



602™

IEEE Recommended Practice for

Electric Systems in Health Care Facilities

Published by the
Institute of Electrical and
Electronics Engineers, Inc.

IEEE Std 602™-2007
(Revision of
IEEE Std 602-1996)

IEEE Std 602™-2007

(Revision of
IEEE Std 602-1996)

IEEE Recommended Practice for Electric Systems in Health Care Facilities

Sponsor

Power Systems Engineering Subcommittee
of the
Industrial and Commercial Power Systems Department
of the
IEEE Industry Applications Society

Approved 26 March 2007

IEEE-SA Standards Board

Abstract: A recommended practice for the design and operation of electric systems in health care facilities is provided. The term *health care facility* as used here encompasses buildings or parts of buildings that contain hospitals, nursing homes, residential custodial care facilities, clinics, ambulatory health care centers, and medical and dental offices. Buildings or parts of buildings within an industrial or commercial complex, used as medical facilities, logically fall within the scope of this recommended practice.

Keywords: anesthetizing, clinical, critical branch, emergency system, equipment system, essential electrical system, examination, fire alarm, ground-fault circuit-interrupter, ground-fault protection, grounding, life safety branch, medical, nurse call, patient care, recovery, safety, standby generator, surgical, transfer switch, treatment, wet location

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Copyright © 2007 by the Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 30 August 2007. Printed in the United States of America.

IEEE is a registered trademark in the U.S. Patent & Trademark Office, owned by the Institute of Electrical and Electronics Engineers, Incorporated.

BOCA is a registered trademark of Building Officials and Code Administrators International, Inc.

Leadership in Energy Efficient Design (LEED) Green Building Rating System is a registered trademark of the U.S. Green Building Commission.

National Electrical Code, NEC, NFPA Fire Protection Handbook, Life Safety Code, and National Fire Alarm Code are registered trademarks in the U.S. Patent & Trademark Office, owned by the National Fire Protection Association.

National Electrical Safety Code and NESC are both registered trademarks and service marks of the Institute of Electrical and Electronics Engineers, Inc.

Print: ISBN 0-7381-5306-0 SH95609
PDF: ISBN 0-7381-5307-9 SS95609

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

Grateful acknowledgment is made to the following for having granted permission to reprint material in this document:

Brian Prechtel Photography.

El Camino Hospital, Mountain View, CA.

John Muir/Mt. Diablo Health System, Walnut Creek, CA.

Kaiser Foundation Health Plan, Inc.

Siemens Medical Solutions USA, Inc.

Sutter Medical Center, Sacramento, CA.

IEEE Standards documents are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. The IEEE develops its standards through a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and serve without compensation. While the IEEE administers the process and establishes rules to promote fairness in the consensus development process, the IEEE does not independently evaluate, test, or verify the accuracy of any of the information contained in its standards.

Use of an IEEE Standard is wholly voluntary. The IEEE disclaims liability for any personal injury, property or other damage, of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, or reliance upon this, or any other IEEE Standard document.

The IEEE does not warrant or represent the accuracy or content of the material contained herein, and expressly disclaims any express or implied warranty, including any implied warranty of merchantability or fitness for a specific purpose, or that the use of the material contained herein is free from patent infringement. IEEE Standards documents are supplied “**AS IS.**”

The existence of an IEEE Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE Standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard. Every IEEE Standard is subjected to review at least every five years for revision or reaffirmation. When a document is more than five years old and has not been reaffirmed, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE Standard.

In publishing and making this document available, the IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity. Nor is the IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing this, and any other IEEE Standards document, should rely upon the advice of a competent professional in determining the exercise of reasonable care in any given circumstances.

Interpretations: Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretations is brought to the attention of IEEE, the Institute will initiate action to prepare appropriate responses. Since IEEE Standards represent a consensus of concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position, explanation, or interpretation of the IEEE.

Comments for revision of IEEE Standards are welcome from any interested party, regardless of membership affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Comments on standards and requests for interpretations should be addressed to:

Secretary, IEEE-SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854
USA

Authorization to photocopy portions of any individual standard for internal or personal use is granted by the Institute of Electrical and Electronics Engineers, Inc., provided that the appropriate fee is paid to Copyright Clearance Center. To arrange for payment of licensing fee, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; +1 978 750 8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Secretary, IEEE-SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854
USA

Introduction

This introduction is not part of IEEE Std 602-2007, IEEE Recommended Practice for Electric Systems in Health Care Facilities.

IEEE Std 602, known as the *IEEE White Book*TM, was last published in 1996. This version of the *White Book* updates topics and categories to 2006.

IEEE Std 602 is written primarily for the practicing electrical design engineer, who may have limited experience with health care facilities, and for hospital operating personnel. It will also be useful for those who supply products and services for health care facilities. While the text deals with a broad range of topics relevant to the design and operation of health care facilities, it focuses on those aspects of facility design and operation that are unique to health care facilities. These include patient electrical safety, patient care issues, continuity of electric service, and a reliable source of power to sensitive computer-based clinical and biomedical equipment. The text also touches on communication and alarm systems that are unique to the health care facility.

Notice to users

Errata

Errata, if any, for this and all other standards can be accessed at the following URL: <http://standards.ieee.org/reading/ieee/updates/errata/index.html>. Users are encouraged to check this URL for errata periodically.

Interpretations

Current interpretations can be accessed at the following URL: <http://standards.ieee.org/reading/ieee/interp/index.html>.

Patents

Attention is called to the possibility that implementation of this recommended practice may require use of subject matter covered by patent rights. By publication of this recommended practice, no position is taken with respect to the existence or validity of any patent rights in connection therewith. The IEEE shall not be responsible for identifying patents or patent applications for which a license may be required to implement an IEEE recommended practice or for conducting inquiries into the legal validity or scope of those patents that are brought to its attention.

Copyright © 2007 IEEE. All rights reserved.

v

Participants

Hugh O. Nash, Jr., and Walter N. Vernon were co-chairmen of this edition of the *IEEE White Book*. The following authors were responsible for the drafts of the individual chapters. Walter N. Vernon provided guidance, review, and editorial revisions to the submitted chapters. Walter N. Vernon's assistant, Matthew Kenney, was responsible for conforming the presentation of text, tables, charts, and figures to IEEE guidelines. James Harvey served as secretary.

The following members of the White Book Working Group contributed to these chapters:

Hugh O. Nash, Jr., *Co-Chair*

Walter N. Vernon, *Co-Chair*

Chapter 1: Overview—**Hugh O. Nash, Jr.,** *Chair*

Chapter 2: Electrical loads—**Walter N. Vernon,** *Chair*; Adrienne Hendrickson, Marty Kobaly

Chapter 3: Electrical power distribution systems—**Matt Dozier,** *Chair*; Edgar Galyon, James Harvey, Philip Keebler, James E. Meade, Ron Wilson

Chapter 4: Electrical power systems for delivering patient care—**David Stymiest,** *Chair*; Bill Bonn, Jason D'Antona, Jan Ehrenwerth, Phil Janeway, Philip Keebler, Leilani Kicklighter, Paul Konz, Neil McGrath, David Norton, Cornelius Regan, Walter N. Vernon, Gerald W. "Jerry" Williams

Chapter 5: Emergency power systems—**Herbert Daugherty,** *Chair*; Lawrence Bey, Bill Bonn, Mark Halpin, James Iverson, James E. Meade, David Norton, Jeffrey Steplowski, Walter N. Vernon, Herbert Whittall

Chapter 6: Lighting—**Jeffrey N. Losnegard,** *Chair*; Rebecca Boulter, Anthony J. Denami, Mary Claire Frazier, Beverley K. Shimmin, Eric Strandberg

Chapter 7: Communications systems—**James R. Duncan,** *Chair*; Spencer L. Bahner, Gregory S. Batie, Carl Cox, Robert J. Eastman, Steven Goegebuer, Nathan T. Larmore, Thomas A. Leonidas, Jr., Brady A. McCoy, Terry Miller, Thomas O. Moore, Scott P. Roberts, Walter N. Vernon, Bill Van Vlack, David F. Zehrung

Chapter 8: Medical equipment instrumentation—**Walter N. Vernon,** *Chair*; Tony Freitas, Rich Fries, Nazrul Islam, Philip Keebler, Paul King, Bill Rostenberg, Bogue Waller

Chapter 9: Health care renovations—**Walter N. Vernon,** *Chair*; Edgar Galyon, James Harvey, William R. Jennings, Jr., Mark Sapphire

The following members of the individual balloting committee voted on this recommended practice. Balloters may have voted for approval, disapproval, or abstention.

Satish K. Aggarwal	Sourav K. Dutta	Michael S. Newman
Ali Al Awazi	Gary R. Engmann	Gregory L. Olson
Wallace B. Binder, Jr.	Dan Evans	Lorraine K. Padden
Michael J. Bio	Carl J. Fredericks	Joshua S. Park
Stuart H. Bouchey	Randall C. Groves	Ralph E. Patterson
William A. Byrd	Nancy M. Gunderson	Howard W. Penrose
Thomas P. Callsen	Ajit K. Gwal	Edward P. Rafter
Juan C. Carreon	Werner Hoelzl	Charles W. Rogers
Keith Chow	Dennis Horwitz	Randall M. Safier
Donald M. Colaberdardino	Jim Kulchisky	Vincent Saporita
Bryan R. Cole	Saumen K. Kundu	Peter E. Sutherland
Tommy P. Cooper	Blane Leuschner	S. Thamilarasan
Stephen Dare	William Lumpkins	Raul Velazquez
F. A. Denbrock	G. L. Luri	Walter N. Vernon
Carlo Donati	Faramarz Maghsoodlou	James L. Wiseman
Gary L. Donner	Keith N. Malmedal	Donald W. Zipse
Neal B. Dowling, Jr.	Mark F. McGranaghan	Ahmed F. Zobaa
	Gary L. Michel	

When the IEEE-SA Standards Board approved this recommended practice on 26 March 2007, it had the following membership:

Steve M. Mills, *Chair*
Robert M. Gown, *Vice Chair*
Don Wright, *Past Chair*
Judith Gorman, *Secretary*

Richard DeBlasio	Richard H. Hulett	Narayanan Ramachandran
Alex Gelman	Hermann Koch	Greg Ratta
William R. Goldbach	Joseph L. Koepfinger*	Robby Robson
Arnold M. Greenspan	John Kulick	Anne-Marie Sahazizian
Joanna N. Guenin	David J. Law	Virginia C. Sulzberger*
Julian Forster*	Glenn Parsons	Malcolm V. Thaden
Kenneth S. Hanus	Ronald C. Petersen	Richard L. Townsend
William B. Hopf	Tom A. Prevost	Howard L. Wolfman

*Member Emeritus

Also included are the following nonvoting IEEE-SA Standards Board liaisons:

Satish K. Aggarwal, *NRC Representative*
Alan H. Cookson, *NIST Representative*

Jennie Steinhagen
IEEE Standards Project Editor

Patricia A. Gerdon
IEEE Standards Program Manager, Technical Program Development

Contents

Chapter 1	
Overview	1
1.1 Scope.....	1
1.2 Health care facilities	1
1.3 Professional registration.....	2
1.4 Codes and standards.....	3
1.5 Manufacturers' data	5
1.6 Safety	5
1.7 Appliances and equipment.....	7
1.8 Operational considerations.....	7
1.9 Maintenance	8
1.10 Design considerations	9
1.11 Other considerations	10
1.12 Normative references	10
1.13 Bibliography	12
Chapter 2	
Electrical loads.....	15
2.1 General discussion	15
2.2 Obtaining load data	21
2.3 Using load data to design health care facilities.....	23
2.4 Using load data to manage energy costs	41
2.5 Load management funding mechanisms.....	67
2.6 Normative references	67
2.7 Bibliography	69
Annex 2A (informative) Sutter general loads	73
Annex 2B (informative) Kaiser Roseville Medical Center continuous electrical demand profile (summer 2001)	78
Chapter 3	
Electrical power distribution systems	95
3.1 General discussion	95
3.2 Systems planning	96
3.3 Electrical power systems basics.....	100
3.4 Voltage considerations.....	102
3.5 Current considerations	106
3.6 Grounding	107
3.7 System protection and coordination.....	111
3.8 Electrical equipment selection, installation, and testing.....	123
3.9 System arrangements	130
3.10 Normative references	138
3.11 Bibliography	140

Chapter 4	
Electrical power systems for delivering patient care	143
4.1 Overview	143
4.2 Definitions.....	143
4.3 Electrical system safety.....	143
4.4 Delivering power to the caregivers and their patients	163
4.5 Normative references	181
4.6 Bibliography	182
Chapter 5	
Emergency power systems.....	183
5.1 Overview	183
5.2 Definitions.....	183
5.3 Generator sets.....	183
5.4 Generator system accessories	188
5.5 Transfer switches	210
5.6 Uninterruptible power supply systems.....	215
5.7 Transfer considerations for types of loads	219
5.8 Elevator loads.....	224
5.9 Engine-generator controls	227
5.10 Maintenance	251
5.11 Normative references	252
5.12 Bibliography	253
Chapter 6	
Lighting	255
6.1 General discussion	255
6.2 Lighting design for hospitals	256
6.3 Hospital lighting applications	259
6.4 Considerations in lighting system design	264
6.5 Normative references	268
6.6 Bibliography	269
Chapter 7	
Communication systems	271
7.1 System design considerations	271
7.2 Telecommunications infrastructure	276
7.3 Wireless networks	289
7.4 Network switching platforms.....	297
7.5 Telephone systems	306
7.6 Intercom systems	317
7.7 Nurse-call and code systems.....	320
7.8 Radio communication systems	334
7.9 Paging systems.....	340
7.10 Physician and staff register systems	352
7.11 Dictation systems	356
7.12 Patient physiological monitoring systems	359

7.13 Picture archiving and communication system	362
7.14 Emergency medical service communications	363
7.15 Clocks	366
7.16 Fire alarm system	369
7.17 Security systems.....	381
7.18 Facility monitoring.....	384
7.19 Television systems	387
7.20 Sound reinforcement systems	394
7.21 Disaster alarm systems.....	398
7.22 Normative references	399
7.23 Bibliography	400
Chapter 8	
Medical equipment and instrumentation.....	403
8.1 Overview	403
8.2 Definitions.....	403
8.3 Trends in medical equipment evolution.....	404
8.4 General electrical considerations for medical equipment.....	405
8.5 Description of certain kinds of medical equipment	410
8.6 Normative references	448
8.7 Bibliography	448
Chapter 9	
Health care renovations.....	451
9.1 Overview	451
9.2 Coordination	453
9.3 Loads and energy management.....	457
9.4 Electrical power distribution system.....	458
9.5 Emergency power systems.....	459
9.6 Planning for patient care	461
9.7 Lighting.....	464
9.8 Communication and signal systems.....	465
9.9 Medical equipment and instrumentation.....	470
9.10 Preparing for renovations.....	471
9.11 Normative references	471
9.12 Bibliography	471
Index	473

IEEE Recommended Practice for Electric Systems in Health Care Facilities

Chapter 1 Overview

1.1 Scope

IEEE Std 602, commonly known as the *IEEE White Book*[™], is published by the Institute of Electrical and Electronics Engineers (IEEE) to provide a recommended practice for the design and operation of electric systems in health care facilities. It has been prepared on a voluntary basis by design engineers and health care end users as well as electrical and medical manufacturers functioning as the White Book Working Group within the Power Systems Design Subcommittee of the Power Systems Engineering Subcommittee.

This recommended practice will probably be of greatest value to the power oriented engineer with limited health care experience. It can also be an aid to all engineers responsible for the electrical design of health care facilities. However, it is not intended as a replacement for the many excellent engineering texts and handbooks commonly in use, nor is it detailed enough to be a design manual. It should be considered a guide and a general reference on electrical design for health care facilities.

1.2 Health care facilities

The term *health care facility*, as used here, encompasses buildings or parts of buildings that contain hospitals, nursing homes, residential custodial care facilities, clinics, and medical and dental offices. Buildings or parts of buildings within an industrial or commercial complex, used as medical facilities, logically fall within the scope of this book. Thus the specific use of the building in question, rather than the nature of the overall development of which it is a part, determines its electric design category.

Today's health care facilities, because of their increasing size and complexity, have become more and more dependent upon safe, adequate, and reliable electrical systems. Every day new types of sophisticated diagnostic and treatment equipment, utilizing microprocessors or computers, come on the market. Many of these items are sensitive to

electrical disturbances and some require a very reliable power source. Invasive medical procedures such as cardiac catheterization make electrical safety extremely important. Moreover, new medical and surgical procedures are constantly being developed, and new technologies are being utilized. Modern facilities use robotics, telemedicine, picture archiving and communications systems (PACS), and the mixing of diagnostic and treatment modalities (i.e., surgical procedures combined with various types of medical imaging). In addition to the special safety and reliability requirements, health care facilities have unique life safety and communication requirements, because patients are generally unable to care for themselves or evacuate in the event of an emergency. For these reasons, perhaps no area of design or construction is changing as fast as health care facilities.

1.2.1 Industry Applications Society

The IEEE is divided into 42 societies that specialize in various technical areas of electrical engineering. Each group or society conducts meetings and publishes papers on developments within its specialized area. The Industry Applications Society (IAS) presently encompasses 18 technical committees covering electrical engineering in specific areas (petroleum and chemical industry, cement industry, glass industry, industrial and commercial power systems, and others). The Power Systems Engineering Subcommittee, which has responsibility for the White Book Working Group, is part of the Industrial and Commercial Power Systems Department of the IAS. Papers of interest to electrical engineers and designers involved in the field covered by the *IEEE White Book* are, for the most part, contained in the *IEEE Transactions on Industry Applications* of the IAS. The IAS also publishes the *IEEE Industry Applications Magazine*, which reports on the development and application of electrical systems, apparatus, devices, and controls to the processes and equipment of industry and commerce; the promotion of safe, reliable, and economic installations; the encouragement of energy conservation; and the creation of voluntary engineering standards and recommended practices.

1.2.2 Engineering in Medicine and Biology Society

Another IEEE group of interest to the electrical engineer involved in health care facility design is the Engineering in Medicine and Biology Society (EMBS). The *IEEE Transactions on Biomedical Engineering*¹ and the *IEEE Engineering in Medicine and Biology Magazine* include articles on the physiological effects of electrical shock and other subjects pertinent to electrical safety. Articles dealing with electrical equipment and instrumentation also appear in *IEEE Transactions on Biomedical Engineering*.

1.3 Professional registration

Most regulatory agencies require that design for public buildings be prepared by state-licensed professional architects or engineers. Information on such registration may be obtained from the appropriate state agency or from the National Council of Examiners for Engineering and Surveying (NCEES). The NCEES offers engineering registration, and

¹Information on references can be found in 1.12.

this registration helps in obtaining registration in the various states through reciprocity. All engineering graduates are encouraged to start on the path to full registration by taking the engineer-in-training examination as soon after graduation as possible. The final written examination in the field of specialization is usually conducted after 4 years of progressive professional experience.

Clinical engineering certification is available through an international commission. When possible, the hospital's clinical engineer should be involved in the electrical design process.

1.4 Codes and standards

1.4.1 National Electrical Code® and other NFPA standards

The electrical wiring and design requirements in the National Electrical Code® (NEC®) (NFPA 70) are vitally important guidelines for health care facility engineers. Article 517 of the NEC deals exclusively with installation criteria for health care facilities. The NEC is revised every 3 years, and care should be taken to use the edition that is current and adopted by the authority having jurisdiction (AHJ) for enforcement at the time of construction. The NEC is published and available from the National Fire Protection Association (NFPA). It does not represent a design specification, but only identifies minimum requirements for the safe installation and utilization of electricity on the premises. The introduction to the NEC, Article 90, covers purpose and scope, and describes the AHJ's role in interpreting and enforcing the code. The *National Electrical Code® Handbook*, published by the NFPA, contains the complete NEC text plus explanations. This book is edited to correspond with each edition of the NEC.

NFPA 99 addresses performance and testing criteria for electric systems in health care facilities as well as requirements for medical gas systems; heating, ventilation, and air conditioning systems; laboratories; emergency management; and other topics of interest to health care designers. Approximately two thirds of NEC Article 517 is extracted from NFPA 99. The *Health Care Facilities Handbook* [B2],² published by NFPA, contains the entire NFPA 99 text as well as comments and explanatory material. The book is published on a 3-year cycle to correspond with each edition of NFPA 99.

The NEC and other selected NFPA codes are generally adopted by local and state governments for enforcement by electrical and building inspectors and fire marshals.

1.4.2 Health care codes and standards

Additional electrical requirements for health care facilities are included in the *Accreditation Manual for Hospitals*, published by the Joint Commission, formerly the Joint Commission for the Accreditation of Healthcare Organizations (JCAHO). Hospitals seeking Joint Commission accreditation must undergo periodic inspection by their

²The numbers in brackets correspond to those of the bibliography in 1.13.

examiners. Accreditation depends on the hospital's conformance with the requirements included in the accreditation manual.

The Department of Health and Human Services formerly published a standard entitled Minimum Requirements for Construction and Equipment of Hospitals and Medical Facilities and enforced it on a national basis. The American Institute of Architects (AIA) obtained the copyright in 1987 and produced a revision called the Guidelines for Construction and Equipment of Hospitals and Medical Facilities. AIA revised the document in 1992–1993, 1996–1997, and again in 2001 as the Guidelines for Design and Construction of Hospital and Health Care Facilities; the 2006 update is called Guidelines for Design and Construction of Health Care Facilities. The Facilities Guidelines Institute (FGI), a non-profit corporation, was formed in 1998 for the purpose of continuing the publication of the Guidelines. FGI, which now owns the intellectual property, published the 2001 Edition with the cooperation of the AIA and the assistance of the U.S. Department of Health and Human Services. More than 40 states use some portion of this document as their model code for health care facilities.

Electrical designers working on projects for the Department of Veterans Affairs, Department of Defense, the General Services Administration, Public Buildings Service, and other government agencies must be aware that these agencies generally publish standards for electrical design. These standards or guidelines can be obtained from the appropriate agency.

1.4.3 Local, state, and federal codes and regulations

While most municipalities, counties, and states use the NEC without change, some have their own codes. In some instances the NEC is adopted by local ordinance as part of the building code, with deviations from the NEC listed as addenda. It is important to note that only the code adopted as of a certain date is official, and that governmental bodies may delay adopting the latest code. Federal rulings may require use of the latest NEC regardless of local rulings, so that reference to the enforcing agencies for interpretation on this point may be necessary.

Some city and state codes are almost as extensive as the NEC. It is generally accepted that in the case of conflict, the more stringent or severe interpretation applies. Generally the entity responsible for enforcing the code has the power to interpret it.

Failure to comply with NEC or local code requirements can affect the owner's ability to obtain a certificate of occupancy and may have a negative effect on insurance.

In most states, health care construction comes under the jurisdiction of a state health department. In some instances the state will have its own hospital or health care code with specific electrical requirements.

Both state and local authorities may adopt and enforce one of the model building codes written by a regional building officials group.

Legislation by the federal government has had the effect of giving standards, such as certain American National Standards Institute (ANSI) standards, the impact of law. The Occupational Safety and Health Act, administered by the U.S. Department of Labor, permits federal enforcement of codes and standards. The Occupational Safety and Health Administration (OSHA) has adopted the 1971 NEC for new electrical installations and also for major replacements, modifications, or repairs installed after 5 March 1972. A few articles and sections of the NEC have been deemed to apply retroactively by OSHA. The NFPA created the NFPA 70E Committee to prepare a consensus standard for possible use by OSHA in developing their standards. Major portions of NFPA 70E have been included in OSHA regulations.

The U.S. Department of Energy (DOE), by encouraging building energy performance standards, has advanced energy conservation standards. A number of states have enacted energy conservation regulations. These include legislation embodying various energy conservation standards such as ASHRAE/IESNA 90.1, which establishes energy or power budgets that materially affect architectural, mechanical, and electrical designs.

1.4.4 Standards and recommended practices

A number of organizations in addition to the NFPA publish documents that affect electrical design. Adherence to these documents can be written into design specifications.

ANSI approves the standards of many other organizations. ANSI coordinates the review of proposed standards among all interested affiliated societies and organizations to ensure a consensus approval. It is in effect a clearinghouse for technical standards of all types.

Underwriters Laboratories, Inc. (UL) is a non-profit organization, operating laboratories for investigation with respect to hazards affecting life and property, materials and products, and especially electrical appliances and equipment. In so doing, they develop test standards. Equipment that has been tested by UL or other nationally recognized testing organizations (NRTL) (e.g., OSHA), and found to conform to their standards, is known as *listed* or *labeled* equipment. UL lists, for example, nurse-call systems (UL 1069-2006 [B13]).

1.5 Manufacturers' data

The electrical industry, through its associations and individual manufacturers of electrical equipment, issues many technical bulletins, data books, and magazines. Manufacturer's catalogs and specification guides are a valuable source of equipment information. Some manufacturers' complete catalogs are quite extensive covering several volumes. However, these companies may issue condensed catalogs for general use. In recent years most manufacturers have begun to provide complete catalog and product information online.

Manufacturers of specialized hospital electrical equipment often publish design and installation recommendations and technical updates. This is particularly true of isolation panel, standby generator, and transfer switch manufacturers.

1.6 Safety

Safety of life and preservation of property are two of the most important factors in the design of the electrical system. This is especially true in health care facilities because of public occupancy, thoroughfare, high-occupancy density, and patients—some of them in serious or critical condition. In some small and rural health care facilities the operating staff may have limited technical knowledge and, perhaps, no specific electrical training.

Various codes provide rules and regulations as minimum safeguards of life and property. The electrical design engineer often needs to provide greater safeguards than outlined in the codes according to his best judgment, while also giving consideration to utilization and economics.

Electrical safety may be divided into the following five categories:

- a) Safety for maintenance and operating personnel
- b) Safety for staff, employees, and the general public
- c) Safety for general care patients
- d) Safety for critical care patients
- e) Safety for patients and staff in wet locations

Safety for maintenance and operating personnel is achieved through proper design and selection of equipment with regard to enclosures, key-interlocking, circuit breaker and fuse interrupting capacity, the use of high-speed fault-detection and circuit-opening devices, clearances from structural members, grounding methods, disconnecting means, and identification of equipment. Adequate lighting in electrical rooms and around electrical equipment is important to personnel safety.

Safety for the general public requires that all circuit making and breaking equipment as well as other electrical apparatus be isolated from casual contact. This is achieved by using locked rooms and enclosures, proper grounding, limiting of fault levels, installation of barriers and other isolation, proper clearances, adequate insulation, and other similar provisions outlined in this recommended practice. Only authorized personnel should have access to electrical equipment.

Safety for general patients requires all of the design features used for protecting the general public as well as special provisions to minimize potential differences between any two conducting surfaces likely to come in contact with the patient directly or indirectly. Green ground conductors, installed in metallic conduit with the power conductors, ensure that potential differences are below 20 mV when first installed. Potential differences in general patient care areas are required to be maintained below 500 mV under normal conditions. Potential differences in critical care areas must be kept below 40 mV under normal conditions. However, the designer must be aware that even with properly sized and installed ground conductors, higher potential differences can be generated during fault conditions. Other special protective systems such as ground-fault circuit-interrupter (GFCI) receptacles or isolation transformers are used in wet locations to protect patients

and staff and in critical care areas to protect catheterized patients from electric shock through an exposed catheter.

Although flammable anesthetics (like ether) are no longer used in the U.S., they are still popular in some foreign countries. Where flammable anesthesia is used, isolation transformers and a properly grounded conductive floor shall be provided. All wiring in the hazardous area must be installed as required for Class 1 Division 1 locations.

The National Electrical Safety Code® (NESC®) (Accredited Standards Committee C2-2007) [B1] is available from the IEEE. It covers outdoor distribution systems, supply and communications systems, overhead lines, high-voltage systems, and other items related to the supply of building power.

Circuit protection is a fundamental safety requirement of all electrical systems. Adequate interrupting capacities are required in services, feeders, and branch circuits. Selective, automatic isolation of faulted circuits represents good engineering. Tripping schemes for the emergency system must be selective, so that faults on adjacent branches or systems or faults on the emergency system itself do not disrupt service to unaffected emergency system circuits—especially if interruption of these circuits can jeopardize the lives or safety of patients. Physical protection of wiring by means of approved raceways under all probable conditions of exposure to electrical, chemical, and mechanical damage is necessary. In health care facilities the applicable codes require redundant grounding for circuits in patient care areas and special provisions for the physical protection of circuits on emergency systems.

Spare or oversized raceways, spare conductors, and pull wires should be considered for future use. The design engineer should locate equipment where suitable ambient temperatures exist and ventilation is available. The operation of fault-detection and circuit-interruption devices under conditions of abnormal voltage and frequency should be ensured.

1.7 Appliances and equipment

Improperly applied or inferior materials can cause electrical failures. The proper use of appliances and equipment listed by UL or other NLRT is recommended. The Association of Home Appliance Manufacturers (AHAM) and the Air-Conditioning and Refrigeration Institute (ARI) specify the manufacture, testing, and application of many common appliances and equipment.

Medium-voltage equipment should be specified to be manufactured in accordance with the National Electrical Manufacturers Association (NEMA), ANSI, and IEEE standards, and the engineer should make sure that the equipment specified conforms to these standards. Properly prepared specifications can prevent the purchase of inferior or unsuitable equipment. The lowest initial purchase price may not result in the lowest cost after taking into consideration operating, maintenance, and owning costs. Value engineering is an organized approach to identification of unnecessary costs; it utilizes such methods as life cycles, cost analyses, and related techniques.

1.8 Operational considerations

When the design engineer plans electrical equipment rooms and locates electrical devices, there may be areas accessible to unqualified persons due to limited space. Dead-front construction and ANSI/NEMA Category A type construction should be utilized whenever practical. Where dead-front construction is not available, all exposed electrical equipment should be placed behind locked doors or gates. This will result in a reduction in electrical failures caused by human error, as well as improved safety.

A serious cause of failure, which is attributable to human error, is unintentional grounding or phase-to-phase short-circuiting of equipment that is being worked upon. By careful design such as proper spacing, barriers, and padlocking, and by enforcement of published work-safety rules, the engineer can minimize unintentional grounding and phase-to-phase, and ground faults in the distribution equipment. High-quality workmanship is an important factor in the prevention of electrical failures. Therefore, the design should incorporate features that are conducive to good workmanship.

Selective coordination of overcurrent devices is important in health care facilities, especially for critical care areas. The system must be studied for both high- and low-level faults. It is therefore important to consider the different levels of available short-circuit current available from utility and standby sources. The selection and coordination of overcurrent protective devices (OCPDs) should take into consideration protection, selectivity, the nature of the circuits (critical or non-critical), and the project budget.

Ground-fault protection schemes on large service mains on wye-grounded 480 V systems will help to minimize damage from arcing ground faults. Arcing ground faults or *burn-downs* can cause total destruction of electrical equipment, jeopardizing patient safety by fire and loss of electrical service. By providing one or more additional steps of ground-fault protection downstream, designers can ensure that otherwise harmless ground faults (such as in the powerhouse or kitchen) will not cause an outage of the hospital main or patient care areas of the hospital. Ground-fault systems should be tested for selective tripping to ensure proper and safe operation per the NEC.

1.9 Maintenance

Maintenance is essential to proper operation. The installation should be so designed that building personnel can perform most of the maintenance with a minimum need for specialized services. Design details should provide proper space and accessibility so that equipment can be maintained without difficulty and excessive cost.

The engineer should consider the effects of a failure in the system supplying the building. Generally, the external systems are operated and maintained by the electrical utility, though at times they are a part of the health care facility distribution system.

In health care facilities where continuity of service is essential, suitable emergency and standby equipment should be provided. Such equipment is needed to maintain minimum lighting requirements for passageways, stairways, and to supply power to critical patient

care areas and essential loads. These systems are usually installed within the building, and they include automatic or manual equipment for transferring loads on loss of normal supply power or for putting battery- or generator-supplied equipment into service.

Although applicable codes determine the need for standby or emergency generating systems in health care facilities, they are generally required in any facility that keeps acutely ill patients overnight, performs invasive procedures, administers anesthesia, has critical patient care areas, or otherwise treats patients unable to care for themselves during an emergency. High-rise health care facilities, regardless of type, should have on-site emergency or standby generators. Periodic testing and exercising of standby generators is essential to system reliability.

Electrical engineers should consider the installation of bypass/isolation switches in conjunction with automatic transfer switches (ATSSs) to permit maintenance on a de-energized transfer switch without jeopardizing patient safety. The isolation/bypass switch permits removal of the transfer switch from the circuit while providing for manual transfer to the normal or emergency source.

Even with isolation/bypass switches, it is possible for a load-side circuit breaker to fail, causing loss of power to all or part of the critical branch. For this reason it is recommended to provide some normal circuits in critical patient care areas per the NEC.

1.10 Design considerations

Electrical equipment usually occupies a relatively small percentage of the total building space, and in design it may be easier to relocate electrical service areas than mechanical areas or structural elements. Allocation of space for electrical areas is often given secondary consideration by architectural and related specialties. In the competing search for space, the electrical engineer is responsible for fulfilling the requirements for a proper electrical installation while at the same time recognizing the flexibility of electrical systems in terms of layout and placement.

Today, architectural considerations and appearances are of paramount importance in the design of a health care facility. Aesthetic considerations may play an important role in the selection of equipment, especially lighting equipment. Provided that the dictates of good practice, code requirements, and environmental considerations are not violated, the electrical engineer may have to compromise the design to accommodate the needs of other members of the design team.

The electrical engineer should work closely with professional associates, such as the architect, the mechanical engineer, the structural engineer, and the civil engineer. There is also concern with the building owner or operator who, as clients, may take an active interest in the design. More often the electrical engineer will work directly with the coordinator of overall design activities, usually the architect. Cooperation with the safety engineer, fire protection engineer, the environmental engineer, and other concerned people, such as interior designers, all of whom have a say in the ultimate design, is essential.

The electrical designer should become familiar with local rules and know the AHJs over the design and construction. The designer should always contact the AHJs and all applicable utilities before beginning design. Local contractors are usually familiar with local ordinances and union work rules and can be of great help. Union work practices may, for reasons of safety or other considerations, discourage the use of certain materials and techniques.

In performing electrical design, it is essential, at the outset, to prepare a checklist of all the design stages that have to be considered. Major items include temporary power, access to the site, and review by others. It is important to note that certain electrical work may appear in nonelectrical sections of the specifications. For example, furnishing and connecting of electric motors and controls may be covered in the mechanical section of the specifications. Another notable example would be elevators, which are usually specified by the architect. The electrical engineer should insist that the proper starter, fireman's recall system, and emergency sequencing of elevators are specified.

Electrical engineers working on health care projects should have a working knowledge of medical gas systems because medical gas outlets often share consoles and headwalls that appear in the electrical specifications. The electrical engineer also should be familiar with medical gas alarm systems.

For administrative control purposes, the electrical work may be divided into a number of contracts, some of which may be under the control of a general contractor and some of which may be awarded to electrical contractors. Among items with which the electrical designer will be concerned are preliminary cost estimates, final cost estimates, plans or drawings, specifications (which are the written presentation of the work), materials, manuals, factory inspections, laboratory tests, and temporary lighting and power. The electrical engineer may well be involved in providing information on how electrical considerations affect financial justification of the project in terms of owning and operating costs, amortization, return on investment, and related items.

1.11 Other considerations

Those involved in the design of health care facilities should understand the process by which drawings are issued for bidding and construction. The designer should also have some knowledge of shop drawing review, estimating, and contract administration.

Design and construction of health care facilities are a team process involving engineers, architects, construction managers, general contractors, estimators, subcontractors and equipment vendors. In recent years the contractors and construction managers have become increasingly involved in the design process. In order to successfully complete a health care project, it is important to involve contractors who have a successful track record in health care construction. The larger and more complex the project the more important it is to have contractors who are skilled and experienced in the specialized construction techniques required for medical facilities.

1.12 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ASHRAE/IESNA 90.1, Energy Standard for Buildings Except Low-Rise Residential Buildings (ANSI).³

Guidelines for Design and Construction of Health Care Facilities.⁴

Joint Commission, *Accreditation Manual for Hospitals*.⁵

NFPA 20, Standard for the Installation of Stationary Pumps for Fire Protection.⁶

NFPA 53, Recommended Practice on Materials, Equipment, and Systems Used in Oxygen-Enriched Atmospheres.

NFPA 70, National Electrical Code® (NEC®).

NFPA 70B, Recommended Practice for Electrical Equipment Maintenance.

NFPA 70E, Electrical Safety in the Workplace.

NFPA 72, National Fire Alarm Code®.

NFPA 75, Standard for the Protection of Electronic Computer/Data Processing Equipment.

NFPA 77, Recommended Practice on Static Electricity.

NFPA 99, Standard for Health Care Facilities.

NFPA 101, Life Safety Code®.

NFPA 101, Life Safety Code® Handbook.

NFPA 110, Standard for Emergency and Standby Power Systems.

³ASHRAE publications are available from the Customer Service Department, American Society of Heating, Refrigerating and Air Conditioning Engineers, 1791 Tullie Circle, NE, Atlanta, GA 30329, USA (<http://www.ashrae.org/>).

⁴The current edition of the Guidelines is available from the American Institute of Architects Academy of Architecture for Health, 1735 New York Ave., N.W. Washington, DC 20006 (http://www.aia.org/aah_gd_hospcons).

⁵Joint Commission standards and manuals can be obtained from the Joint Commission, One Renaissance Blvd., Oakbrook Terrace, IL 60181 (<http://www.jcrlinc.com/77/>).

⁶NFPA publications are available from Publications Sales, National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101, USA (<http://www.nfpa.org/>).

NFPA 111, Standard on Stored Electrical Energy Emergency and Standby Power Systems.

NFPA 780, Standard for the Installation of Lightning Protection Systems.

NFPA Fire Protection Handbook™.

29 CFR 1910, Occupational Safety and Health Standards, Occupational Safety and Health Administration.⁷

1.12.1 Periodicals

IEEE Transactions on Biomedical Engineering.⁸

IEEE Engineering in Medicine and Biology Magazine.⁹

1.13 Bibliography

Additional information may be found in the following sources:

[B1] Accredited Standards Committee C2-2007, National Electrical Safety Code® (NESC®).¹⁰

[B2] *Health Care Facilities Handbook*, 2005 Edition.¹¹

[B3] IEEE Std 141™-1993, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (*IEEE Red Book*™).^{12, 13}

[B4] IEEE Std 142™-1992, IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (*IEEE Green Book*™).

[B5] IEEE Std 241™-1990, IEEE Recommended Practice for Electric Power Systems in Commercial Buildings (*IEEE Gray Book*™).¹⁴

⁷CFR publications are available from the Superintendent of Documents, U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20013-7082, USA (<http://www.access.gpo.gov/>).

⁸*IEEE Transactions on Biomedical Engineering* is available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://www.embs.org/pubs.html>).

⁹*IEEE Engineering in Medicine and Biology Magazine* is available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://www.ieee.org/organizations/pubs/magazines/emb.htm>).

¹⁰The NESC is available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).

¹¹See footnote 5.

¹²IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).

¹³The IEEE standards or products referred to in this subclause are trademarks of the Institute of Electrical and Electronics Engineers, Inc.

[B6] IEEE Std 242™-2001, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (*IEEE Buff Book™*).

[B7] IEEE Std 399™-1997, IEEE Recommended Practice for Industrial and Commercial Power Systems Analysis (*IEEE Brown Book™*).

[B8] IEEE Std 446™-1995, IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (*IEEE Orange Book™*).

[B9] IEEE Std 493™-2007, IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (*IEEE Gold Book™*).

[B10] IEEE Std 739™-1995, IEEE Recommended Practice for Energy Management in Industrial and Commercial Facilities (*IEEE Bronze Book™*).

[B11] IEEE Std 1100™-2005, IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment (*IEEE Emerald Book™*).

[B12] National Electrical Code® Handbook (NFPA 70), 2005 Edition.

[B13] UL 1069-2006, Hospital Signaling and Nurse Call Equipment.¹⁵

1.13.1 Periodicals

[B14] *ASHRAE Journal*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, 1791 Tullie Circle NE, Atlanta, GA 30329.

[B15] *Consulting-Specifying Engineer*, 2000 Clearwater Dr., Chicago, IL 60523.

[B16] *Electrical Construction and Maintenance*, 900 Metcalf Ave., Overland Park, KS 66212.

[B17] *Engineering Times*, National Society of Professional Engineers, 1420 King Street, Alexandria, VA 22314.

[B18] *Health Facilities Management*, Health Forum, Inc., One North Franklin St., 28th Floor, Chicago, IL 60606.

[B19] *Hospitals & Health Networks*, Health Forums Inc., One North Franklin, Chicago, IL 60606.

¹⁴The *IEEE Gray Book™* will be of particular importance as a reference book to the hospital designer because of the many similarities between commercial buildings and health care facilities. Health care facilities typically have kitchens, dining areas, business offices, computer rooms, and central energy plants similar to commercial buildings. Moreover, medical outpatient facilities routinely exist in office buildings, shopping malls, and strip shopping centers.

¹⁵UL standards are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (<http://global.ihs.com/>).

[B20] *IAWT News*, International Association of Electrical Inspectors, 901 Waterfall Way, Suite 602, Richardson, TX 75080-7702.

[B21] *Journal of Clinical Engineering*, Ovid Technologies, 100 River Ridge Dr., Norwood, MA 02062.

[B22] *LD+A*, Illuminating Engineering Society of North America, 120 Wall St., 17th Floor, New York, NY 10005.

[B23] *Modern Healthcare*, 360 N. Michigan Ave., 5th Floor, Chicago, IL 60601-3806.

[B24] *Neta World*, published by the International Electrical Testing Association, P.O. Box 687, Morrison, CO 80465.

[B25] *NFPA Journal*, National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

[B26] *Plant Engineering*, 2000 Clearwater Dr., Oak Brook, IL 60523.

Chapter 2

Electrical loads

2.1 General discussion

Engineers should pay attention to health facility electrical loads for at least two reasons. First, engineers designing health care facilities should understand the nature of health care electrical system loads in order to coordinate the demand on the system with the relevant codes and standards to produce a system design that meets the needs of the project owner. Second, engineers designing and managing health care facilities should understand the costs that will be imposed on the owner of the electrical system as a result of the electrical system loads and the nature of the energy procurement process in order to select the optimal combination of systems and devices.

2.1.1 Overview

This chapter has two goals. First, the chapter will look at ways to understand and predict electrical loads for health care facilities. The goal for this subclause is to assist the engineer designing a hospital to size various system elements. Second, the chapter will summarize some of the options for procuring, generating/storing/distributing, and consuming electrical energy with the goal of assisting the engineer to optimize system design and operation to minimize energy consumption and costs.

2.1.2 Groups of loads

The cumulative effect of groups of individual loads is one of the determinants of distribution system design. Facility loads can be understood in a number of ways. First, the loads can be seen as calculated loads or as measured loads. They can be understood as load density (i.e., watts per square foot, W/ft^2) or in terms of circuits required. They can be viewed in terms of the one-time peak or in terms of the profile of the loads from hour to hour, from day to day, and from month to month. Each perspective has a different dynamic, and each perspective is important for a different reason. Each perspective will depend on many different factors, all of which are likely to change as the facility evolves. The best engineers who deal with health care facilities will attempt to understand the nature of the electrical loads under all of these kinds of circumstances and apply that knowledge to optimize the design and operation of the facility over its lifetime.

The figures that follow provide historical data summarizing health facility load data from a number of different sources. This data includes loads for different types of facilities, in different geographical areas, over different time frames. Taken together, these data can be used to generate some initial estimates of health facility loads. However, this data should be carefully applied, as it is data taken from one or another particular facility, with particular lines of services, patient census, weather conditions, etc. Engineers using this data should use common sense in applying it to another health care facility under a different set of circumstances.

2.1.3 Load evolution

Patterns of health care delivery have changed dramatically in recent years. No evidence suggests that this rate of change will abate. Some of the ongoing changes include the growing concentration of data systems in delivering health care services; the continuing evolution of health care technologies, often in ways that blur the lines between imaging and treatment for instance; the movement of more and more procedures to outpatient settings; the resultant acuity intensification for the patients in hospitals; and the nearly universal application of digital technologies in different kinds of loads.

Moreover, individual facilities constantly change and adapt to the particular demographics of the patient populations they serve, as well as changes in ownership and management structure and reimbursement policies. And, the nature of the facility itself will dictate the probable nature and rate of changes. For example, large teaching and research hospitals generally undergo a much more dramatic set of changes over the life of a building than will a small rural hospital, for instance. Outpatient facilities may undergo the most dramatic changes of all in future years as more and more procedures become simpler, more automated, and less invasive, and therefore more prevalent in outpatient settings.

Medical planners and building owners generally concur that the average projected life of a hospital being designed in the early part of the twenty-first century will be in the range of 50 years. Consider the changes that have taken place over the past 50 years, the increasing rate of change, and contemplate the kinds of changes that the hospitals we are designing now will undergo.

The upshot of the needs for change and the pace of change on electrical system loads is that the engineer who is designing electrical systems should design systems using historical data, but doing so in the context of the need for a system sufficiently robust to provide for the change that will likely come.

2.1.3.1 Ampacity vs. space

Obviously, engineers should design electrical systems with an eye towards sufficient ampacity or power ratings. Less obvious, but equally important, engineers should design electrical systems with space for additional distribution equipment. Recent history has taught that the need for additional breaker space in branch circuit panels usually determines when the panel is “out of capacity” far sooner than the need for additional ampacity. Sensitive electronic equipment with demands for dedicated circuits has been a primary driver of this need at the branch circuit level, and it may be that as technologies mature, the need for dedicated circuits may lessen. On the other hand, more and more devices are electrified and more and more devices are simple plug-in type, meaning that the need for outlets continues to grow.

So, while the rating of the equipment is important in the ability for an electrical system to support evolution over time, of equal importance is the space in the panels, the space within motor control centers, the space within switchboards, and the physical space within rooms dedicated to electrical equipment.

2.1.3.2 New technologies

As mentioned in the previous subclause, one of the drivers in the changes to clinical practice is the continued (and accelerating) advance in the development of medical technologies. As with other technological areas, in medical devices so too are we seeing more and more devices of more and more kinds, all demanding electrical power. Such advances are creating new procedures (robotic surgery), merging differing kinds of procedures (imaging and surgery), and putting constant demands on facility electrical systems for increased capacity, reliability, and power quality. On the other hand, as with all other technological areas, more and more medical devices are being designed to operate with lower and lower voltages, and even on batteries.

Complicating matters is the growing prevalence of digital equipment. Digital equipment often requires relatively clean electrical waveforms, while simultaneously injecting irregularities onto the incoming signal that are then transferred to other portions of the system. Many digital devices now include input filters that mitigate both the incoming signals as well as the disruption the device causes back onto the system.

Again, the evolution of these kinds of loads will impact the systems that are designed to serve them, and the engineer should design any new systems with the evolving nature of the loads to be served in mind.

2.1.3.3 Demand vs. connected loads

The word *demand* creates some confusion as it is commonly used to refer to two different things. One sense of the “demand” load for a system is the load that is actually on the system at any one time. This sense of the word is frequently used by utility companies, for example, who often bill for the peak demand for a facility. The National Electrical Code® (NEC®) (NFPA 70),¹ however, uses the word both in this sense [see, for example, 517-30(D) in the NEC] and in another sense. The NEC defines a *demand factor* as the “ratio of the maximum demand of a system, or part of a system, to the total connected load of a system or the part of the system under consideration.” Expressed this way, “demand” means essentially the same thing as expressed previously, but in practice, the NEC uses the phrase “demand factor” in a very different way. Various sections of the code list specific demand factors that may be used in calculating the loads for branch circuits, feeders, and other portions of the distribution system. This use of “demand factor” is therefore not the ratio of maximum demand of a system to the connected load; instead, it is the ratio of minimum permissible calculated load for equipment/feeder sizing compared to connected load. The code therefore uses “demand” in both senses. And again, the electrical engineer needs to understand both kinds of “demand,” for in sizing the electrical system, the engineer cannot violate the codes, but at the same time, the engineer should be mindful of the actual loads that the system will experience, in order to apply the appropriate diversity factors and be able to forecast the usage of the facility over time for budgeting purposes.

¹Information on references can be found in 2.6.

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. This difference results from the fact that the codes generally do not take into effect the notion of diversity. Diversity refers to the fact that, for any group of loads, not all will be on at any one time. And the more loads that are grouped together, the more that will likely be off at one time. IEEE Std 241™ (*IEEE Gray Book*™) points out this difference and defines diversity as the ratio of the sum of a group of demand loads to the total "maximum demand of the system" (see IEEE Std 241, 2.1).

In general then, 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. The *IEEE Gray Book* notes that the engineer may want to use a diversity of 100% in order to provide spare capacity, but in practice, using a diversity of 100% can create a system that is significantly larger than it will ever need to be. The engineer designing a health care facility needs to understand well the code-allowed demand factors, the loads that the system will actually be likely to experience, and the owner's needs for spare capacity. Only then can the engineer do a creditable job of specifying the right size for the various elements in the system.

Note, finally, that various authorities having jurisdiction (AHJs) over the design of health care facilities enforce and interpret various portions of the codes they enforce with varying levels of enthusiasm (one hospital engineer once complained that every person who walked in his door claimed that he was the AHJ.) However, various provisions of the NEC such as 220-21—which allow the engineer to reduce the sizes of feeders and services "where it is unlikely that two or more non-coincident loads will be used simultaneously"—can be used to allow more accurate sizing of electrical equipment or feeders if properly applied by the AHJ.

In designing electrical systems, therefore, engineers for health care facilities should be aware of the connected loads of their facilities, the relevant demand factors required and diversity factors allowed by their codes and their AHJs, and the likely actual maximum demand loads.

2.1.3.4 Occupancy type

Varying types of health care facilities have varying types of load profiles (see 2.5). The nature of health care facilities is such that occupancies are blurring. More and more outpatient procedures are being performed in outpatient facilities. More and more procedures are being moved to outpatient facilities and out of inpatient facilities. And more and more housing of patients is being transferred to the home, with resulting increase in the acuity of patients who remain in the hospital.

Different kinds of occupancies create different kinds of loads and different kinds of load profiles (see 2.5). Outpatient facilities may operate during business hours only. Ambulatory surgery facilities, offering 23.5 hour stays, may have profiles similar to those of acute care hospitals. Emergency departments and the associated diagnostic and treatment areas will have profiles differing from those of other areas of the hospitals.

Hospitals with full kitchens will have different profiles from hospitals with food prepared off-site and only served on-premises. Medical centers with laundries will have significantly different profiles than medical centers without. In general, facilities and portions of facilities dedicated to housing patients and their families will have relatively smaller load densities, while diagnostic and treatment areas will generally have higher load densities. Even these broad rules, however, should be used with caution, in view of the likely continuing evolution of patient care.

In general, the engineer analyzing or predicting or attempting to understand load profiles for medical centers should understand the occupancies within the medical center, their hours of operation, and their probable electrical load profiles. Moreover, the “shell and core” of a particular building may house many different occupancies over its lifetime. The nature of a modern health care facility is that it should respond to changes in ownership, in reimbursement policies, and in changes to its patient population. All of these external forces, together with technological changes in the practice of medicine, will create constant pressures for changing the mix of services within any particular facility.

2.1.3.5 Normal vs. emergency loads

Most health care buildings have loads on emergency distribution systems. Engineers should size components for these generation and distribution systems in addition to sizing the elements for those loads only on emergency power.

The relevant building codes set forth the loads that should be on the building emergency system. Loads on the emergency distribution system include loads for egress lighting, alarm and alerting systems, fans, pumps, and general lighting and receptacles. The considerations for sizing equipment serving these loads are similar to those for sizing normal equipment, except that the engineer should be aware of certain “tricks” available that can be applied to more closely size the generators to the actual loads.

In many instances, certain loads that run when the building is receiving utility power may, when transferred to emergency power, exhibit different running characteristics. For example, the engineer may put controls in place so that when the building is running on emergency power, only one elevator per bank may be used, rather than all of the elevators. Similarly, though the electrical code requires the generator to be sized for starting current for the fire pump, a particular sequence of operation may also require the fans to stop upon activation of the fire detection system. In this case, the fan load may be larger than the starting current of the fire pump, and the starting current of the fire pump can thus be ignored in sizing the emergency generator and its primary components. A third example is the recent addition to the NEC of language allowing an additional transfer switch(es) to serve loads that are not specifically named as having to be on emergency power. Here, the engineer need not size the generator based on these loads, as the control sequence may be designed to shed these loads upon generator overload.

Surveys of emergency power systems for various hospitals across the country show that the peak demand load for such systems is generally less than or equal to 3.5 W/f^2 , with the connected load two to three times more than this amount. Of this total, approximately half

is load on the equipment system, one-third is load on the critical branch of the emergency system, and the balance is load on the life safety branch of the life safety system.

2.1.4 Sustainable/green buildings

In the early 1970s, the Arab oil embargo left the U.S. reeling, and together with the flourishing environmental movement, created the first interest in energy efficient buildings. Health care facilities generally implemented energy savings measures largely in order to contain operating costs and were generally reluctant to implement energy solutions that did not offer a “payback” of only a few years.

However, energy prices remained relatively stable for many years, thus lessening the interest of health care facilities in investing in new energy saving technologies (see Mann [B24]).²

In the closing years of the twentieth century, however, new forces have emerged that are rekindling the interest of health care facilities in reducing their energy usage and in implementing *green* technologies. First, the U.S. energy supply infrastructure and reserve capacity have changed as markets have changed, with the result that both infrastructure and reserve capacity limits are being tested. This results in various kinds of energy price and supply volatility in the face of sudden or unexpected changes to the underlying assumptions as to supply or demand (see Joskow [B21]).

Second, the deregulation efforts for the electricity markets have been “incomplete, balkanized, and suffer from serious market design and regulatory imperfections.” These unsuccessful attempts to deregulate some of the country’s electricity producers have exacerbated the problems caused by relatively limited infrastructure and reserve capacity. While little of the country’s electricity is currently produced from petroleum supply (see Joskow [B21]), the pervasive impact of petroleum shortages tends to magnify public perceptions of “energy crisis” in the event of disruptions (or threatened disruptions) to oil supply].³ Coupled with the U.S.’ growing dependence on foreign oil supplies (see Joskow [B21]), this problem is likely to persist for many years. Finally, the link between energy consumption and the health of the environment are becoming daily more and more obvious (see Mann [B24]).

The result of these forces, together with a propensity to change our national energy policy only in response to crises, tends to breed an air of uncertainty in the energy field.

Another development is the rise of the *green buildings* movement. Many organizations have promoted the ideas of green or sustainable building for many years.⁴ But the U.S. Green Building Council’s recent publication of its LEED rating system [Leadership in Energy and Environmental Design (LEED) Green Building Rating System™] has greatly accelerated the interest in energy technologies that create less harm to the environment.

²The numbers in brackets correspond to those of the bibliography in 2.7.

³For example, one frequently cited fear of a U.S.-led attack on Iraq in 2002 was the fear of oil shocks.

⁴For example, the Rocky Mountain Institute has promoted the use of green technologies in building for many years.

Indeed, the *healthy buildings* movement⁵ has combined with the green movement to create a force for developing energy strategies that are both environmentally benign, as well as promoting health for the occupants of staff and for patients.⁶

All of these factors combine with continuing pressures to reduce costs in the face of often declining revenues faced by health care facilities to create a continued pressure to manage the energy costs of the health care facility in a way that supports the overall mission of the organization (see American Society for Healthcare Engineering [B3]). Indeed, a recent survey by the U.S. Department of Energy (DOE) show that 99% of inpatient health care buildings are owner occupied. Owners of buildings have a fiduciary interest in their economical operation, unlike say, a landlord who passes energy costs on to tenants, or tenants who may or may not benefit from energy saving investments. The combination of financial pressures together with the healing mission of the organizations who own and operate health care facilities combine to drive better and better decisions regarding the *greenness* of health care facilities.

2.2 Obtaining load data

Engineers may obtain load data from a number of different sources, depending upon the precise nature of the need. Obviously, equipment manufacturers publish data on the energy consumption of their equipment. Often, these manufacturers express their data in the form of “minimum circuit ampacity,” which does not accurately reflect the actual energy demand of the equipment supplied. In these cases, a quick phone call to the manufacturer will usually yield more accurate information. This kind of detailed information is usually required in the final design stages of a project.

Engineers can obtain estimates of calculated demand loads from other projects performed in the same jurisdiction or in a jurisdiction following similar interpretations of the codes. At least one engineering firm has compiled a database, by department, of the watts per square foot and circuits per square foot for the normal system and each emergency branch and system in a hospital. This kind of data can be used to quickly and accurately estimate the loads for a facility early in the design process, allowing for accurate layouts of distribution equipment early in the process. Table 2-1 and Table 2-2 show some typical data for two different medical office buildings (MOBs) in California.

⁵ Propounded, for example, by the Healthy Buildings Network; see www.healthybuilding.net.

⁶ Kaiser Permanente’s National Facilities Services has adopted the following statement of green goals: “Kaiser Permanente’s mission is to improve the health of the communities we serve. In recognition of the critical linkages between environmental health and public health, it is KP’s desire to limit adverse impacts upon the environment resulting from the siting, design, construction and operation of our health care facilities. We will address the life cycle impacts of facilities through design and construction standards, selection of materials and equipment, and maintenance practices. Additionally, KP will require architects, engineers, and contractors to specify commercially available, cost-competitive materials, products, technologies and processes, where appropriate, that have a positive impact, or limit any negative impact on environmental quality and human health.” See similar goals from the UT Hospital at <http://www.swarthmore.edu/NatSci/sciproject/GreenGoals.html>.

Table 2-1—Sample MOB load/circuit data^a

MOB	ft ²	480 V poles	480 V spares	480 V spaces	480 V poles/ ft ²	208 V poles	208 V spares	208 V spaces	208 V poles/ ft ²
1	54 000	258	91	66	0.004778	848	161	98	0.015704
2	32 430	54	9	12	0.001665	394	72	27	0.012149
ave	43 215	156	50	39	0.003221	621	116.5	62.5	0.013926

^aReprinted with permission from Kaiser Foundation Health Plan Inc.**Table 2-2—Sample MOB load/circuit data, continued^a**

MOB	ft ²	Ltg (VA)	Ltg (VA/ ft ²)	Receps (VA)	Receps (VA/ ft ²)	Equip (VA)	Equip (VA/ ft ²)	HVAC (VA)	HVAC (VA/ ft ²)
1	54 000	144 725	2.68	429 371	7.9513	283 600	5.2519	197 670	3.6606
2	32 430	33 010	1.02	117 800	3.6324	159 010	4.9032	89 560	2.7616
ave	43 215	88 867	1.85	273 586	5.7919	221 305	5.0775	143 615	3.2111

^aReprinted with permission from Kaiser Foundation Health Plan Inc.

With respect to the actual demand loads, this kind of data can only come from experience. The state of California requires that an engineer adding load to an existing system measure the loads for the system for a minimum of three days to verify that the system has adequate capacity for adding more load (see OSHPD Policy Intent Notice 3-220). These kinds of measurements dramatically show the differences between connected loads, calculated demand loads, and actual demand loads.

Recording existing loads is not always as straightforward as it might appear. For example, most recording ammeters will record motor starting surges. Using the motor starting surge as the “peak load” for a particular point in a system is highly inaccurate, as overcurrent devices are designed to ride through a certain amount of surge without tripping. Indeed, the rating of most overcurrent devices reflects the load that the device can tolerate for a long time, not the load that the device will trip on in an instantaneous surge situation (see Nash [B25]).

2.3 Using load data to design health care facilities

2.3.1 General considerations

As previously mentioned, when a circuit or feeder serves a single load, that load can generally be either on or off. So, the engineer should size that circuit or feeder to carry 100% of the connected load for that device. (In the case of a continuous load, as defined by the NEC, the engineer should size the circuit or feeder to carry 125% of the connected load in order to protect against excessive heat buildup over time.) However, as more and more loads are concentrated onto a single feeder, the engineer should use more and more demand and diversity factors in order to ensure that the feeders are not oversized relative to the loads they will actually have to carry.

The data in Annex 2B show the daily consumption of electricity during a typical summer day for a typical hospital, as well as showing a breakdown of electricity demands for different portions of the hospital distribution system. This hospital was constructed in 1995 and uses centrifugal electric chillers in a central plant for cooling. The portions of the system studied were as follows.

2.3.2 Internal building loads and distribution system

2.3.2.1 Lighting loads

Lighting for the health care facilities is presented in Chapter 6. Loads imposed by the lighting systems will be a function of several variables, including the following:

- a) Tasks to be performed
- b) Quality and quantity of illumination required
- c) Choice of lighting sources

Lighting design for some areas will be similar to that for other commercial buildings. Other spaces will require the application of specialized lighting techniques. Among the latter are patient rooms, intensive care units, nurseries, and surgical and obstetrical suites.

In all cases, task lighting techniques should be applied, in the interest of energy management and of optimum distribution system capacity.

2.3.2.1.1 Lighting loads by function

For initial calculations, lighting connected loads are estimated by relying on the designer's previous experience, or they may be estimated using the Illuminating Engineering Society of North America (IESNA) lighting power budget technique. Refer to 2.6, 2.7, and Chapter 6 for more on this subject.

2.3.2.1.2 Lighting demand

As with other types of loads, demand factors may be applied to lighting connected load when determining distribution system component capacity. The appropriate factor will depend upon some or all of the following:

- a) Function performed in the area served
- b) Means of lighting control, i.e., switching, dimming
- c) Hours of operation for the area served
- d) Local code authority requirements

As an upper limit, the continuous load supplied by a lighting branch circuit should not exceed 80% of the branch circuit rating. For good design practice, the continuous load supplied should not exceed 70% of the branch circuit rating and in some cases should be even lower.

The NEC permits the use of lighting demand factors in calculating lighting load on feeders. Refer to Table 220-11 of the NEC. However, designers should develop their own factors based on the characteristics of a specific project, consistent with restraints imposed by code authorities.

The factors shown in Table 2-3 may be used in sizing the distribution system components shown and should result in a conservative design.

As a general rule, the life safety branch in a hospital, consisting primarily of exit signs and egress lighting, will show little diversity. So a demand factor of 100% is appropriate for these lighting loads. Similarly, areas where the entire lighting is likely to be used at one time should also be sized at 100%.

Table 2-3—Factors used in sizing distribution system components

Distribution system component	Lighting demand factor
Lighting panel bus and main overcurrent device	1.0
Lighting panel feeder and feeder overcurrent device	1.0
Distribution panel bus and main overcurrent device	
First 50 000 W or less	0.5
All load over 50 000 W	0.4
Remaining components	0.4

2.3.2.2 Power loads

Power loads may be divided into the following broad categories:

- a) Building equipment
- b) Heating, ventilating, air conditioning, and refrigeration (HVAC&R)
- c) Transportation (elevators, trolleys)
- d) Auxiliary pumps (fire, sump, clinical air and vacuum, pneumatic tube)
- e) Functional equipment
- f) Kitchen
- g) Dialysis
- h) Communication systems
- i) Business machines
- j) Laundry
- k) Medical equipment
- l) X-ray and imaging systems
- m) Radiation therapy
- n) Laboratory
- o) Surgery
- p) Intensive care, recovery, emergency
- q) Physical and occupational therapy
- r) Inhalation therapy
- s) Pharmacy
- t) Materials management
- u) Medical records

NOTE—Major loads occur in categories a) and b), and these loads are similar to those in other types of commercial buildings. Category c) is unique to health care facilities.⁷

2.3.2.3 Building equipment

The types of HVAC&R equipment chosen for a specific building will have the greatest single effect on the electrical load. First, the choice of fuel will be critical. If natural gas, fuel oil, or coal is chosen, electrical loads will be lower than would be the case if electricity were chosen. Second, the choice of refrigeration cycle will have considerable impact. If absorption chillers are chosen, electrical loads will be lower than those imposed by electric centrifugal or reciprocating chillers. Early discussions between mechanical and electrical designers will be advantageous in planning the electrical distribution system.

For initial estimates, before actual loads are known, the factors shown in Table 2-4 may be used to establish the major elements of the electrical system serving HVAC&R systems.

⁷Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

Table 2-4—Factors used to establish major elements of the electrical system serving HVAC&R systems

Item	Unit
Refrigeration machines	kVA/ton of chiller capacity
Absorption	0.10
Centrifugal/reciprocating	1.0
Auxiliary pumps and fans	
Chilled water pumps	0.08
Condenser water pumps	
Absorption	0.15
Centrifugal/reciprocating	0.07
Cooling tower fans	
Absorption	0.10
Centrifugal/reciprocating	0.07
Boilers	kVA/boiler hp
Natural gas/fuel oil	0.07
Boiler auxiliary pumps	kVA/boiler hp 0.10
Deaerator	
Auxiliary equipment	kVA/bed
Clinical vacuum pumps	0.18
Clinical air compressors	0.10

Where it is unlikely that two dissimilar loads will be in use simultaneously, it is permissible to omit the smaller of the two loads in computing the total load for a feeder. For example, if the heating hot water pumps and the air conditioning chilled water pumps are connected to the same feeder and are not used at the same time, only the larger of the two loads is considered. Likewise, if a pump or air compressor has two motors that operate on an alternating basis, only one of the motors need be included in the calculation.

Similarly, where feeders serve motors that duty cycle, operate intermittently, or where all motors will not operate at the same time, the AHJ often grants permission for feeder conductors to have an ampacity of less than that required for the total connected load (NEC 430-26). While this option will be exercised rarely for feeders with only a few motors, it should be used more aggressively for feeders supplying large groups of motors (i.e., the equipment system). Diversity factors are appropriate for hospitals that have a great number of motors of different types (air compressors, pumps, etc.) that operate intermittently.

Another potential reason for applying diversity factors for feeders to motor loads has to do with sizing round off and safety factors used by the mechanical engineer in sizing the equipment. If the actual fan load is 42 hp, the mechanical engineer will specify a 50 hp motor simply because a 50 hp motor is the next standard size. Likewise, if the calculation calls for 48 hp, the mechanical engineer will specify a 60 hp motor as a safety factor. Moreover, inlet vanes and variable frequency drives (VFDs) will modulate airflow according to demand. So since induction motors produce load in proportion to the torque on the shaft, regardless of the motor nameplate rating, the actual motor load will be less than the calculated load most of the time. Therefore, it is reasonable to use a diversity factor of something less than 100% for portions of the electrical system serving a large number of air handling units.

Elevators are usually large loads, but since only a few are required in most health care facilities, elevators do not represent a large portion of total load. For preliminary design of the distribution system in buildings of up to 12 stories, assuming vertical speeds up to 450 ft/min, 4500 lb capacity, the following estimates may be use:

Electric traction elevators, each: 40 hp to 75 hp

Hydraulic elevators, each: 35 hp to 50 hp

Hydraulic elevators ordinarily will not be used in buildings higher than seven stories and speeds usually will be limited to 150 ft/min. However, capacities may be higher than 4500 lb. Actual loads should be obtained from the elevator vendor once vertical transportation requirements have been defined sufficiently to permit calculation.

The NEC contains demand factors that may be assigned to feeders serving groups of elevator loads, and the engineer should be certain to take advantage of them. Similarly, some, but not all, of the elevators may be required to be on the emergency generator. Codes usually required one elevator per bank to be on generators. Hospital engineers should verify the requirements of their local AHJ, as well as the needs of the owner, and size the emergency system components appropriately.

Escalators are not installed frequently in health care facilities, but may be employed in a few buildings. For initial estimates, escalator load will be approximately 25 hp for each landing served above the lowest landing served.

Horizontal and vertical transportation systems for food, supplies, and materials using automated trolleys or carts are found in a few large health care facilities. Pneumatic tube systems are more common and may be used as the sole means of transport of small supplies and paper records or as one component in a materials handling system. Automated trolleys or carts impose relatively small loads (less than 10 hp) at numerous locations but will usually be combined with dedicated elevators whose loads will be similar to a service elevator. Pneumatic tube systems are powered by vacuum pumps or exhausters located in a few central locations. Motor drives will vary depending on the extent of the system but are under 10 hp (many are less than 3 hp).

2.3.2.4 Functional equipment

Equipment of this type usual consists of numerous small loads except that used in the kitchen and some office copiers. The effect on the electrical system is to require panel space and multiple branch circuits but low load density.

The type of kitchen (full kitchen or cook-chill) and the fuel in the kitchen is the major determinant of loads for the kitchen. If natural gas is the primary fuel, electrical loads will be lower on a watts per square foot basis than where electricity is the primary fuel. Preliminary planning should address this question early. For estimating purposes, the following factors may be used in calculating kitchen floor area include cooking and preparation, dishwashing, storage, walk-in refrigerator/freezer, food serving lines, tray assembly, and offices.

Primary fuel	W/ft ²
Natural gas	25
Electricity	125

Data processing equipment is now used in most areas of the hospital. Generally, centralized equipment for these systems will occupy one or more rooms with satellite rooms distributed throughout the building. The centralized room will often have an equipment load of between 50 W/ft² and 100 W/ft², while the satellite telecom rooms will have loads of between 1 kW and 2 kW. However, the engineer should work closely with the information technology (IT) and telephony staff to determine power requirements for these spaces. Often they will need uninterruptible power supply (UPS) backup in addition to the emergency power system available from the generators. The facility may want to have a single UPS located in or near the central room with feeders to the satellite telecom rooms, or they may have small UPSs scattered through all of the spaces. Again, the engineer needs to work closely with the IT and telephony staff for the hospital to determine the optimal mix of UPS distribution.

For individual workstations, the nameplate data for the equipment can be 1 kW to 2 kW per workstation. In practice, however, the stations rarely draw that kind of load, especially on a consistent basis. Printers, however, can reach their stated connected load, and circuits to feeders should be sized for the connected loads. Again, however, as more and more of these devices are grouped together, a higher and higher diversity factor will apply, as all of these devices have various kinds of internal power saving devices, and not all will ever be operating at full capacity at one time.

2.3.2.5 Medical equipment

Types of medical equipment used in the various departments of health care facilities are discussed in Chapter 8.

Power distribution systems serving multiple x-ray machines require special attention. Designers should always be guided by the specific data furnished by vendors supplying equipment for the specific facility. However, an excellent planning guide is available as a

National Electrical Manufacturers Association (NEMA) standard (NEMA XR 9) and should be consulted.

Quality of voltage supplied is important to x-ray installations. Again, service as direct as possible from the source is desirable. Minimum transient disturbance and voltage drop are essential.

Note that most x-ray machines have two load ratings: continuous and momentary. The continuous load is usually small and poses little problem for either source—utility or standby generator. The momentary demand, however, can be a problem for a standby generator, especially a large x-ray machine served by a small generator. Since x-ray machines have a high power factor, a real power load is imposed on the generator. The effect of this should be evaluated in sizing the generator set.

While momentary demand of x-ray installations will figure prominently in feeder and distribution equipment sizing, it need not be considered in calculating overall power demand imposed on the utility source, provided it is a part of a moderate size system. If the system requires 750 kVA or more, the momentary nature of x-ray operation will not add measurably to the overall demand. For small systems and for additions to existing facilities where service equipment is near capacity, some provision for x-ray demand may be advisable.

Clinical laboratories in hospitals require numerous branch circuits to serve the multitude of electrical devices, but load density is usually low and individual equipment loads are low, most under 1 kVA. A few pieces of equipment in laboratories today perform multiple specialized tests. The loads for these will range between 3 kVA and 8 kVA each. These same items often are sensitive to transient conditions on the power system and may require locally applied surge arrestors.

2.3.3 Building service

As discussed many times within this chapter, the more loads that are on a feeder, the more diversity in loads that feeder will benefit from. Since the building service is the feeder in the building that combines all of the loads together, it is the feeder that will have the greatest difference between its connected load, its calculated demand load, and its actual demand load. Again, however, the engineer designing a hospital should not necessarily design the service to the minimum size to meet the probable maximum demand. Rather, the engineer should apply restrictions of the AHJ, of the serving utility, and should consider needs for future expansion and/or spare capacity in sizing the service.

Table 2-5 presents the actual peak service entrance demand per gross square foot for a group of health care facilities operated by the VA. The tables in Annex 2A show similar, related data for more hospitals.

**Table 2-5—Service entrance peak demand
(Hospital Corporation of America)**

Hospital and location	Floor area (ft ²)	Beds ^a	Degree days ^b		Principal ^c fuel	W/ft ² ^d
			Cooling	Heating		Maximum
#1 East	273 000	458	1353	3939	NG/FO	6.8
#2 Southeast	278 000	250	2294	2240	NG/FO	6.3
#3 Central	123 000	157	—	—	NG/FO	7.5
#4 Central	36 365	62	2029	3227 ^e	E	13.7
#5 Central	318 000	300	1107	4306	NG/FO	4.6
#6 Southeast	182 000	225	3786	299 ^e	NG/FO	5.3
#7 East	283 523	320	1030	4307	NG/FO	6.8
#8 Southwest	135 396	150	2250	2621 ^e	NG/FO	6.6
#9 West	190 000	97	927	5983	NG/FO	2.8
#10 Southeast	161 000	170	3226	733 ^e	NG/FO	6.3
#11 Southeast	157 639	214	2078	2146	NG/FO	7.3
#12 Southeast	162 187	222	2143	2378 ^e	NG/FO	4.3
#13 East	109 617	146	1030	4307 ^e	NG/FO	5.7
#14 East	76 000	153	1030	4307 ^e	E	8.8
#15 Southeast	135 150	190	1995	2547 ^e	NG/FO	5.9
#16 Southwest	75 769	131	2587	2382 ^e	NG/FO	7.4
#17 Central	75 769	128	1636	3505 ^e	NG/FO	6.3
#18 Northwest	129 000	150	714	5833 ^e	NG/FO	4.4
#19 Central	54 938	108	1694	3696 ^e	E	13.3
#20 West	144 000	160	2814	1752	NG/FO	4.5
#21 Southeast	149 000	123	2078	2146 ^e	NG/FO	4.5
#22 Central	89 000	128	2029	3227 ^e	E	8.4
#23 Central	128 500	150	1197	4729 ^e	NG/FO	6.2
#24 West	135 169	170	927	5983 ^e	NG/FO	4.7
#25 Southeast	80 000	124	1722	2975 ^e	NG/FO	6.2
#26 Southeast	83 117	126	3226	733 ^e	NG/FO	8.5

**Table 2-5—Service entrance peak demand
(Hospital Corporation of America) (continued)**

Hospital and location	Floor area (ft ²)	Beds ^a	Degree days ^b		Principal fuel ^c	W/ft ² ^d
			Cooling	Heating		Maximum
#27 Central	51 000	97	1569	3478	NG/FO	8.8
#28 Southeast	66 528	120	2929	902 ^e	E	9.7
#29 East	112 000	140	1394	3514	E	4.3
#30 Central	202 000	223	1636	3505	NG/FO	4.8
#31 Southeast	56 000	51	3786	299 ^e	NG/FO	7.4
#32 West	47 434	50	927	5983 ^e	NG/FO	7.0
#33 Central	23 835	32	1694	3696 ^e	E	10.8
#34 Southeast	105 000	95	2706	1465 ^e	NG/FO	8.3
#35 West	48 575	60	3042	108 ^e	NG/FO	7.7
#36 Southwest	130 000	185	2587	2382 ^e	NG/FO	6.3
#37 Central	42 879	66	1694	3696 ^e	E	15.7

^aTotal beds shown. Beds actually occupied could affect values shown for watts per square foot.

^bDegree days: Normals, base 65 °F, based on 1941–1970 period. From *Local Climatological Data Series*, 1974, NOAA.

^cNG/FO = Natural gas/fuel oil. Principal fuel is defined as that used for heating. In all cases, electricity was the fuel used for refrigeration.

^dWatts per square foot (W/ft²) based on measured values at service entrance during metering periods ranging from 9 days to 17 days, during cooling season in all instances, 1981.

^eData shown for nearest recorded location.
(Each facility was self-contained in that refrigeration and air-conditioning equipment loads are included in the power demands shown.)

Table 2-5 shows the type of facility, the gross floor area and number of beds for each, the geographic location, and the major fuel type employed for HVAC&R systems in that facility. The derived factors may be used to estimate the anticipated demand for other facilities similar in size, location, and type of fuel. They also may be used to make initial estimates of service entrance capacity, switchgear size, and space required for service entrance equipment. It is important to recognize, however, that they will be useful principally in the schematic design phase. As design proceeds through the preliminary and working drawing phases, these initial estimates should be modified by the actual conditions prevalent in the project.

Table 2-6, Table 2-7, and Table 2-8 present operating load data for large general medical and surgical hospitals. This data is useful for visualizing changes in demand over time for a typical operating hospital.

Table 2-6—Kaiser service entrance peak demand table (1998–2001)^a

Location in California	Gross ft ²	Peak demand, 1998–2001	
		kW	W/ft ²
Vallejo	217 839	1935	8.88
Richmond	95 100	762	8.01
South San Francisco	114 436	1295	11.32
Santa Clara	385 790	1632	4.23
San Jose	226 041	1352	5.98
South Sacramento	214 253	1896	8.85
Sacramento	309 499	2380	7.69
Roseville	282 016	2350	8.33
Walnut Creek	345 420	3109	9.00

^aReprinted with permission from Kaiser Foundation Health Plan Inc.**Table 2-7—John Muir Medical Center load monthly electricity and natural gas load profiles (1999–2002)^a**

Electrical date	Total usage (kWh)	Billing demand (kW)	Kitchen therms	Therms (gas Phase 1, 2)	Therms (gas Phase 3)	Gas date
09/22/1999	1 002 310	2230	674	n/a	n/a	09/23/1999
10/22/1999	1 022 602	2036	641	n/a	n/a	10/22/1999
11/22/1999	889 308	1964	655	n/a	n/a	11/22/1999
12/23/1999	818 478	1706	695	n/a	n/a	12/23/1999
01/25/2000	852 457	1652	722	n/a	n/a	01/25/2000
02/24/2000	768 893	1636	650	n/a	n/a	02/24/2000
03/24/2000	778 081	1922	631	n/a	n/a	03/24/2000
04/24/2000	879 066	1958	653	n/a	n/a	04/24/2000
05/24/2000	909 490	2282	630	n/a	n/a	05/24/2000
06/23/2000	985 176	2066	634	n/a	n/a	06/23/2000
07/25/2000	1 001 813	2006	660	n/a	n/a	07/25/2000

Table 2-7—John Muir Medical Center load monthly electricity and natural gas load profiles (1999–2002)^a (continued)

Electrical date	Total usage (kWh)	Billing demand (kW)	Kitchen therms	Therms (gas Phase 1, 2)	Therms (gas Phase 3)	Gas date
08/23/2000	1 011 026	2090	613	n/a	n/a	08/23/2000
09/22/2000	990 350	2220	620	n/a	n/a	09/22/2000
10/23/2000	912 312	2034	603	n/a	n/a	10/23/2000
11/21/2000	742 564	1818	542	n/a	n/a	11/20/2000
12/21/2000	738 274	1592	596	n/a	n/a	12/21/2000
01/31/2001	203 271	1324	653	n/a	n/a	01/23/2001
02/22/2001	479 597	1594	621	n/a	n/a	02/22/2001
03/23/2001	725 136	1862	563	n/a	n/a	03/23/2001
04/23/2001	790 280	1886	616	n/a	n/a	04/23/2001
05/01/2001	219 157	1870		n/a	n/a	
05/31/2001	967 004	2176	620	n/a	n/a	05/24/2001
06/30/2001	989 319	2174	641	n/a	n/a	06/25/2001
07/31/2001	988 818	2214	606	n/a	n/a	07/25/2001
08/31/2001	967 829	2118	575	51 094	80 709	08/22/2001
09/30/2001	909 671	1930	594	16 075	17 983	09/21/2001
10/31/2001	908 626	1966	645	16 208	21 253	10/23/2001
11/30/2001	800 611	1692	587	16 244	20 260	11/20/2001
12/31/2001	791 935	1540	615	12 693	37 663	12/21/2001
01/31/2002	758 936	1434	635	16 060	40 462	01/23/2002
02/28/2002	717 829	1696	606	14 549	34 653	02/22/2002
03/31/2002	841 221	1666	669	15 433	36 779	03/26/2002
04/30/2002	791 240	1910	643	32 856	8 289	04/25/2002
05/31/2002	909 730	2064	619	72 562		05/23/2002
06/30/2002	980 269	2040	704		2 850	06/24/2002
07/31/2002	1 066 598	2046	666	66 221	20	07/24/2002
08/31/2002	1 086 967	2046	603	33 718		08/22/2002

^aReprinted with permission from John Muir Medical Center.

2.3.4 Campus distribution system

The various feeders on a campus may serve one or more buildings. The engineer designing a campus type system will be operating more like a utility engineer than a building engineer. In this case, the engineer needs to understand the actual peak loads of the various buildings being served, as well as the load profiles of each type of building. The engineer should consider all of the load profiles, together with the system topology and needs for redundancy and expansion, to size components for the system. Table 2-8 gives some typical peak load data for several kinds of buildings on a typical hospital campus, which, combined with the load profiles given in the other tables, can provide a good starting point for such an analysis.

Annex 2A describes loads recorded at an urban hospital in California. The campus consists of a large hospital, an MOB, a cancer center with two linear accelerators, and a central plant. The central plant W/ft² loads given in the annex uses the square foot for the total of the three buildings. The profiles given show how loads are divided between different kinds of buildings, as well as how the loads are divided between the central plant and the other loads within a hospital.

Table 2-8—Emergency generator peak loading

Facility	Gross ft ²	Emer- gency capacity (kW)	EP dem (kW)	EP capac (W/ ft ²)	EP dem (W/ft ²)	Norm dem (kW)	Norm dem (W/ft ²)
#1 SF Bay Area	156 000	550	499	3.53	3.20		
#2 LA Basin	150 000	500	83	3.33	0.55		
#3 Orange County CA	407 000	1250	850	3.07	2.09		
#4 Arkansas	173 000	900	390	5.20	2.25	1120	6.47
#5 San Louis Obispo County CA	646 000	1800	1300	2.79	2.01		
#6 Kern County CA	390 000	3600	600	9.23	1.54		
#7 LA Basin	43 500	250	94	5.75	2.16		
#8 LA Basin	29 600	250	36	8.45	1.22		
#9 LA Basin	14 529	145	36	9.98	2.48		
#10 Tulare County	50 000	350	60	7.00	1.20		
#11 Butte County	120 000	400	100	3.33	0.83		

Table 2-8—Emergency generator peak loading (continued)

Facility	Gross ft ²	Emer- gency capacity (kW)	EP dem (kW)	EP capac (W/ ft ²)	EP dem (W/ft ²)	Norm dem (kW)	Norm dem (W/ft ²)
#12 SF Bay Area	210 000	1100	435	5.24	2.07	1,638	7.80
#13 Northern CA	254 000	1700	1650	6.69	6.50		
#14 Florida	130 000	600	324	4.62	2.49	790	6.08
#15 Central CA	117 380	670	287	5.71	2.45		
#16 SF Bay Area	114 000	600	320	5.26	2.81		
#17 Santa Cruz County	240 000	1500	932	6.25	3.88		
#18 Florida	265 000	800	490	3.02	1.85	1644	6.20
#19 Central CA	500 000	3500	100%	7.00	n/a	2800	5.60
#20 Humboldt County	90 000	500	360	5.56	4.00		
#21 LA Basin	900 000	1730	1040	1.92	1.16		
#22 Central CA	42 699	135	36	3.16	0.84		
#23 SF Bay Area	400 000	2210	1400	5.53	3.50	2340	5.85
#24 San Diego County	849 722	1800	420	2.12	0.49	1850	2.18
#25 LA Basin	200 000	420	186	2.10	0.93	960	4.80
#26 LA Basin	118 000	600	240	5.08	2.03		
#27 San Diego County	99 000	425	120	4.29	1.21	592	5.98
#28 SF Bay Area	112 000	350	200	3.13	1.79	692	6.18
#29 Orange County CA	550 000	2400	2000	4.36	3.64		
#30 LA Basin	212 000	800	675	3.77	3.18	1660	7.83
#31 Central CA	422 097	2900	1000	6.87	2.37		
#32 SF Bay Area	344 251	2650	815	7.70	2.37		

Table 2-8—Emergency generator peak loading (continued)

Facility	Gross ft ²	Emer- gency capacity (kW)	EP dem (kW)	EP capac (W/ ft ²)	EP dem (W/ft ²)	Norm dem (kW)	Norm dem (W/ft ²)
#33 SF Bay Area	303 872	850	600	2.80	1.97	1856	6.11
#34 SF Bay Area	387 000	1000	482	2.58	1.25	1632	4.22
#35 Sonoma County CA	165 000	1200	350	7.27	2.12	540	3.27
#36 SF Bay Area	227 913	1050	512	4.61	2.25	1352	5.93
#37 Central CA	385 200	2000	400	5.19	1.04	1270	3.30
#38 Kern County	45 867	250	166	5.45	3.62		
#39 Humboldt County	70 000	230	67	3.29	0.96		
#40 Orange County	240 000	830	316	3.46	1.32		
#41 Central CA	415 000	1200	400	2.89	0.96		
#42 Central CA	50 000	300	240	6.00	4.80		
#43 LA Basin	1 200 000	2175	1056	1.81	0.88		
#44 SF Bay Area	102 200	300	120	2.94	1.17	507	4.96
#45 SF Bay Area	325 000	810	460	2.49	1.42	991	3.05
#46 LA Basin	500 000	1500	500	3.00	1.00		
#47 LA Basin	22 326	115	72	5.15	3.22		
#48 SF Bay Area	48 000	315	75	6.56	1.56		
#49 Stanislaus County	38 000	229	87	6.03	2.29		
#50 Butte County	175 000	350	249	2.00	1.42		
#51 Napa County	299 000	1300	700	4.35	2.34		
#52 LA Basin	281 000	800	332	2.85	1.18	1400	4.98