations and design become complicated, more expensive to design, and more difficult for a reviewer to check. Another approach would be to focus data collection and analysis on one type of occupancy at a time. This may provide more specific information. For example, one might study restaurant plug loads, the university plug loads, then laboratory plug loads. Once multiple studies are performed, comparison between space types for different occupancy types is possible. This approach may make it more likely for codes to be updated based on building type and not specific space types within the building, reducing complexity for designers and code officials. And the depth of information is richer than the opposite approach (study space types would then allow for comparison of space types across occupancy types).

Similarly, it is recommended that studies attempt to obtain longer duration data. While plug load data is not thought to be weather dependent, code-making committees and policy makers typically give more credence to longer duration data. The original study required data collection for at least one month at each location. It is suggested the minimum be increased to two months and that data collection occur for as long as possible within resource constraints.

5 REFERENCES

Black, Douglas R., Steven M. Lanzisera, Judy Lai, Richard E. Brown, and Brett C. Singer. "Evaluation of Miscellaneous and Electronic Device Energy Use in Hospitals." (2012).

D'Antona, Jason and Messervy, John. 2014. *Quantifying Hospital Cord-Connected Plug Loads in Inpatient Areas.* Chicago, The American Society for Healthcare Engineer (ASHE) of the American Hospital Association.

"IEEE Recommended Practice for Electric Systems in Health Care Facilities," in IEEE Std 602-2007 (Revision of IEEE Std 602-1996), vol., no., pp.1-436, 29 Aug. 2007, doi: 10.1109/IEEESTD.2007.4299432.

NEC 70.220 Branch-Circuit, Feeder, and Service Load Calculations. NEC 70: National Electrical Code, 2020 Edition. NFPA (© 2019)

Ranganathan, Sreenivasan, and Victoria Hutchison. "Balancing safety and efficiency. Research project builds database of information to help in development of health care electrical standards." Health Facilities Management. Available online: https://www.hfmmagazine.com/articles/4072-balancing-safety-and-efficiency

Ruecker, Ross, Arash Guity, and Jun Timbang. "Plug and Process Loads in Medical Office Buildings." *ASHRAE Transactions 121*, no. 2 (2015): 63-71.

Sheppy, Michael, Shanti Pless, and Feitau Kung. *Healthcare energy end-use monitoring*. No. NREL/TP-5500-61064. National Renewable Energy Lab. (NREL), Golden, CO (United States), 2014.

6 APPENDIX 1: ADDITIONAL METHODOLOGICAL DETAILS

As mentioned above, various data was available for different sites. For each type of site, a different analysis was performed.

6.1 FOR THE WESTCOAST HOSPITAL 1

At Westcoast Hospital 1, circuit and panel-level metering was performed; specific floor plans and schedules are available. Therefore, the most comprehensive analysis could be performed at this site.

6.1.1 Panel Level Analysis:

The focus of this analysis is to compare the calculated, NEC calculated, and actual measured circuit loads. Several steps are necessary to prepare such an analysis. It is helpful to understand how these comparisons are produced. The steps are as follows:

Identify floor plans and panel schedules for the circuits and panels metered.

Figure 10 below depicts a portion of a typical electrical floor plan. The clouded portion notes the panel and circuit numbers for the receptacles feeding this particular area. So, each circuit and each receptacle is associated with a specific location and use in the hospital.

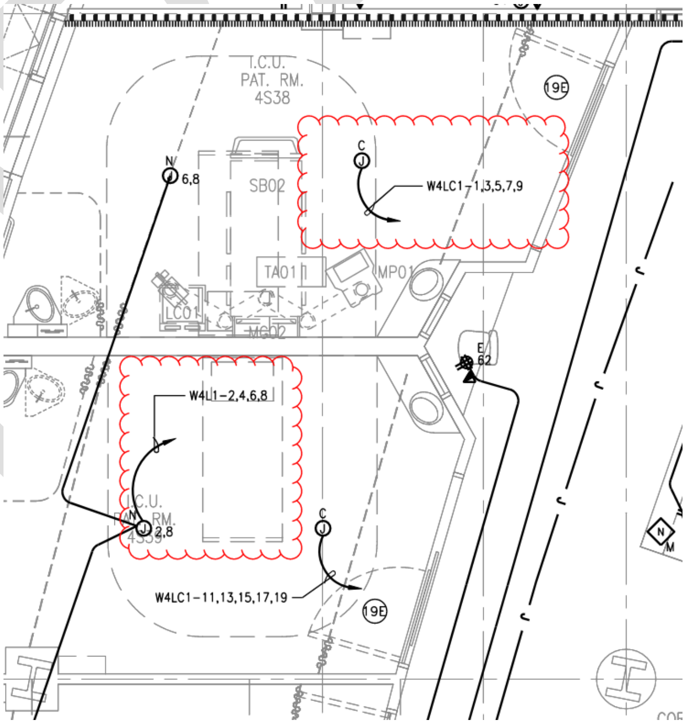


Figure 10: Floor Plan Example

The drawing in Figure 10 indicates panel W4LC1 and W4L1 and indicates the circuits on that panel that are connected in this room. For example, circuits 1, 3, 5, 7 and 9 on panel W4CL1 are connected to the junction box for this room. The important thing to note here is that specific circuits that serve floors of the hospital are then connected back to the panel. These receptacle circuits may be general receptacles or may be dedicated equipment receptacles, if the plans specifically noted that one piece of equipment would be plugged in. For example, if the designer here indicated a refrigerator in a certain location, they may specify that the refrigerator (and only the refrigerator) would be plugged into a certain circuit. This load would then be from a dedicated piece of equipment.

Where available, the electrical floor plans were analyzed to determine the connected load, the NEC connected load (which applies a demand factor to general receptacle circuits) and, in some instances, a calculation based on proposals by CMP-2 and CMP-15.

The following is a brief explanation of how this was done. The plans were reviewed, and each circuit is identified and traced back to its panel.

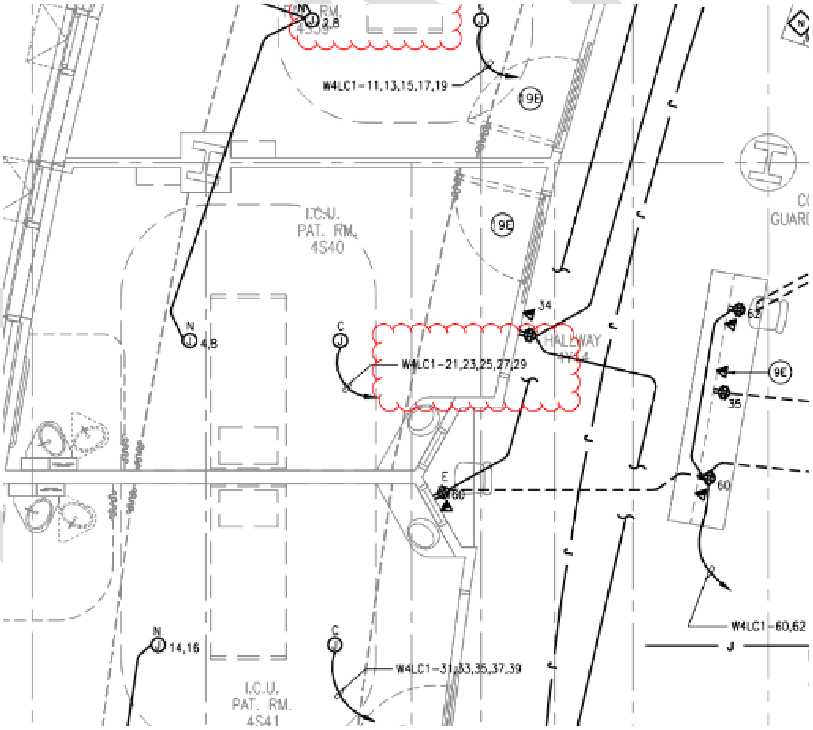
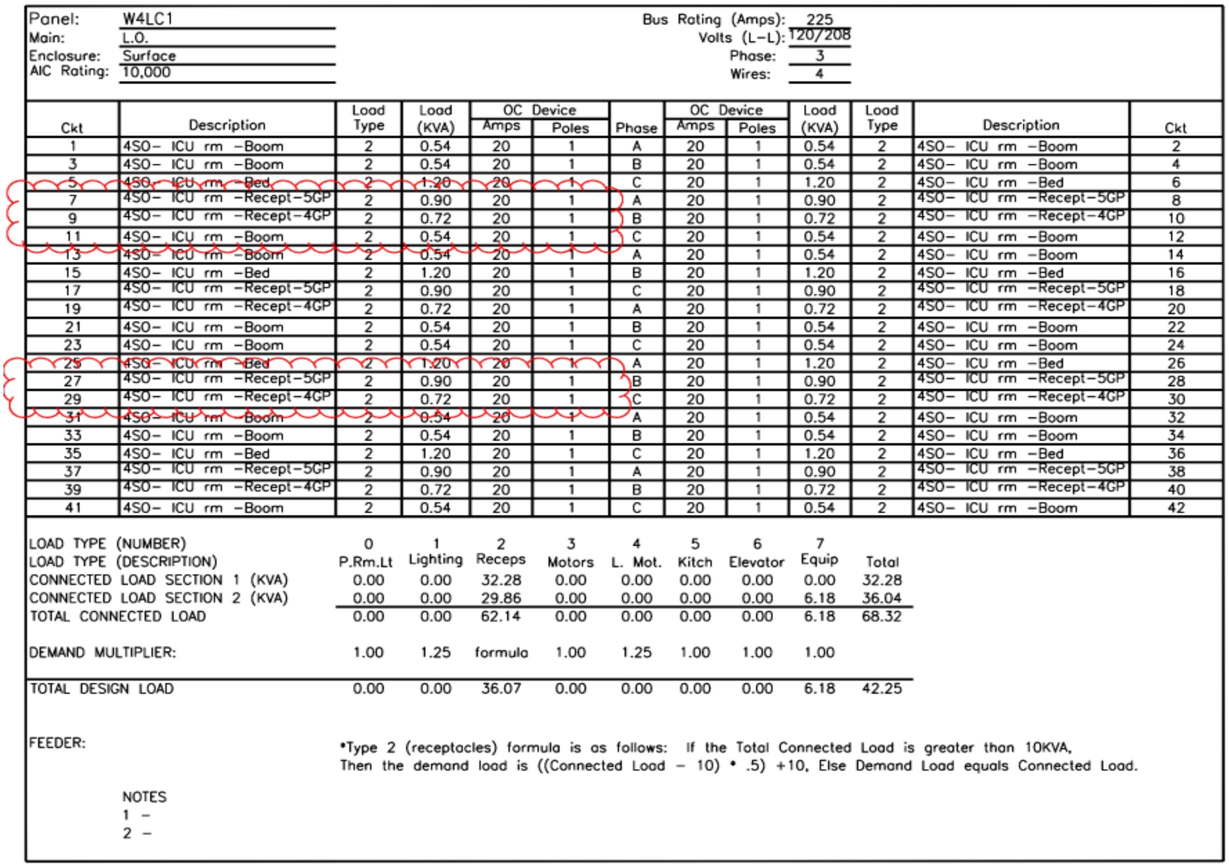


Figure 11: Another Floor Plan Example

Count the number of general receptacles and specific equipment receptacles on each panel

Then the panel schedules were reviewed. Each item on the panel schedule indicates either a general receptacle (type 2) or an equipment receptacle (type 7, i.e., a dedicated receptacle) or some other type.

Figures 12 and 13 below depict typical panel schedules used to identify the type of load and the associated calculated load.



Panel: W4LC1
Main: L.O.
Enclosure: Surface
AIC Rating: 10,000

Bus Rating (Amps): 225
Volts (L-L): 120/208
Phase: 3
Wires: 4

Ckt	Description	Load Type	Load (KVA)	OC Device		Phase	OC Device		Load (KVA)	Load Type	Description	Ckt
				Amps	Poles		Amps	Poles				
1	4SO– ICU rm –Boom	2	0.54	20	1	A	20	1	0.54	2	4SO– ICU rm –Boom	2
3	4SO– ICU rm –Boom	2	0.54	20	1	B	20	1	0.54	2	4SO– ICU rm –Boom	4
5	4SO– ICU rm –Bed	2	1.20	20	1	C	20	1	1.20	2	4SO– ICU rm –Bed	6
7	4SO– ICU rm –Recept–5GP	2	0.90	20	1	A	20	1	0.90	2	4SO– ICU rm –Recept–5GP	8
9	4SO– ICU rm –Recept–4GP	2	0.72	20	1	B	20	1	0.72	2	4SO– ICU rm –Recept–4GP	10
11	4SO– ICU rm –Boom	2	0.54	20	1	C	20	1	0.54	2	4SO– ICU rm –Boom	12
13	4SO– ICU rm –Boom	2	0.54	20	1	A	20	1	0.54	2	4SO– ICU rm –Boom	14
15	4SO– ICU rm –Bed	2	1.20	20	1	B	20	1	1.20	2	4SO– ICU rm –Bed	16
17	4SO– ICU rm –Recept–5GP	2	0.90	20	1	C	20	1	0.90	2	4SO– ICU rm –Recept–5GP	18
19	4SO– ICU rm –Recept–4GP	2	0.72	20	1	A	20	1	0.72	2	4SO– ICU rm –Recept–4GP	20
21	4SO– ICU rm –Boom	2	0.54	20	1	B	20	1	0.54	2	4SO– ICU rm –Boom	22
23	4SO– ICU rm –Boom	2	0.54	20	1	C	20	1	0.54	2	4SO– ICU rm –Boom	24
25	4SO– ICU rm –Bed	2	1.20	20	1	A	20	1	1.20	2	4SO– ICU rm –Bed	26
27	4SO– ICU rm –Recept–5GP	2	0.90	20	1	B	20	1	0.90	2	4SO– ICU rm –Recept–5GP	28
29	4SO– ICU rm –Recept–4GP	2	0.72	20	1	C	20	1	0.72	2	4SO– ICU rm –Recept–4GP	30
31	4SO– ICU rm –Boom	2	0.54	20	1	A	20	1	0.54	2	4SO– ICU rm –Boom	32
33	4SO– ICU rm –Boom	2	0.54	20	1	B	20	1	0.54	2	4SO– ICU rm –Boom	34
35	4SO– ICU rm –Bed	2	1.20	20	1	C	20	1	1.20	2	4SO– ICU rm –Bed	36
37	4SO– ICU rm –Recept–5GP	2	0.90	20	1	A	20	1	0.90	2	4SO– ICU rm –Recept–5GP	38
39	4SO– ICU rm –Recept–4GP	2	0.72	20	1	B	20	1	0.72	2	4SO– ICU rm –Recept–4GP	40
41	4SO– ICU rm –Boom	2	0.54	20	1	C	20	1	0.54	2	4SO– ICU rm –Boom	42

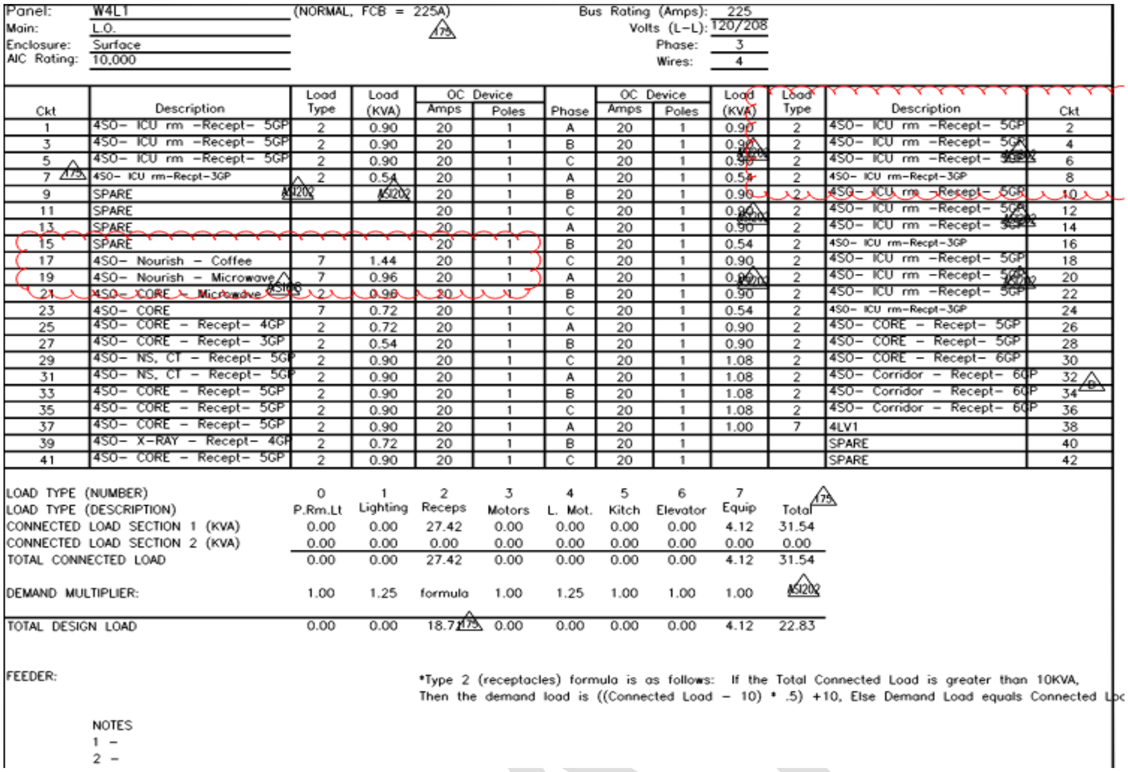
LOAD TYPE (NUMBER)	0	1	2	3	4	5	6	7	
LOAD TYPE (DESCRIPTION)	P.Rm.Lt	Lighting	Receps	Motors	L. Mot.	Kitch	Elevator	Equip	Total
CONNECTED LOAD SECTION 1 (KVA)	0.00	0.00	32.28	0.00	0.00	0.00	0.00	0.00	32.28
CONNECTED LOAD SECTION 2 (KVA)	0.00	0.00	29.86	0.00	0.00	0.00	0.00	6.18	36.04
TOTAL CONNECTED LOAD	0.00	0.00	62.14	0.00	0.00	0.00	0.00	6.18	68.32
DEMAND MULTIPLIER:	1.00	1.25	formula	1.00	1.25	1.00	1.00	1.00	
TOTAL DESIGN LOAD	0.00	0.00	36.07	0.00	0.00	0.00	0.00	6.18	42.25

FEEDER:

*Type 2 (receptacles) formula is as follows: If the Total Connected Load is greater than 10KVA, Then the demand load is ((Connected Load – 10) * .5) +10, Else Demand Load equals Connected Load.

NOTES
1 –
2 –

Figure 12: Example Panel Schedule (1)



Panel: W4L1 (NORMAL, FCB = 225A)
Main: L.O.
Enclosure: Surface
AIC Rating: 10,000

Bus Rating (Amps): 225
Volts (L-L): 120/208
Phase: 3
Wires: 4

Ckt	Description	Load Type	Load (KVA)	OC Device Amps	OC Device Poles	Phase	OC Device Amps	OC Device Poles	Load (KVA)	Load Type	Description	Ckt
1	4SO- ICU rm -Recept- 5GP	2	0.90	20	1	A	20	1	0.90	2	4SO- ICU rm -Recept- 5GP	2
3	4SO- ICU rm -Recept- 5GP	2	0.90	20	1	B	20	1	0.90	2	4SO- ICU rm -Recept- 5GP	4
5	4SO- ICU rm -Recept- 5GP	2	0.90	20	1	C	20	1	0.90	2	4SO- ICU rm -Recept- 5GP	6
7	4SO- ICU rm-Recpt-3GP	2	0.54	20	1	A	20	1	0.54	2	4SO- ICU rm-Recpt-3GP	8
9	SPARE			20	1	B	20	1	0.90	2	4SO- ICU rm -Recept- 5GP	10
11	SPARE			20	1	C	20	1	0.90	2	4SO- ICU rm -Recept- 5GP	12
13	SPARE			20	1	A	20	1	0.90	2	4SO- ICU rm -Recept- 5GP	14
15	SPARE			20	1	B	20	1	0.54	2	4SO- ICU rm-Recpt-3GP	16
17	4SO- Nourish - Coffee	7	1.44	20	1	C	20	1	0.90	2	4SO- ICU rm -Recept- 5GP	18
19	4SO- Nourish - Microwave	7	0.96	20	1	A	20	1	0.90	2	4SO- ICU rm -Recept- 5GP	20
21	4SO- CORE - Microwave	2	0.96	20	1	B	20	1	0.90	2	4SO- ICU rm -Recept- 5GP	22
23	4SO- CORE	7	0.72	20	1	C	20	1	0.54	2	4SO- ICU rm-Recpt-3GP	24
25	4SO- CORE - Recept- 4GP	2	0.72	20	1	A	20	1	0.90	2	4SO- CORE - Recept- 5GP	26
27	4SO- CORE - Recept- 3GP	2	0.54	20	1	B	20	1	0.90	2	4SO- CORE - Recept- 5GP	28
29	4SO- NS, CT - Recept- 5GP	2	0.90	20	1	C	20	1	1.08	2	4SO- CORE - Recept- 6GP	30
31	4SO- NS, CT - Recept- 5GP	2	0.90	20	1	A	20	1	1.08	2	4SO- Corridor - Recept- 6GP	32
33	4SO- CORE - Recept- 5GP	2	0.90	20	1	B	20	1	1.08	2	4SO- Corridor - Recept- 6GP	34
35	4SO- CORE - Recept- 5GP	2	0.90	20	1	C	20	1	1.08	2	4SO- Corridor - Recept- 6GP	36
37	4SO- CORE - Recept- 5GP	2	0.90	20	1	A	20	1	1.00	7	4LV1	38
39	4SO- X-RAY - Recept- 4GP	2	0.72	20	1	B	20	1			SPARE	40
41	4SO- CORE - Recept- 5GP	2	0.90	20	1	C	20	1			SPARE	42

LOAD TYPE (NUMBER)	0	1	2	3	4	5	6	7	
LOAD TYPE (DESCRIPTION)	P.Rm.Lt	Lighting	Receps	Motors	L. Mot.	Kitch	Elevator	Equip	Total
CONNECTED LOAD SECTION 1 (KVA)	0.00	0.00	27.42	0.00	0.00	0.00	0.00	4.12	31.54
CONNECTED LOAD SECTION 2 (KVA)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL CONNECTED LOAD	0.00	0.00	27.42	0.00	0.00	0.00	0.00	4.12	31.54
DEMAND MULTIPLIER:	1.00	1.25	formula	1.00	1.25	1.00	1.00	1.00	
TOTAL DESIGN LOAD	0.00	0.00	18.71	0.00	0.00	0.00	0.00	4.12	22.83

FEEDER:

*Type 2 (receptacles) formula is as follows: If the Total Connected Load is greater than 10KVA, Then the demand load is ((Connected Load – 10) * .5) +10, Else Demand Load equals Connected Lo

NOTES
1 –
2 –

Figure 13: Example Panel Schedule (2)

Calculate the connected load, NEC connected load for each panel

A calculation is then performed to determine the required demand. General receptacles (type 2) are calculated at 180 VA (0.18 kVA) per receptacle. Dedicated equipment receptacles (type 7) are calculated at the nameplate amperage rating per the NEC. For the general receptacles, any receptacle loads above 10 kVA of the total are reduced by 50% per the existing demand factors in the NEC.

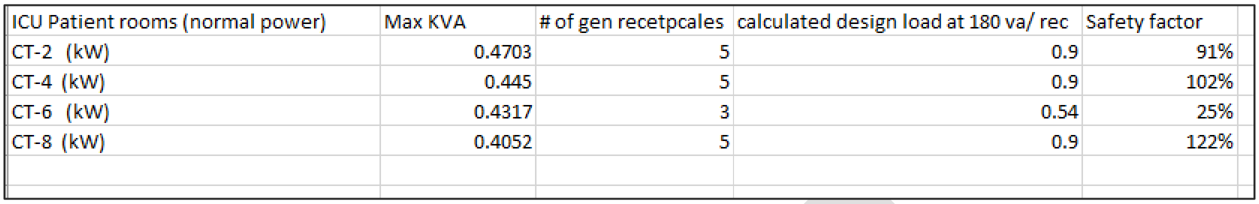
Review the meter data and determine the peak load on each panel

The calculated load is then compared to the peak load measured on each panel. The peak load is the maximum load seen on a panel over the entire time period. At the West Coast Hospital 1, the panoramic meters provide the maximum load seen over an interval period. The interval period is hourly; therefore, the meters record the highest load seen each hour.

The calculated load is then compared to the actual metered load.

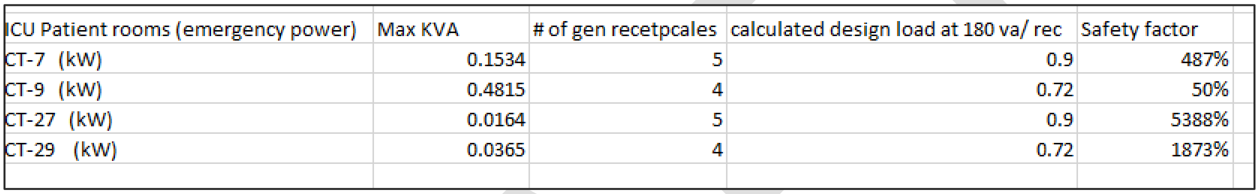
Table 8 and Table 9 provide an example of how this information is then used to compare the calculated load to the measured load. For example, on CT-2 in Table 8, the circuit has five general receptacles and therefore a raw calculated load of 0.9 kVA (5 receptacles x 0.18 kVA/receptacle = 0.9 kVA.) The maximum demand metered on this circuit is 0.4703. Therefore, the calculated load (i.e., what it was design for) is 91% more than the maximum actual load on this circuit ((0.9-0.4703)/0.4703 = 91%). This value is defined as “safety factor” in the tables below.

Table 7: Example comparison of metered vs calculated load on circuit



ICU Patient rooms (normal power)	Max KVA	# of gen recetpcales	calculated design load at 180 va/ rec	Safety factor
CT-2 (kW)	0.4703	5	0.9	91%
CT-4 (kW)	0.445	5	0.9	102%
CT-6 (kW)	0.4317	3	0.54	25%
CT-8 (kW)	0.4052	5	0.9	122%

Table 8: Another example comparison of metered vs calculated load on a circuit



ICU Patient rooms (emergency power)	Max KVA	# of gen recetpcales	calculated design load at 180 va/ rec	Safety factor
CT-7 (kW)	0.1534	5	0.9	487%
CT-9 (kW)	0.4815	4	0.72	50%
CT-27 (kW)	0.0164	5	0.9	5388%
CT-29 (kW)	0.0365	4	0.72	1873%

Create the summary chart
For an example of a summary chart, please refer to Table 3 on page 23 of this report.

Create the graph
A graph is then prepared comparing the connected load, NEC connected load, and the maximum peak metered load. (See, for example, Figure 1 on page 22.) The graph is cumulative, reflecting the impact as additional panels are summed. This cumulative value considers the effects of demand factors. In this way, it mimics the effect of calculating further upstream where the demand factor impacts more of the connected load.

For example, if the calculated load of 50,000 VA is reached over five panels (assume 10,000 VA for each panel), the NEC load at this point would be calculated as 10,000 VA + 40,000 VA * 0.5 = 30,000 VA. Note, this is less than if we summed the NEC load of the 5 individual panels (this would result in 50,000 VA NEC load).

The graph provides a quick and easy visual depiction of the difference in calculated versus measured demand, as more capacity is aggregated.

6.1.2 Circuit level – Westcoast Hospital 1

Circuit-level metering was installed at Westcoast Hospital 1, using Panoramic Power meters. By monitoring at the circuit level, the power draw was mapped to specific circuits. Panoramic Power meters easily snap onto the wires of individual circuits providing an unobtrusive installation. The CT amperage meters communicate with a wireless bridge, which collects data and provides access to that data via the cloud.

The panel-level data provides a clear picture of load at the site. The circuit-level data allows disaggregation between general receptacle circuits and specified equipment circuits to obtain a clearer sense of what happens for general receptacles and equipment receptacles. Since every circuit on each panel was not metered, this data provides a sample of how receptacle vs dedicated loads function.

The steps for performing circuit-level analysis at the California site are similar to the panel-level analysis. The steps are as follows.

Step 1: Identify floor plans and panel schedules for the circuits and panels metered.

Step 2: Count the number of general receptacles and specific equipment receptacles on each circuit.

This is the same process as for the panel level analysis above, only calculated at the individual circuit level.

Step 3: Calculate the connected load and NEC calculated load for each circuit.

Step 4: Review the meter data and determine the load on each circuit when the peak load on the panel is reached.

Each panel has a maximum output. The analysis of what the circuits are doing at the time of maximum output is helpful, because it demonstrates the split between general receptacles and equipment receptacles at peak power intervals.

Step 5: Create the graph

The graph is similar to that created for the panel level analysis except in this case, two graphs are created – one for the general receptacles and one for dedicated receptacles.

6.2 SOUTHEAST HOSPITALS WITH DRAWINGS AVAILABLE

For the southeast hospitals, the availability of plans and panel schedules were limited. However, where floor plans and panel schedules were available, the analysis procedure was exactly the same as panel-level analysis for Westcoast Hospital 1.

6.3 SOUTHEAST HOSPITALS WITHOUT DRAWINGS AVAILABLE[32]

Most of the southeast hospitals did not have plans and panel schedules available. However, these sites were still able to provide valuable information, including how COVID-19 affects overall demand. By examining the peak use (and the general trend) and comparing it to available hospitalization data (and/or COVID case load data), the impact of COVID hospitalization on electrical load can be assessed.

Therefore, where detailed plans were not available, the general trend was examined, and inferences made on if and how the load on these panels changed during and after the COVID-19 surge.

---

[32] The distinction in the southeast hospitals occurs at the panel level. In some cases, the facility was able to find some floor plans and panel schedules and an analysis indicating the specific receptacles could be performed. Otherwise, such a receptacle specific analysis could not be performed.

6.4 NORTHEAST HOSPITAL

For the northeast hospital, floor plans were available, but panel schedules were not. It was possible to determine the number of receptacles, but it was not possible to determine which receptacles had dedicated equipment. Therefore, all receptacles were calculated at 180 VA per receptacle.

Additionally, an integral meter at the northeast hospital site provided the data. This meter provides the average and not the maximum load over the metered time period.

Therefore, the analysis of the northeast hospital follows the procedure for the Westcoast Hospital 1 panel-level analysis, except that all receptacles are considered as general receptacles.

7 APPENDIX 2 – WESTCOAST HOSPITAL 2 DATA

Data from a circuit level monitoring study conducted at Kaiser Permanent Westside Hospital is provided here an appendix. This hospital is identified as Westcoast Hospital 2 above. Permission was granted to identify this hospital.

The data, provided here, was previously submitted to the NEC® Code Making Panels.
The data comes from the monitoring of receptacle loads in Kaiser Permanente Westside Hospital. Over the course of 6 months and 8 individual phases, Panoramic Power amperage meters were installed on 37 panels and over 1000 individual circuits. For each phase, 1 minute interval data was collected for 2 weeks, then removed and installed on new panels for the next phase. Circuits and panels were mapped to floor plans, to determine the room type, department, and square footage that they serve. Panel level peak demand data is presented in Table 9 below.[33] Figure 14 below provides a comparison of the connected, NEC® calculated and maximum load accumulated across panels for this study.

---

[33] This data is also included in the dataset.

Table 9: Connected load and metered load at Westcoast Hospital 2.

		Connected Load (VA)					Measured Peak VA	NEC DEMAND LOAD	Safety Factor Above Measured Demand	Cumulative Loads				
Panel	Department	# Receps	Recep load	# CORD CONN EQP	Cord Con Load (nameplate)	Total Conn. Load, equip at nameplate		CORD CONN AT nameplate	NEC (w/ eqp at nameplate)	Measured peak demand	Recep Load	Cord Conn Load (nameplate)	Total Load (w/ eqp at nameplate)	NEC (w/ eqp at nameplate)
1ACL1	ICU - Critical	164	29,520	4	3,400	32,920	6,240	23,160	271%	6,240	29,520	3,400	32,920	23,160
1ANL2	ICU - Normal	164	29,520	0	0	29,520	2,780	19,760	611%	9,020	59,040	3,400	62,440	37,920
1ECL2	ED - Critical	119	21,420	10	6,883	28,303	2,170	22,593	941%	11,190	80,460	10,283	90,743	55,513
1ENL2	ED - Normal	156	28,080	0	0	28,080	2,170	19,040	777%	13,360	108,540	10,283	118,823	69,553
1DCL1	Imaging - Critical	111	19,980	17	12,914	32,894	7,230	27,904	286%	20,590	128,520	23,197	151,717	92,457
1DCL2	Imaging - Critical	156	28,080	9	5,101	33,181	1,900	24,141	1171%	22,490	156,600	28,298	184,898	111,598
1DNL1	Imaging - Normal	147	26,460	10	7,007	33,467	5,950	25,237	324%	28,440	183,060	35,305	218,365	131,835
1DNL2	Imaging - Normal	118	21,240	11	11,326	32,566	7,680	26,946	251%	36,120	204,300	46,631	250,931	153,781
1DNL3	Imaging - Normal	107	19,260	14	8,976	28,236	6,620	23,606	257%	42,740	223,560	55,607	279,167	172,387
1DNL4	Imaging - Normal	28	5,040	21	8,716	13,756	3,010	13,756	357%	45,750	228,600	64,323	292,923	183,623
2ANL1	Patient - Normal	148	26,640	8	6,205	32,845	4,160	24,525	490%	49,910	255,240	70,528	325,768	203,148
2ANL2	Patient - Normal	147	26,460	0	0	26,460	3,170	18,230	475%	53,080	281,700	70,528	352,228	216,378
2ANL3	Patient - Normal	95	17,100	1	500	17,600	2,000	14,050	603%	55,080	298,800	71,028	369,828	225,428
2ACL1	Patient - Critical	128	23,040	0	0	23,040	3,150	16,520	424%	58,230	321,840	71,028	392,868	236,948
2ACL2	Patient - Critical	110	19,800	6	2,310	22,110	3,880	17,210	344%	62,110	341,640	73,338	414,978	249,158

		Connected Load (VA)					Measured Peak VA	NEC DEMAND LOAD	Safety Factor Above Measured Demand	Cumulative Loads				
Panel	Department	# Receps	Recep load	# CORD CONN EQP	Cord Con Load (nameplate)	Total Conn. Load, equip at nameplate		CORD CONN AT nameplate	NEC (w/ eqp at nameplate)	Measured peak demand	Recep Load	Cord Conn Load (nameplate)	Total Load (w/ eqp at nameplate)	NEC (w/ eqp at nameplate)
2ACL3	Patient - Critical	3	540	23	16,712	17,252	5,780	17,252	198%	67,890	342,180	90,050	432,230	266,140
2ENL1	Surgery - Normal	138	24,840	4	3,333	28,173	3,650	20,753	469%	71,540	367,020	93,383	460,403	281,893
2ENL2	Surgery - Normal	117	21,060	8	9,165	30,225	3,740	24,695	560%	75,280	388,080	102,548	490,628	301,588
2ENL3	Surgery - Normal	114	20,520	5	6,704	27,224	3,410	21,964	544%	78,690	408,600	109,252	517,852	318,552
2DCL1	Surgery - Critical	102	18,360	1	360	18,720	3,850	14,540	278%	82,540	426,960	109,612	536,572	328,092
2DCL2	Surgery - Critical	92	16,560	9	7,602	24,162	6,140	20,882	240%	88,680	443,520	117,214	560,734	343,974
2DCL4	Surgery - Critical	22	3,960	8	4,681	8,641	3,290	8,641	163%	91,970	447,480	121,895	569,375	350,635
2DNL2	Surgery - Normal	136	24,480	0	0	24,480	2,890	17,240	497%	94,860	471,960	121,895	593,855	362,875
2DNL3	Surgery - Normal	119	21,420	5	3,620	25,040	3,710	19,330	421%	98,570	493,380	125,515	618,895	377,205
OR-1	OR - Critical	50	9,000	13	11,302	20,302	6,420	20,302	216%	104,990	502,380	136,817	639,197	393,007
OR-4	OR - Critical	47	8,460	7	8,302	16,762	5,760	16,762	191%	110,750	510,840	145,119	655,959	405,539
3DCL3	OB - Critical	57	10,260	18	12,767	23,027	4,350	22,897	426%	115,100	521,100	157,886	678,986	423,436
3DNL1	OB - Normal	112	20,160	8	5,728	25,888	2,930	20,808	610%	118,030	541,260	163,614	704,874	439,244
3DNL3	OB - Normal	106	19,080	2	2,522	21,602	2,350	17,062	626%	120,380	560,340	166,136	726,476	451,306
3ECL2	OB - Critical	76	13,680	7	5,584	19,264	4,000	17,424	336%	124,380	574,020	171,720	745,740	463,730
3ECL3	OB - Critical	66	11,880	13	15,805	27,685	5,920	26,745	352%	130,300	585,900	187,525	773,425	485,475
3ENL2	OB - Normal	113	20,340	7	7,837	28,177	4,750	23,007	384%	135,050	606,240	195,362	801,602	503,482
3ENL3	OB - Normal	87	15,660	0	0	15,660	1,030	12,830	1146%	136,080	621,900	195,362	817,262	511,312
C-Section 1	OB - Critical	28	5,040	7	5,843	10,883	3,790	10,883	187%	139,870	626,940	201,205	828,145	519,675

		Connected Load (VA)					Measured Peak VA	NEC DEMAND LOAD	Safety Factor Above Measured Demand	Cumulative Loads				
Panel	Department	# Receps	Recep load	# CORD CONN EQP	Cord Con Load (nameplate)	Total Conn. Load, equip at nameplate		CORD CONN AT nameplate	NEC (w/ eqp at nameplate)	Measured peak demand	Recep Load	Cord Conn Load (nameplate)	Total Load (w/ eqp at nameplate)	NEC (w/ eqp at nameplate)
C-Section 2	OB - Critical	28	5,040	7	5,663	10,703	3,670	10,703	192%	143,540	631,980	206,868	838,848	527,858
BDNL1	Pharm. - Normal	97	17,460	11	10,372	27,832	2,870	24,102	740%	146,410	649,440	217,240	866,680	546,960
BDNL2	Ops/Admin - Normal	113	20,340	5	5,080	25,420	7,550	20,250	168%	153,960	669,780	222,320	892,100	562,210

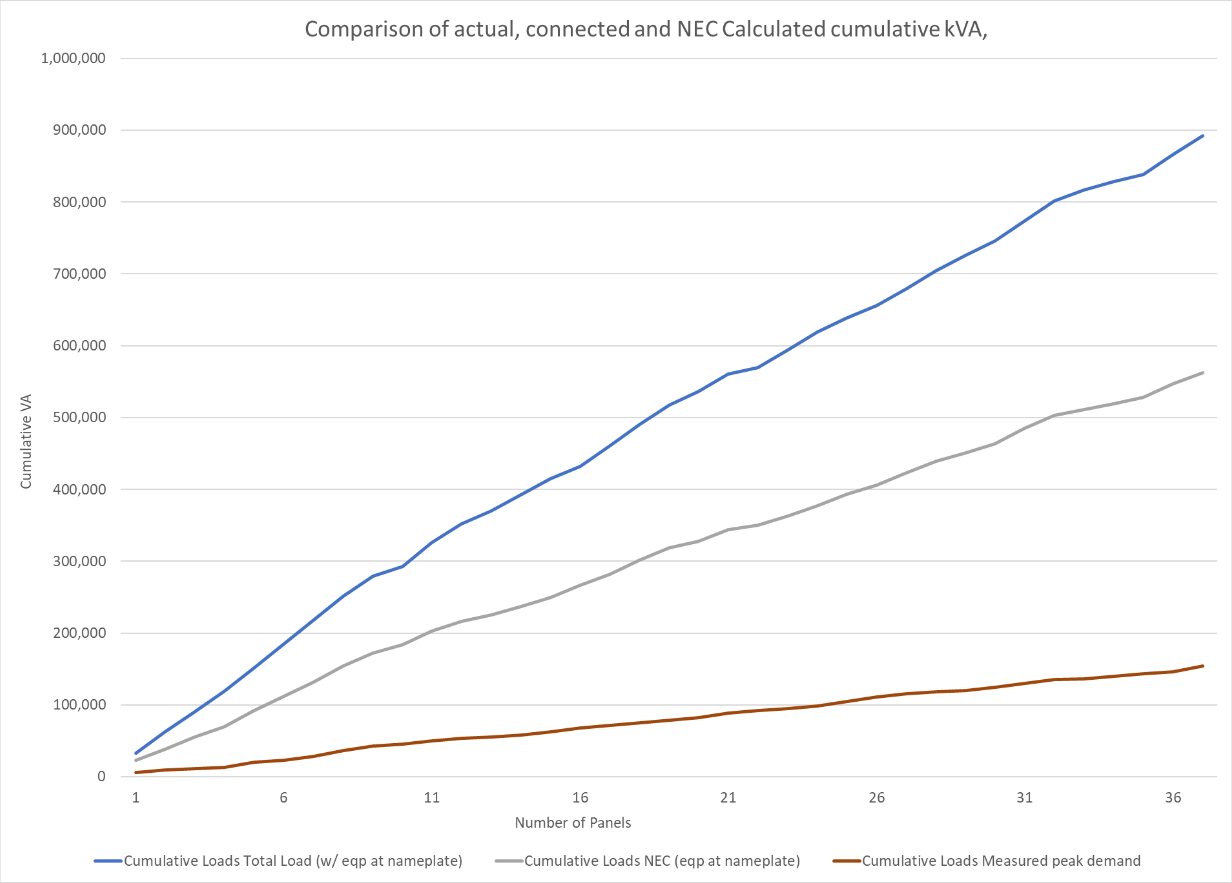


Figure 14: Comparison of calculated and actual load values at the panel level Westcoast Hospital 2