



NFPA 99 Health Care Facilities 1984



NOTICE

All questions or other communications relating to this document should be sent only to NFPA Headquarters, addressed to the attention of the Committee responsible for the document.

For information on obtaining Formal Interpretations of the document, proposing Tentative Interim Amendments, proposing amendments for Committee consideration, and appeals on matters relating to the content of the document, write to the Secretary, Standards Council, National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

A statement, written or oral, that is not processed in accordance with Section 16 of the Regulations Governing Committee Projects shall not be considered the official position of NFPA or any of its Committees and shall not be considered to be, nor be relied upon as, a Formal Interpretation.

Users of this document should consult applicable Federal, State and local laws and regulations. NFPA does not, by the publication of this document, intend to urge action which is not in compliance with applicable laws and this document may not be construed as doing so.

Policy Adopted by NFPA Board of Directors on December 3, 1982

The Board of Directors reaffirms that the National Fire Protection Association recognizes that the toxicity of the products of combustion is an important factor in the loss of life from fire. NFPA has dealt with that subject in its technical committee documents for many years.

There is a concern that the growing use of synthetic materials may produce more or additional toxic products of combustion in a fire environment. The Board has, therefore, asked all NFPA technical committees to review the documents for which they are responsible to be sure that the documents respond to this current concern. To assist the committees in meeting this request, the Board has appointed an advisory committee to provide specific guidance to the technical committees on questions relating to assessing the hazards of the products of combustion.

Licensing Provision — This document is copyrighted by the National Fire Protection Association (NFPA).

1. Adoption by Reference — Public authorities and others are urged to reference this document in laws, ordinances, regulations, administrative orders or similar instruments. Any deletions, additions and changes desired by the adopting authority must be noted separately. Those using this method are requested to notify the NFPA (Attention: Vice President and Chief Engineer) in writing of such use. The term "adoption by reference" means the citing of title and publishing information only.

2. Adoption by Transcription — **A.** Public authorities with lawmaking or rule-making powers only, upon written notice to the NFPA (Attention: Vice President and Chief Engineer), will be granted a royalty-free license to print and republish this document in whole or in part, with changes and additions, if any, noted separately, in laws, ordinances, regulations, administrative orders or similar instruments having the force of law, provided that: (1) due notice of NFPA's copyright is contained in each law and in each copy thereof; and, (2) that such printing and republication is limited to numbers sufficient to satisfy the jurisdiction's lawmaking or rulemaking process. **B.** Once this NFPA Code or Standard has been adopted into law, all printings of this document by public authorities with lawmaking or rulemaking powers or any other persons desiring to reproduce this document or its contents as adopted by the jurisdiction in whole or in part, in any form, upon written request to NFPA (Attention: Vice President and Chief Engineer), will be granted a nonexclusive license to print, republish, and vend this document in whole or in part, with changes and additions, if any, noted separately provided that due notice of NFPA's copyright is contained in each copy. Such license shall be granted only upon agreement to pay NFPA a royalty. This royalty is required to provide funds for the research and development necessary to continue the work of NFPA and its volunteers in continually updating and revising NFPA standards. Under certain circumstances, public authorities with lawmaking or rulemaking powers may apply for and may receive a special royalty when the public interest will be served thereby.

All other rights, including the right to vend, are retained by NFPA.

(For further explanation, see the Policy Concerning the Adoption, Printing and Publication of NFPA Documents which is available upon request from the NFPA.)

Statement on NFPA Procedures

This material has been developed under the published procedures of the National Fire Protection Association, which are designed to assure the appointment of technically competent Committees having balanced representation. While these procedures assure the highest degree of care, neither the National Fire Protection Association, its members, nor those participating in its activities accepts any liability resulting from compliance or noncompliance with the provisions given herein, for any restrictions imposed on materials or processes, or for the completeness of the text.

NFPA has no power or authority to police or enforce compliance with the contents of this document and any certification of products stating compliance with requirements of this document is made at the peril of the certifier.

Errata

NFPA 99-1984

Standard for Health Care Facilities

NFPA 99

Reference: 3-3.3.1.2(a)

1. In paragraph 3-3.3.1.2(a), **Power for Fixed Equipment**, change reference in item (a) from "3-3.4.1.10" to "3-2.3.4.2".

This reference was incorrectly printed when incorporating NFPA 56A into NFPA 99.

Copyright © 1984 All Rights Reserved
NATIONAL FIRE PROTECTION ASSOCIATION

Errata

NFPA 99 - 1984

NFPA 99

Reference: 9-1.5

The Committee on Health Care Facilities notes the following error in the Standard for Health Care Facilities:

1. In paragraph 9-1.5, line 1, change "health care facility" to "hospital."

Copyright © 1984 All Rights Reserved
NATIONAL FIRE PROTECTION ASSOCIATION

© 1984 NFPA, All Rights Reserved

Standard for Health Care Facilities

NFPA 99-1984

1984 Edition of NFPA 99

This edition of NFPA 99, *Standard for Health Care Facilities*, was prepared by the Technical Committees on: Anesthetizing Agents; Disaster Planning; Essential Electrical Systems in Health Care Facilities; Hyperbaric and Hypobaric Facilities; Laboratories in Health Care Facilities; Medical-Surgical Vacuum Systems in Health Care Facilities; Respiratory Therapy; Safe Use of Electricity in Patient Care Areas of Health Care Facilities; and Safe Use of High-Frequency Electricity in Patient Care Areas of Health Care Facilities, released by the Correlating Committee on Health Care Facilities, and acted on by the National Fire Protection Association, Inc., at its Fall Meeting held November 14-17, 1983, in Orlando, Florida. It was issued by the Standards Council on January 20, 1984 with an effective date of February 9, 1984. NFPA 99 combines all documents under the jurisdiction of the Correlating Committee on Health Care Facilities, and supercedes all previous editions of NFPA 3M, 56A, 56B, 56C, 56D, 56E, 56G, 56HM, 56K, 76A, 76B and 76C.

This edition of NFPA 99 has been submitted for approval by the American National Standards Institute as an American National Standard.

Changes other than editorial are indicated by a vertical rule to the left of text. These lines are included as an aid to the user in identifying changes from the latest previous editions of individual documents from which NFPA 99 was compiled.

Origin and Development of NFPA 99

The idea for this document grew as the number of documents under the original Committee on Hospitals grew. By the end of 1980, there existed 12 documents on a variety of subjects, 11 directly addressing fire-related problems in and about Health Care Facilities. The Health Care Facilities Correlating Committee reviewed the matter beginning in late 1979, and concluded that combining all the documents under its jurisdiction would be beneficial to those who use these documents for the following reasons:

(1) The referenced documents were being revised independent of each other. As such it was not always easy to know whether one had the latest edition of a particular document. Combining all the individual documents into one document would place all of them on the same revision cycle. Further, a regular revision cycle (similar to that of NFPA 70, *National Electrical Code*® and NFPA 101®, *Life Safety Code*®) could be established to help users of the document.

(2) It would place in one unit many documents which reference each other.

(3) It would be an easier and more complete reference for the various users of the document (e.g., hospital engineers, medical personnel, designers and architects as well as the various types of enforcing authorities).

To learn if this proposal was desired or desirable to users of the individual documents, the Committee issued a request for public comments in the spring of 1981, asking whether purchasers of the individual documents utilized more than one document in the course of their activities, and whether combining these individual documents would be beneficial. Seventy-five percent of responses supported such a proposal, with 90 percent of health care facilities and organizations supportive of it. Based on this support, the Correlating Committee proceeded with plans to combine all the documents under its jurisdiction into one document.

In January 1982, a compilation of the latest edition of each of the 12 individual documents under the jurisdiction of the Correlating Committee was published. It was designated NFPA 99, *Health Care Facilities Code*, since it was, and still is, the intention of the Correlating Committee to develop this document into a Code. The Correlating Committee also entered the document into the revision cycle reporting to the 1983 Fall Meeting for the purpose of formally adopting the document.

For this edition of NFPA 99, the following administrative and organizational changes have been made (following the NFPA *Manual of Style*): (1) definitions from all previous individual documents (except NFPA 56HM) have been placed in Chapter 2; (2) all previous standards have been designated as chapters in the text; (3) all previous recommended practices and manuals have been designated as appendices; (4) all explanatory material on specific paragraphs in chapters has been placed in Appendix A; (5) all references have been grouped into Chapter 12 and Appendix B; and (6) all additional informatory material from previous individual standards has been placed in Appendix C. The document was presented for adoption as a standard as a result of public comments, although the Correlating Committee's intent is for the document to become a Code.

Technical changes have also been made to this edition (following normal NFPA procedures as contained in NFPA "Regulations Governing Committee Projects"). The major changes are included at the end of the Origin and Development of each chapter and appendix below.

Origin and Development of Chapter 3, Use of Inhalation Anesthetics (Flammable and Nonflammable)

The original (1941) edition of NFPA 56 was in the form of an advisory pamphlet entitled "Combustible Anesthetics in Hospital Operating Rooms." In 1951 this was expanded and became "Safe Practices for Hospital Operating Rooms," and in 1962 it was renamed "Use of Flammable Anesthetics."

In 1970, the document, redesignated NFPA 56A, was expanded to include the use of nonflammable as well as flammable anesthetics. Other changes included the requirements for a dynamic Line Isolation Monitor, special grounding procedures, and the revision of electrical safeguards to mitigate the hazard of electric shock in anesthetizing locations. The number was changed to NFPA 56A, and the title was changed to "Use of Inhalation Anesthetics." In 1971 amendments included requirements for the equipotential grounding system and the introduction of new designs for plugs and receptacles for use with the isolated power system. The 1972 edition included changes in testing requirements for antistatic materials, clarification of requirements for the Line Isolation Monitor, additional definitions, and new appendix material. The 1973 edition rearranged material into a more logical sequence of requirements for all anesthetizing locations, and for flammable and nonflammable anesthetizing locations.

Major changes in requirements for the 1978 edition included: threshold level for total hazard current of the Line Isolation Monitor; wall-mounted receptacles (1) in nonflammable inhalation anesthetizing locations and (2) above the hazardous area of flammable inhalation anesthetizing locations; removal of immersion requirement for portable equipment; and testing requirements for conductive floors in nonflammable inhalation anesthetizing locations. In addition, requirements relative to isolated power systems and the definition of "hazardous area in a flammable anesthetizing location" were modified at the Association meeting, but reverted to previously approved (1973) text after the Technical Committee did not concur in them. Upon appeal to the NFPA Board of Directors, the Board sustained the Standards Council action of releasing the document with the previously approved text of the issues in question, but it directed the Technical Committee to clarify these issues and that of retroapplication of the standard as it related to isolated power. As a result, several Tentative Interim Amendments were issued.

For this edition of Chapter 3 of NFPA 99, the following major changes were made to the 1978 edition of NFPA 56A: (1) deletion of mandatory requirements for isolated power systems except for those in flammable inhalation anesthetizing locations; (2) inclusion of criteria for humidity requirements in nonflammable anesthetizing locations; (3) addition of provisions for three-phase wiring up to 600 volts; (4) changes in electrical requirements for fixed equipment; (5) incorporation of TIA allowing low-impedance type Line Isolation Monitors (LIM); (6) inclusion of transient criteria for LIMs; (7) incorporation of TIAs on criteria for "convenience" and "overhead" outlets; (8) further modifications due to the continued diminishing use of flammable anesthetics; (9) changes

in testing requirements for conductive floors in nonflammable anesthetizing locations; and (10) modifications to reflect the scope of Article 517 of NFPA 70, *National Electrical Code*.

Origin and Development of Chapter 4, Use of Inhalation Anesthetics in Ambulatory Care Facilities

NFPA 56G (now Chapter 4 of NFPA 99), was developed in response to the need for a standard to cover the administration of anesthesia and analgesia in “ambulatory care facilities” that began to function in late 1969. Classified as ambulatory care facilities were those facilities dedicated to the performance of minor operative procedures on ambulatory patients, and freestanding in the sense that they were not connected physically, or in any other way, to a hospital. Dental offices which employed a technique called “relative analgesia” were also considered to be a type of “ambulatory care facility,” because the analgesia was produced by an inhalation anesthetic agent (nitrous oxide).

Both types of facilities employed relatively large volumes of nitrous oxide and oxygen, dispensed via pipeline systems.

The then Sectional Committee on Anesthetizing Agents recognized the potential hazards created by the use of these gases in freestanding facilities (especially after receiving a report of a fire caused by the improper installation of a piping system in a dental office on the West Coast); and it also recognized that much of NFPA 56A, *Standard for the Use of Inhalation Anesthetics*, was inapplicable to such freestanding facilities. It was thus decided to develop a separate document.

A tentative standard on the subject was adopted in May, 1973. In November, 1975, the document was proposed and adopted by the Association as a standard.

The document was revised in 1980, with the major change being the clarification of the term “hospital-based facility.”

For this edition, only minor editorial changes were made to the 1980 edition of NFPA 56G.

Origin and Development of Chapter 5, Respiratory Therapy

A growing use of respiratory therapy in health care facilities, and the fire explosion hazards associates with such use (particularly from oxygen cylinders and elevated levels of oxygen in the atmosphere where respiratory therapy was being administered), prompted the then Committee on Hospitals to address the subject in the early 1960s. A Subcommittee was appointed in 1965 and a tentative standard on the subject, NFPA 56B-T, was adopted at the 1966 NFPA Annual Meeting. A revised tentative standard was adopted at the 1967 NFPA Annual Meeting. The document was adopted as an official standard, NFPA 56B, at the 1968 NFPA Annual Meeting. Revisions were approved in 1973 and again in 1976.

A complete review of NFPA 56B was made for the 1981 NFPA Fall Meeting. The following major changes resulted: (1) revision of policy regarding the transfilling of high-pressure gaseous cylinders; (2) inclusion of guidance on the use and transferring of contents of portable low-pressure liquid oxygen systems now being used for respiratory therapy; and (3) updating of definitions and the gas cylinder table. That edition was designated NFPA 56B-1982.

For this edition, the following major changes were made to the 1982 edition of NFPA 56B: (1) inclusion of reference to a new CGA pamphlet on transfilling liquid oxygen containers; (2) definition of a new term “oxygen delivery equipment”; and (3) clarification on the use of high-energy devices when oxygen is in use.

Origin and Development of Chapter 6, Medical-Surgical Vacuum Systems in Hospitals

In 1971, the then Committee on Hospitals was approached by several organizations to address the subject of medical-surgical vacuum systems in hospitals. After reviewing the matter, a Subcommittee was formed to further investigate the subject. In 1974, the Subcommittee examined equipment and determined design parameters (*see Appendix C-6.4*). The Subcommittee was raised to a Sectional Committee in 1975 and to a Technical Committee in 1976. Work continued through 1977, during which time the vacuum systems of a number of hospitals were examined. A document, NFPA 56K, was presented for adoption as a recommended practice at the 1978 NFPA Fall Meeting, but

was returned to Committee.

Following this, the Committee revised the structure of the document, placing performance criteria in the text of the document, and removing design parameters to the appendix. In addition, more hospitals were surveyed through the summer and fall of 1979. (See *Appendix C-6.4 for further details.*) At the 1980 NFPA Fall Meeting, the document was again presented for adoption as a recommended practice. This time it was approved by the Association.

For this edition, of the following major changes were made to the 1980 edition of NFPA 56K: (1) upgrading of the previous recommended practice to a standard; (2) modification of installation requirements and final installation leakage tests; (3) harmonization with terms used in an ANSI approved document on the subject; and (4) clarification on the use of a medical-surgical vacuum system for waste anesthetic gas disposal.

Origin and Development of Chapter 7, Laboratories in Health-Related Institutions

NFPA 56C (now Chapter 7 of NFPA 99), was started in the middle 1960s by the then Sectional Committee on Hospital Laboratories because of the very minimal consideration then being given to the subject of firesafety in laboratories. Proximity of many laboratories to patient care areas and the increasing combustible loading were also factors in establishing this project. The document was first presented for adoption in 1968 as a tentative standard. It was officially adopted as a standard in 1969, and then revised in 1970, 1972 and 1973.

The 1980 edition of NFPA 56C was a complete revision of the 1973 edition since changes in laboratory practice had necessitated revising nearly three-fourths of the material contained in the 1973 edition. Major changes included the following: (1) clarifying the applicability of the standard; (2) changing definitions in order to be in concurrence with other NFPA documents; (3) reflecting current NFPA *101, Life Safety Code* requirements; (4) changing requirements on the installation of automatic fire extinguishing systems; (5) revising storage requirements for flammable liquids and high-pressure gas cylinders; (6) clarifying and broadening responsibilities of the laboratory safety officer; and (7) adding appendix material.

For this edition, of the following major changes were made to the 1980 edition of NFPA 56C: (1) inclusion of recommendations on extinguishing systems for sensitive areas such as computer rooms; (2) modification of requirements on the storage of flammable and combustible liquids in refrigerators; (3) inclusion of requirements for nonflammable gases supplied by a manifold compressed system; (4) definition of a new term "hazardous area in laboratories"; and (5) further clarification on automatic fire extinguishing systems.

Origin and Development of Chapter 8, Essential Electrical Systems for Health Care Facilities

Growing reliance on continual electric power, even during internal emergencies, was a major reason for the development of NFPA 76 (now Chapter 8 of NFPA 99). With many patients unable to be evacuated, "noninterruption" of essential services (particularly electricity) became a necessity. A Sectional Committee of the then Committee on Hospitals was established to develop performance criteria for emergency power generators and the functions to be connected to them. Initially, only hospitals were addressed. Later, all types of health care facilities were included.

Following adoption by the Association of tentative editions in 1960 and 1961, NFPA 76 was adopted as a full standard at the 1962 NFPA Annual Meeting with the designation Standard for Essential Hospital Electrical Service. A revised edition with the present designation was adopted at the 1965 NFPA Annual Meeting, with subsequent revisions in 1967, 1970, 1971 and 1973.

For the 1977 edition of NFPA 76A, a major reorganization was carried out so that requirements common to *all* facilities were in one chapter, and additional requirements unique to each different type of facility listed in subsequent chapters.

Major changes in technical requirements included: (1) a new purpose and scope (reflecting a change in the Sectional Committee's jurisdiction since the 1973 edition); (2)

clarification of the requirements for nursing homes and custodial care facilities; (3) new requirements for nonhospital facilities; and (4) clarification of the tests of generator sets, mechanical protection of wiring, types of permissible fuel, and the required number of transfer switches.

For this edition, the following major changes were made to the 1977 edition of NFPA 76A: (1) clarification on "dual sources of normal power"; (2) modification of what equipment could be placed on the Critical Branch and on the Equipment System; (3) incorporation of TIAs on criteria for heating only portions of facilities; (4) consideration for retransferring to normal power; (5) definition of a new term "electrical life support equipment"; (6) further deletion of "installation" requirements; (7) modification to requirements on receptacles in anesthetizing locations; (8) allowance for central suctioning to be placed on the Critical Branch if warranted; and (9) revision of time requirements for electric power in some health care facilities in order to be in concert with NFPA 101, *Life Safety Code*.

Origin and Development of Chapter 9, Safe Use of Electricity in Patient Care Areas of Hospitals

The idea for a document on the Safe Use of Electricity in Patient Care Areas of Hospitals began in 1965 when the then Committee on Hospitals organized an ad hoc Committee to study electric hazards in hospitals in response to a suggestion by the American College of Surgeons' Committee on Preoperative and Postoperative Care. In April 1968, a workshop on Electrical Hazards in Hospitals was held at the National Academy of Sciences in Washington, DC, under the auspices of the Committee on Anesthesia and the Committee on Shock, Division of Medical Sciences, National Research Council (*see 9-1.9 and Appendix A-9-1.9 for a description of the hazards involved in hospitals*).

The ad hoc NFPA Committee actively participated. The workshop concluded that there were electrical safety problems peculiar to hospitals. A number of documents addressed aspects of the problem but because of its multifaceted nature, there was a need for a comprehensive unified document that would present a system approach to improving safety.

That workshop, plus the growing utilization of electro-medical devices and the reports of problems associated with their use, led to the formation in 1969 of a Sectional Committee on the Safe Use of Electricity in Patient Care Areas of Health Care Facilities under the Committee on Hospitals. The Sectional Committee developed guidelines which were adopted as a manual, NFPA 76BM, at the Association Meeting in May 1971. The Committee continued to work on the subject, and presented a revised document at the Association Meeting in May 1973. It was adopted as a tentative standard, NFPA 76BT.

The tentative standard served as a basis for good practice in hospitals while studies, surveys and seminars continued on the subject, both within the US and internationally. In addition, manufacturers' standardization of (1) mechanical integrity; (2) electrical integrity, and (3) measurement techniques for leakage current, began to occur as a result of publication of the tentative standard. Testing organizations also formulated testing standards for medical appliances based in part on the tentative standard. Consequently, this document, in its various editions as a manual and tentative standard, served to inform those concerned with electrical installation and appliances in hospitals of the hazards involved with the use of electricity in patient care areas, and served as a means to improve the safety to patients and staff from such use.

The Committee, elevated to a Technical Committee in 1975 under the Correlating Committee on Health Care Facilities, worked on modifications and improvements in preparing the document as a standard. As the health care community became more aware of the nature of electrical hazards and as practice improved in system design and instrumentation, safety concepts and requirements changed. Versions of the standard were proposed at Association Annual Meetings in May 1976 and May 1978, but were returned to Committee. With further revision, it was again proposed as a standard at the 1980 NFPA Fall Meeting.

For this edition, the following major changes were made to the 1980 edition of NFPA 76B: (1) reorganization of leakage current limits for consistency between hospital and manufacturer requirements, and between Chapter 9 of this document and other domestic and international documents on the subject of leakage current limits; (2) clarification on

hospital-owned household appliances used in patient care areas; (3) modification of resistance requirement, as measured by hospitals, between the chassis and the ground pin of attachment plugs; (4) clarification on leakage current measurements for cart- or rack-mounted appliances; (5) definition of "double-insulated"; (6) clarification of the Reference Grounding Point; and (7) inclusion of requirements to test electrical safety test instrumentation.

Origin and Development of Chapter 10, Hyperbaric Facilities

A growing use of hyperbaric chambers for medical purposes (e.g., burn treatment, gas gangrene, carbon monoxide poisoning, respiratory-related problems) led the then Committee on Hospitals to appoint a Subcommittee in 1965 to address the fire and explosion hazards of such facilities. The conditions within a hyperbaric chamber during such medical procedures (i.e., usually elevated oxygen content as well as the pressure of the atmosphere) stressed the need to provide guidance on construction, fire protection equipment, safe practices and maintenance to prevent the possibilities of, as well as to provide rapid suppression in the event of, fire within such facilities. The fatal accident involving the Apollo 1 spacecraft on January 23, 1967, provided impetus for the development of this document.

A tentative standard, NFPA 56D-T, was adopted at the 1968 NFPA Annual Meeting. An official standard, consisting of amendments to the tentative standard, was adopted at the 1970 NFPA Annual Meeting. The document was revised again for the 1976 NFPA Fall Meeting.

A complete review of NFPA 56D was accomplished for the 1981 NFPA Fall Meeting. Major changes included: (1) addition of a statement in then Chapter 1 regarding the application of the standard; (2) updating of all definitions, particularly "oxygen-enriched atmosphere" for purposes of the standard; (3) updating of suggested procedures in the event of a fire in Class A chambers; and (4) a complete review and updating of construction, equipment, administration and maintenance for hyperbaric facilities. Extensive review by the Undersea Medical Society, Inc. was provided in the form of public proposals for that edition, which was designated NFPA 56D-1982.

For this edition, the following major changes were made to the 1982 edition of NFPA 56D: (1) modification of finish requirements for the interior of chambers; (2) incorporation of a TIA making optional the automatic activation of fixed extinguishing system; (3) modification of electrical equipment requirements for chambers which used only compressed air; and (4) modification of exhaust requirements.

Origin and Development of Chapter 11, Hypobaric Facilities

In 1965, when the Subcommittee on Hyperbaric Facilities was appointed, several hospitals were employing hypobaric therapy to treat respiratory diseases. Additionally, NASA and the US Air Force were working with hypobaric chambers for space and air flight. The name of the Subcommittee was then changed to Hyperbaric and Hypobaric Facilities, and the initial version of a document on this subject was prepared. A tentative standard on the subject, NFPA 56E-T, was adopted at the 1971 NFPA Annual Meeting. In May 1972, the document was adopted as an official standard. The document was revised again for the 1977 NFPA Annual Meeting.

A complete review of NFPA 56E was accomplished for the 1981 NFPA Fall Meeting. Major changes included: (1) addition of statement in then Chapter 1 regarding the application of the standard; (2) updating of all definitions including "oxygen-enriched atmosphere" for the purposes of the standard; and (3) complete updating of construction, equipment, fire protection, safe practices and maintenance of hypobaric facilities. That edition was designated NFPA 56E-1982.

For this edition, the major change made to the 1982 edition of NFPA 56E was a complete revision of requirements for Class D chambers to reflect their use for high altitude training purposes. (Such chambers do not require as extensive safety precautions as research and clinical chambers.)

Origin and Development of Appendix D, Health Care Emergency Preparedness

NFPA 3M (now Appendix E of NFPA 99), was first adopted in 1970 as a manual for hospital emergency preparedness. In 1975, the scope was broadened to include other health care facilities, since the need for such information was seen to extend beyond the confines of a hospital. It was also observed that emergency preparedness could involve the coordination of several types of health care facilities. In 1980 it was updated again.

For this edition, the major changes made to the 1980 edition of NFPA 3M were: (1) inclusion of guidance on hazardous material, volcanic eruptions and recovery-planning; (2) expansion of evacuation and relocation guidance; and (3) a new listing of film and slide packages useful in preparing for emergencies.

Origin and Development of Appendix E, Safe Use of High-Frequency Electricity in Health Care Facilities

In the late 1960s, the then NFPA Committee on Hospitals became concerned over the growing incidence of fires, explosions, burns and serious injuries accompanying the use of high-frequency electricity. There were also reports of damage to electronic appliances and distortion of the display of physiologic signals. Medicolegal grievances stemming from injuries due to the improper use of high-frequency had also been noted.

Following a workshop on Electric Hazards in Hospitals (sponsored by the Committee on Anesthesia and the Committee on Shock, Division of Medical Sciences, National Research Council), on April 4-5, 1968, the Committee on Hospitals voted to develop a manual that would define the hazards, describe the effects of high-frequency electricity, and guide its broadening use in medical practice. In 1970, NFPA 76CM, *Manual for the Safe Use of High Frequency Electrical Equipment in Hospitals* was adopted.

After numerous comments by both the medical community and manufacturers the manual was rewritten as a recommended practice. At the same time the Sectional Committee responsible for the document requested, and was granted, a change in its name and scope to more fully indicate the actual use of high-frequency electricity in health care facilities. NFPA 76C, *Recommended Practice on the Safe Use of High-Frequency Electricity in Health Care Facilities* was adopted in November 1975.

The document was revised again in 1980. Changes included updating of practices and reflection of current technology, and an expansion on the subject of the area of dispersive electrodes and power dissipation.

For this edition, relatively minor changes were made to the 1980 edition of NFPA 76C.

Origin and Development of Appendix F, Home Use of Respiratory Therapy

The advancements in the development of equipment and techniques in recent years have resulted in the increased use of respiratory therapy in the home. A manual was developed in the early 1970s by the then Sectional Committee on Inhalation Therapy to provide guidance for the users of this equipment. It was first adopted as a tentative manual, NFPA 56HM-T, at the 1972 NFPA Annual Meeting. It was adopted as a full manual at the 1973 NFPA Annual Meeting, and further amended at the 1976 NFPA Fall Meeting.

NFPA 56HM was revised again for the 1981 NFPA Fall Meeting. Major changes included: (1) inclusion of information and guidance on the use of portable low-pressure liquid oxygen systems; and (2) inclusion of Committee opinion regarding mixing or transfilling of compressed gas cylinders. That edition was designated NFPA 56HM-1982.

For this edition, the major changes made to the 1982 edition of NFPA 56HM were: (1) guidance on transfilling of high-pressure cylinders by suppliers, and their use of a CGA document; (2) additional recommendation by the Committee against patients and family members transfilling high-pressure cylinders; and (3) reference to another CGA document for guidance when transfilling low-pressure liquid oxygen containers in the home environment.

Committee on Health Care Facilities

Correlating Committee

Marvin J. Fischer, Chairman
Brookdale Hospital Medical Center

Burton R. Klein, Secretary
National Fire Protection Association
(Nonvoting)

Saul Aronow, PhD, Project Hope
J. Armand Burgun, Rogers, Burgun, Shahine, & Deschler Architects
Rep. NFPA Comm. on Safety to Life
W. H. L. Dornette, MD, Armed Forces Institute Of Pathology
William T. Guy, Jr., The Elizabeth General Hospital, NJ
Rep. NFPA Health Care Section

David M. Jeffers, York Laboratory Associates
James W. Kerr, Federal Emergency Management Agency
Ralph Loeb, Sherlock Smith & Adams, Inc.
David A. McWhinnie, Jr., Hickory Hills, IL
Ray J. Nichols, MD, University of Texas Medical Branch
Bryan Parker, Montefiore Hospital and Medical Ctr. NY

Technical Committee on Anesthetizing Agents

(Responsible for Chapter 3, Use of Inhalation Anesthetics and Chapter 4, Use of Inhalation Anesthetics in Ambulatory Care Facilities)

W. H. L. Dornette, MD, Chairman
Armed Forces Institute of Pathology

J. Philip Berggren, Secretary
Aetna Life & Casualty Co.

Deryck Duncalf, MD, Montefiore Hospital and Medical Center., NY
Rep. Assoc. for the Advancement of Medical Instrumentation
Leo G. Foxwell, Hartford Insurance Group
Rep. NFPA Comm. on Industrial and Medical Gases
Byron G. Hall, Hospital Corp. of America
George B. Hart, MD, Memorial Hospital Medical Ctr. of Long Beach, CA
Rep. American College of Surgeons
Ode Richard Keil, Joint Comm. on Accreditation of Hospitals, Chicago, IL
W. M. Lampe, Post-Glover, Inc.
Rep. NEMA
Frank Maziariski, American Assn. of Nurse Anesthetists
Norman Menken, DDS, American Analgesia Society
M.T. Merrigan, Underwriters Laboratories, Inc.
James A. Meyer, MD, Loma Linda Veterans Hospital, CA
Rep. American Society of Anesthesiologists

Dr. Ralph A. Milliken, NY Medical College, NY
Allan R. Morse, National Research Council of Canada
Ray J. Nichols, Jr., MD, University of Texas Medical Branch
Rep. American Society of Anesthesiologists
Gerald M. Olderman, American Hospital Supply Corp.
Rep. Health Industry Mfrs. Assn.
John E. Owens, E I du Pont de Nemours & Co.
Rep. NFPA Comm. on Static Electricity
George W. Scrivens, Surgikos Co.
Rep. Intl. Nonwovens & Disposables Assn.
John P. Swope, MD, Derwood, MD
Rep. US Dept. of the Navy
Charles R. Tobin, Puritan Bennett Corp.
Rep. Compressed Gas Assn., Inc.
George N. Webb, Johns Hopkins Hospital, MD
Rep. American Hospital Assn.

Alternates

John M. Bruner, MD, Massachusetts General Hospital
(Alternate to R. J. Nichols, Jr., MD)
William F. Doran, Square D Co., WI
(Alternate to W. H. Lampe)
Dr. Ronald A. Gabel, Brigham and Women's Hospital, MA
(Alternate to D. Duncalf)
Mary Ann Kelly, American Hospital Assn., IL
(Alternate to G. N. Webb)

Paul F. Leonard, MD, Mayo Medical School, MN
(Alternate to J. A. Meyer)
Dr. S. E. Longo, Dr. Salvador E. Longo Assoc.
(Alternate to NFPA Health Care Section Rep.)
Gerald A. McFarren, Wilmington, DE
(Alternate to G. W. Scrivens)
Earl J. Schlosser, Underwriters Laboratories, Inc.
(Alternate to M. J. Merrigan)
Philip E. Shipper, DDS, American Analgesia Society
(Alternate to N. Menken)

Technical Committee on Disaster Planning
(Responsible for Appendix D, Health Care Emergency Preparedness)

James Kerr, Chairman
Federal Emergency Management Agency

John H. Brenner, Peninsula General Hospital Medical Ctr., MD
Rep. NFPA Health Care Section
C. Roger Camplin, Joint Comm. on Accreditation of Hospitals, Chicago, IL
John P. Jarrett, New Paltz Nursing Home, NY
Rep. American Health Care Assn.
John M. MacNeill, Natl. Assn. of Emergency Medical Technicians

Charles F. Morrison, Church Hospital Corp.
Rep. American Hospital Assn.
J. Benjamin Roy, Jr., Office of the State Fire Marshall, DE
Rep. Fire Marshalls Assn. of North America
James Shipley, City of Alexandria, VA

Alternates

Peter J. O'Hagen, Jr., Morristown Memorial Hospital, NJ
(Alternate to J. Brenner)

John A. Zang, American Hospital Assn.
(Alternate to C. Morrison)

**Technical Committee on Essential Electrical Systems
in Health Care Facilities**
(Responsible for Chapter 8, Essential Electrical Systems for Health Care Facilities)

Ralph Loeb, Chairman
Sherlock Smith and Adams, Inc.

Jack W. Barrett, Barrett Associates, Inc.
Harry Callan, Health Services & Promotion Br., Canada
John F. Chapman, Florida Hospital, FL
Rep. NFPA Health Care Section
Bert Coddington, Atherton, CA
Rep. US Dept. of Health & Human Services
Marvin J. Fischer, Brookdale Hospital Medical Ctr., NY
W. H. Frick, East Ohio Gas Co.
Rep. American Gas Assn.
J. Gary Goleski, US Army Corps of Engineers, DC
Rep. US Army Corp of Engineers
George B. Hart, MD, Memorial Hospital Medical Ctr. of Long Beach, CA
Rep. American College of Surgeons
Lawrence F. Hogrebe, Automatic Switch Co.
Gordon S. Johnson, Kohler Co.
Rep. Elec. Generating System Marketing Assn.
Eli G. Katz, North Miami Beach, FL
Ode Richard Keil, Joint Comm. on Accreditation of Hospitals, Chicago, IL

Eugene A. Lakos, The Methodist Hospital, NY
Rep. Greater NY Hospital Assn.
Alfred J. Longhitano, Gage-Babcock & Associates, Inc.
Herbert Marsteller, HEW/OS/OFE, Washington, DC
M. T. Merrigan, Underwriters Laboratories, Inc.
James A. Meyer, MD, Loma Linda Veterans Hospital, CA
Rep. American Society of Anesthesiologists
Richard W. Nalbert, Square D Company
Rep. National Electrical Manufacturers Assn.
John M. Owen, Owen & Mayes, Inc.
Rep. Natl. Society of Professional Engineers
Charles C. Quickel, York Hospital, PA
Rep. American Hospital Assn.
Paul J. Savoie, General Electric Co.
Anthony J. Scalone, US Veterans Admin.
Georg Stromme, Onan Corp.
John P. Swope, MD, Washington, DC
Rep. US Dept. of the Navy
David L. Vosloh, Naval Regional Medical Center, PA

Alternates

Kenneth W. Breher, Square D Company
(Alternate to R. W. Nalbert)
Vernon L. Gatewood, Veterans Administration, DC
(Alternate to J. Scalone)
Paul F. Leonard, MD, Mayo Medical School, MN
(Alternate to J. A. Meyer)

George E. Schall, Jr., Underwriters Laboratories, Inc.
(Alternate to M. T. Merrigan)
Richard diMonda, American Hospital Association
(Alternate to C. C. Quickel)

Technical Committee on Hyperbaric and Hypobaric Facilities (Responsible for Chapter 10, Hyperbaric Facilities and Chapter 11, Hypobaric Facilities)

W. H. L. Dornette, MD, Chairman
Armed Forces Institute of Pathology

John J. Canty, N.E. Baptist Hospital, MA
Rep. American Hospital Assn.
James H. Chappee, US Natl. Aeronautics & Space
Administration
Ronald J. Czajka, Scott Aviation
Rep. Compressed Gas Assn.
Francis T. Gorman, Naval Facilities Engineering Com-
mand
George B. Hart, MD, Memorial Hospital Medical Ctr. of
Long Beach, CA
Rep. American College of Surgeons
John Howard Kimzey, US Natl. Aeronautics & Space
Administration

M. T. Merrigan, Underwriters Laboratories, Inc.
James A. Meyer, MD, Loma Linda Veterans Hospital,
CA
Rep. American Society of Anesthesiologists
Allan R. Morse, Natl. Research Council of Canada
J. Ronald Sechrist, Sechrist Industries
Dr. Paul J. Sheffield, USAF School of Aerospace
Medicine
Cleve T. Svetlik, Johnson and Higgins of Ohio, Inc.
Rep. NFPA Health Care Section
Joseph G. Weiss, Health Corp. of Archdiocese of New-
ark
Rep. Greater NY Hospital Assn.

Alternates

Paul F. Leonard, MD, Mayo Medical School, MN
(Alternate to J. A. Meyer)
Earl J. Schlosser, Underwriters Laboratories, Inc.
(Alternate to M. T. Merrigan)

Joseph Sprague, American Hospital Association
(Alternate to J. J. Canty)

Technical Committee on Laboratories in Health Care Facilities (Responsible for Chapter 7, Laboratories in Health-Related Institutions)

David M. Jeffers, Chairman
York Laboratory Associates

Henry Beltramini, Brigham & Women's Hospital, MA
Spencer Burney, MD, US Veterans Administration
Rep. American Society of Clinical Pathologists
C. Roger Camplin, Joint Comm. on Accreditation of
Hospitals
George D. Harlow, Tufts New England Medical Ctr.,
MA
Rep. American Hospital Assn.
William A. Hawk, MD, Cleveland Clinic Foundation,
OH
Rep. College of American Pathologists
Clifford Houser, Joint Comm. on Accreditation of Hospi-
tals, Chicago, IL

Franklin H. Page, Bossier City General Hospital
Rep. NFPA Comm. on Industrial and Medical Gas
(Vote limited to medical gases)
Albert J. Platt, The Ritchie Organization
Rep. NFPA Health Care Section
William L. Ruff, PhD, Howard University Hospital
Rep. American Assn. for Clinical Chemistry
Earl J. Schlosser, Underwriters Laboratories, Inc.
Norman V. Steere, Norman V. Steere Associates
Rep. NFPA Comm. on Chemistry Labs
Barbara Tucker, Abbott-Northwestern Hospital, Inc.,
MN
Rep. American Society for Medical Technology

Alternates

Gerald A. Hoeltge, MD, Cleveland Clinic Foundation,
OH
(Alternate to W. A. Hawk)
Robert E. Lenhard, Compressed Gas Association
(Alternate to Compressed Gas Assn., Inc.)

Dr. Leroy D. Mell, Uniformed Services Univ.
(Alternate to W. L. Ruff)
M.T. Merrigan, Underwriters Laboratories, Inc.
(Alternate to E. J. Schlosser)
Joseph Sprague, American Hospital Association
(Alternate to G. D. Harlow)

Technical Committee on Medical-Surgical Vacuum Systems in Health Care Facilities

(Responsible for Chapter 6, Medical-Surgical Vacuum Systems in Hospitals)

David Mc Whinnie, Jr., Chairman
Hickory Hills, IL

Leo G. Foxwell, Secretary
Hartford Insurance Group
Rep. NFPA Comm. on Industrial and Medical Gases

Harold K. Haavik, Nash Engineering Co.
George B. Hart, MD, Memorial Hospital Medical Ctr. of
Long Beach, CA
Rep. American College of Surgeons
Henry R. Kaht, Squire-Cogswell Co.
Rep. Compressed Gas Association, Inc.

Donald J. Kohler, Bridgeport Hospital, CT
Rep. American Hospital Assn.
John T. O'Rourke, Oakdale, PA
Richard J. Reilly, Jaros, Baum & Bolles

Alternates

Ray J. Nichols, Jr., MD, Univ. of Texas Medical
Branch
(Alternate to American Society of Anesthesiologists
Rep.)

Richard diMonda, American Hospital Association
(Alternate to D. J. Kohler)

Technical Committee on Respiratory Therapy

(Responsible for Chapter 5, Respiratory Therapy and Appendix F,
Home Use of Respiratory Therapy)

W. H. L. Dornette, MD, Chairman
Armed Forces Institute of Pathology

William D. Clark, The Mary Imogene Bassett Hospital
Rep. American Hospital Assn.
Leo G. Foxwell, Hartford Insurance Group
Rep. NFPA Comm. on Industrial & Medical Gases
George B. Hart, MD, Memorial Hospital Medical Ctr. of
Long Beach, CA
Rep. American College of Surgeons
E. P. Knox, Union Carbide Corp.
Rep. Compressed Gas Assn.
Alan Lipschultz, Waterbury Hospital Health Center,
CT
Rep. Assn. for Advancement of Medical Instrumenta-
tion
Frank Maziarski, American Assn. of Nurse Anesthetists

Ray J. Nichols, Jr., MD, Univ. of Texas Medical
Branch
Rep. American Society of Anesthesiologists
T. K. Raman, MD, Baystate Medical Center, MA
Rep. American College of Chest Physicians
David L. Rowland, Druid City Hospital
Rep. American Association of Respiratory Therapy
Earl J. Schlosser, Underwriters Laboratories, Inc.
John P. Swope, MD, Derwood, MD
Rep. US Dept. of the Navy
Joseph G. Weiss, Health Corp. of the Archdiocese of
Newark
Rep. Greater NY Hospital Assn.

Alternates

J. A. Cedervall, Underwriters Laboratories, Inc.
(Alternate to J. A. Schlosser)
Deryck Duncalf, MD, Montefiore Hospital & Medical
Ctr.
(Alternate to R. J. Nichols)

Dennis A. Hachenberg, St. Luke's Hospital, MO
(Alternate to D. L. Rowland)
Robert E. Lenhard, Compressed Gas Association
(Alternate to E. P. Knox)
Joseph Sprague, American Hospital Association
(Alternate to W. D. Clark)

Technical Committee on Safe Use of Electricity in Patient Care Areas of Health Care Facilities

(Responsible for Chapter 9, Safe Use of Electricity in Patient Care
Areas of Hospitals)

Bryan Parker, Chairman
Montefiore Hospital & Medical Center, NY
(Alternate to A. Lipschultz)

Grady R. Smith, Secretary
US Dept. of Health & Human Services

Saul Aronow, PhD, Project Hope
James H. Bernard, University of Vermont
Rep. N.E. Hospital Engineers Society
Hy Abe Bershad, Staten Island Hospital, NY
Yadin David, Texas Children's Hospital
Rep. The Inst. of Electrical & Electronics Engineers,
Inc.
Alfred M. Dolan, Canadian Standards Assn.
Kenneth J. Dragman, Picker Corp.
Rep. National Electrical Manufacturers Assn.
(Vote limited to matters on radiographic equipment)
George Hart, MD, Memorial Hospital Medical Ctr. of
Long Beach, CA
Rep. American College of Surgeons
Ode Richard Keil, Joint Comm. on Accreditation of
Hospitals, Chicago, IL
Eugene A. Lakos, The Methodist Hospital, NY
Rep. Greater NY Hospital Assn.
Alan Lipschultz, Waterbury Hospital, CT
Rep. Association for the Advancement of Medical
Instrumentation

Alfred J. Longhitano, Gage-Babcock & Associates Inc.
Rep. American Health Care Assn.
M. T. Merrigan, Underwriters Laboratories, Inc.
James A. Meyer, MD, Loma Linda Veterans Hospital,
CA
Rep. American Society of Anesthesiologists
Richard W. Nalbert, Square D Company
Rep. National Electrical Manufacturers Association
(Vote limited to other than radiographic equipment)
Roy W. Nelson, Baptist Memorial Hospital, MO
Donald E. Orner, Geiger Berger Associates
Bernard Stankevich, Aetna Life and Casualty Co.
Rep. American Insurance Association
Howard C. Stauffer, Hospital Corp. of America
John P. Swope, MD, Derwood, MD
Rep. US Dept. of the Navy
Richard L. Troth, VA Office of Construction

Alternates

Mary Ann Kelly, American Hospital Association
(Alternate to H. A. Bershad)
Robert E. Lenhard, Compressed Gas Association
(Alternate to Compressed Gas Assn., Inc.)
Paul F. Leonard, MD, Mayo Medical School, MN
(Alternate to J. A. Meyer)
Robert D. Miller, Hospital Systems, Inc.
(Alternate to R. W. Nalbert)

Lawrence S. Sandler, VA Central Office
(Alternate to R. L. Troth)
George E. Schall, Jr., Underwriters Laboratories, Inc.
(Alternate to M. T. Merrigan)
George N. Webb, Johns Hopkins Hospital, MD
(Alternate to Y. David)

Technical Committee on Safe Use of High-Frequency Electricity in Health Care Facilities

(Responsible for Appendix E, Safe Use of High-Frequency Electricity
in Health Care Facilities)

Saul Aronow, PhD, Chairman
Project Hope

James H. Bernard, University of Vermont
Rep. American Hospital Assn.
John M. Bruner, MD, Massachusetts General Hospital
Rep. American Society of Anesthesiologists
Leslie A. Geddes, PhD, Purdue University
George Hart, MD, Memorial Hospital Medical Ctr. of
Long Beach, CA
Rep. American College of Surgeons

Carl E. Johnson, MD, Mayo Clinic, MN
Paul F. Leonard, MD, Mayo Medical School
John W. Martin, PhD, Cameron-Miller Inc.
M. T. Merrigan, Underwriters Laboratories, Inc.
Charles T. Patrick Jr., NDM Corporation
Joseph G. Weiss, Health Corp. of the Archdiocese of
Newark
Rep. Greater NY Hospital Assn.

Alternates

Gerard Bashein, MD, University of Washington
(Alternate to J. M. Bruner)
Joseph F. DeRosa, NDM Corp.
(Alternate to C. T. Patrick)

Richard diMonda, American Hospital Association
(Alternate to J. H. Bernard)

Technical Committee on Industrial and Medical Gases
 (Not a Health Care Facilities Committee but concurrence required for
 Chapter 5, Respiratory Therapy)

Fred K. Kitson, Chairman
 Air Products & Chemicals, Inc.
 Rep. Compressed Gas Assn., Inc.

W. L. Walls, Secretary
 National Fire Protection Assn.
 (Nonvoting)

J. A. Cedervall, Underwriters Laboratories, Inc.

William H. Doyle, Simsbury, CT

Robert Falaguerra, Phelps Memorial Hospital Center,
 NY

Rep. American Hospital Assn.
 (Vote limited to medical gases)

Leo G. Foxwell, Hartford Insurance Group

Rep. American Insurance Assn.

Charles B. Henrici, Elk Grove Village Fire Dept., IL

Rep. Intl. Assn. of Fire Chiefs

Bernhard K. Kuehn, Compressed Gas Assn., Inc.

James A. Meyer, MD, Loma Linda Veterans Hospital,
 CA

Rep. American Society of Anesthesiologists
 (Vote limited to medical gases)

William W. Russell, Monsanto Co.

Rep. Chemical Manufacturers Assn.

Henry C. Scuoteguazza, Factory Mutual Research
 Corp.

Thomas S. Staron Jr., Industrial Risk Insurers

Arnold Weintraub, US Dept. of Energy

Thomas E. Willoughby, Union Carbide Corp.

Rep. Compressed Gas Assn., Inc.

Alternates

William H. Barlen, Compressed Gas Assn., Inc.
 (Alternate to B. Kuehn)

Robert I. Clift, Industrial Risk Insurers
 (Alternate to T. S. Staron Jr.)

John J. Crowe, Airco Welding Products
 (Alternate to F. K. Kitson)

Marvin E. Kennebeck Jr., American Welding Society
 (Alternate to American Welding Society Rep.)
 (Vote limited to NFPA 51)

David Eric Lees, MD, National Institutes of Health
 (Alternate to J. A. Meyer)

Joseph Sprague, American Hospital Assn.
 (Alternate to F. H. Page)

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Contents

Chapter 1 Introduction	99-1
1-1 Purpose	99-1
1-2 Scope	99-1
1-3 Discretionary Powers of Authority Having Jurisdiction	99-1
Chapter 2 Definitions	99-3
2-1 Official NFPA Definitions	99-3
2-2 Definitions of Terms Used in Standard	99-3
Chapter 3 Use of Inhalation Anesthetics (Flammable and Nonflammable)	99-11
3-1 Introduction	99-11
3-2 Requirements for All Facilities	99-12
3-3 Requirements for Flammable Inhalation Anesthetizing Locations and Flammable Inhalation Anesthetic Agent Storage Locations	99-19
3-4 Nonflammable Anesthetizing Locations	99-29
3-5 Mixed Facilities	99-29
Chapter 4 Use of Inhalation Anesthetics in Ambulatory Care Facilities	99-31
4-1 Introduction	99-31
4-2 Nature of Hazards	99-32
4-3 Equipment	99-32
4-4 Administration and Maintenance	99-33
Chapter 5 Respiratory Therapy	99-35
5-1 Introduction	99-35
5-2 Scope	99-35
5-3 Nature of Hazards	99-35
5-4 Equipment	99-36
5-5 Administration and Maintenance	99-38
Chapter 6 Medical-Surgical Vacuum Systems in Hospitals	99-41
6-1 Introduction	99-41
6-2 Terminal Performance Criteria	99-41
6-3 System Components	99-42
6-4 Warning Systems	99-45
6-5 Installation of Piping System	99-45
6-6 Maintenance and System Protection	99-46
Chapter 7 Laboratories in Health-Related Institutions	99-47
7-1 Introduction and Scope	99-47
7-2 Nature of Hazards	99-47
7-3 Structure, Equipment, and Fire Protection	99-47
7-4 Flammable and Combustible Liquids	99-49
7-5 Gases	99-50
7-6 Maintenance and Inspection	99-51
Chapter 8 Essential Electrical Systems for Health Care Facilities	99-53
8-1 General	99-53
8-2 General Systems Requirements	99-53
8-3 Essential Electrical Systems for Hospitals	99-56
8-4 Essential Electrical Systems for Nursing Homes and Residential Care Facilities	99-59
8-5 Essential Electrical Systems for Other Health Care Facilities	99-60
Chapter 9 Safe Use of Electricity in Patient Care Areas of Hospitals	99-63
9-1 Introduction	99-63
9-2 Electrical Power Systems for Patient Care Areas	99-64
9-3 Hospital Requirements for Electric Appliances in Patient Care Areas	99-67
9-4 Administration and Maintenance	99-70
9-5 Requirements for Manufacturers of Patient Care-Related Electric Appliances	99-71

Chapter 10 Hyperbaric Facilities	99-79
10-1 Introduction and Scope	99-79
10-2 Construction and Equipment	99-80
10-3 Administration and Maintenance	99-85
Chapter 11 Hypobaric Facilities	99-89
11-1 General	99-89
11-2 Construction and Equipment	99-90
11-3 Administration and Maintenance	99-94
Chapter 12 Mandatory Referenced Publications	99-99
Appendix A Explanatory Notes to Chapters 1-11	99-101
Appendix B Informatory Referenced Publications	99-119
Appendix C Additional Explanatory Notes to Chapters 1-11	99-121
Appendix D Health Care Emergency Preparedness	99-149
Appendix E Safe Use of High-Frequency Electricity in Health Care Facilities	99-161
Appendix F Home Use of Respiratory Therapy	99-175
Cross Reference to Previous Individual Documents	99-183
Chronology of Health Care Documents	99-187
Index	99-189

NOTICE

Following release of this edition of NFPA 99, *Standard for Health Care Facilities*, an appeal was filed with the NFPA Board of Directors.

The appeal requests that Section 3-2.3.1 be changed to require isolated power systems as originally proposed in the Technical Committee Report for NFPA 99-1984. NFPA will announce the disposition of the appeal when it has been determined. Anyone wishing to receive automatically the disposition of the appeal should notify in writing the Secretary, Standards Council, NFPA Headquarters.

**Standard for
Health Care Facilities**

NFPA 99-1984

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.

Information on referenced publications can be found in Chapter 12 and Appendix B.

Chapter 1 Introduction

1-1 Purpose.

The purpose of this standard is to bring into one document all standards, recommended practices, and manuals under the jurisdiction of the Health Care Facilities Correlating Committee.

1-2 Scope.

The scope of this standard consists of the scopes included at the beginning of each chapter and Appendices D, E, and F herein.

1-3 Discretionary Powers of Authority Having Jurisdiction. The authority having jurisdiction for the enforcement of this standard shall be permitted to grant exceptions to its requirements.

Chapter 2 Definitions

[Secretary's Note: The Health Care Facilities Correlating Committee has correlated definitions that were contained in each of the documents under its jurisdiction, and selected a definition in those instances (1) where two or more Health Care Facilities documents had defined the term and also (2) where the definitions differed from each other (which in all instances was minor). The Correlating Committee also selected a committee in those instances where more than one committee defined a term. The letters in parentheses at the end of each definition refer to the Technical Committee responsible for defining the term. Key to identifying committees is as follows:

Technical Committee on:

- (AA): Anesthetizing Agents
- (DIS): Disaster Planning
- (EES): Essential Electrical Systems in Health Care Facilities
- (HHF): Hyperbaric and Hypobaric Facilities
- (LAB): Laboratories in Health Care Facilities
- (MSVS): Medical-Surgical Vacuum Systems in Health Care Facilities
- (RT): Respiratory Therapy
- (SUE): Safe Use of Electricity in Patient Care Areas of Health Care Facilities
- (SUH): Safe Use of High-Frequency Electricity in Patient Care Areas of Health Care Facilities]

For purposes of this standard, the following definitions apply as indicated.

2-1 Official NFPA Definitions.

Approved. Acceptable to the "authority having jurisdiction."

NOTE: The National Fire Protection Association does not approve, inspect or certify any installations, procedures, equipment, or materials nor does it approve or evaluate testing laboratories. In determining the acceptability of installations or procedures, equipment or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations which is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The "authority having jurisdiction" is the organization, office or individual responsible for "approving" equipment, an installation or a procedure.

NOTE: The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner since jurisdictions and "approval" agencies vary as do their responsibilities. Where public safety is primary, the "authority having jurisdiction" may be a federal, state, local or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, health department, building official, electrical inspector, or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the "authority having jurisdiction." In many circumstances the property owner or his designated agent assumes the role of the "authority having jurisdiction"; at government installations, the commanding officer or departmental official may be the "authority having jurisdiction."

Code. A Document containing only mandatory provisions using the word "shall" to indicate requirements and in a form generally suitable for adoption into law. Explanatory material may be included only in the form of "fine print" notes, in footnotes, or in an appendix.

Labeled. Equipment or materials to which has been attached a label, symbol or other identifying mark of an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed. Equipment or materials included in a list published by an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The "authority having jurisdiction" should utilize the system employed by the listing organization to identify a listed product.

Manual or Guide. A Document which is informative in nature and does not contain requirements.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Standard. A Document containing only mandatory provisions using the word "shall" to indicate requirements. Explanatory material may be included only in the form of "fine print" notes, in footnotes, or in an appendix.

2-2 Definitions of Terms Used in the Standard.

ACFM. Actual cubic feet per minute. The unit used to express the measure of the volume of gas flowing at operating temperature and pressure, as distinct from the volume of a gas flowing at standard temperature and pressure (*see definition of SCFM*). (MSVS)

Adiabatic Heating. The heating of a gas caused by its compression. (HHF)

Administration, Area of. The room in which oxygen is being administered, except that rooms containing more than two patients shall be designated as patient wards. The area of administration in patient wards shall be any point within 15 ft (4.3 m) of oxygen equipment or an enclosure containing or intended to contain an oxygen-enriched atmosphere. In all cases the area of administration shall include access aisles and immediately adjacent patient beds. (RT)

Administration, Site of. All points within 1 ft (.3 m) of oxygen administration equipment (including oxygen-powered aspirators) except that if the equipment contains, or is intended to contain, an oxygen-enriched atmosphere

larger than 2 L (.56 gal) in volume (measured at atmospheric pressure), the site of administration shall include all points within 5 ft (1.5 m) of the equipment. (RT)

Aerosol. An intimate mixture of a liquid or a solid in a gas; the liquid or solid, called the dispersed phase, is uniformly distributed in a finely divided state throughout the gas, which is the continuous phase or dispersing medium. (RT)

Air, Oil-Free, Dry. Air complying, as a minimum, with Grade "D" in CGA Pamphlet G-7.1, *Commodity Specification for Air*, and having a maximum dew point of -63°F (-52.8°C). (AA)

Alternate Power Source. One or more generator sets, or battery systems where permitted, intended to provide power during the interruption of the normal electrical service; or the public utility electrical service intended to provide power during interruption of service normally provided by the generating facilities on the premises. (EES)

Ambulatory Care Facility. A facility, not hospital-based, wherein nonflammable inhalation anesthetic agents are administered to ambulatory patients for the production of general anesthesia or relative analgesia. (AA)

Ampacity. Current-carrying capacity of electric conductors expressed in amperes. (SUE)

Anesthetic. As used in this standard, applies to any inhalation agent used to produce relative analgesia or general anesthesia. (AA)

Anesthetizing Location. Any area of the facility which has been designated to be used for the administration of any flammable or nonflammable inhalation anesthetic agents in the course of examination or treatment, including the use of such agents for relative analgesia (see definition of *Relative Analgesia*). (AA)

Anoxia. A state of markedly inadequate oxygenation of the tissues and blood, of more marked degree than hypoxia. (HHF)

Antistatic. Adjective describing that class of materials which includes conductive materials and, also, those materials which throughout their stated life, meet the requirements of 3-3.6.6.3 and 3-3.6.6.4 of Chapter 3. (AA)

Apparatus. Furniture, laboratory hoods, centrifuges, refrigerators, and commercial or man-made on-site apparatus or equipment used in a laboratory. (LAB)

Appliance. Electrical equipment, generally other than industrial, normally built in standardized sizes or types, which is installed or connected as a unit to perform one or more functions. (SUE)

Applicator. A means of applying high-frequency energy to a patient other than by an electrically conductive connection. (SUH)

NOTE: An applicator is not an electrode in the above sense since it does not use a conductive connection to the patient in order to function. The radio frequency "horn" of a diathermy machine is a typical applicator.

Atmosphere. The pressure exerted by, and gaseous composition of, an environment. As employed in this standard, atmosphere may refer to the environment within or outside of the hypobaric facility. When used as a measure of pressure, atmosphere is expressed as a fraction of standard air pressure (14.7 psi). (See *Appendix C-11.3, Pressure Table, Col. 1.*) (HHF)

Atmosphere, Absolute (ATA). (See definition of *Atmosphere*.) Two ATA = two atmospheres. (HHF)

Atmosphere, Ambient. The pressure and composition of the environment surrounding the chamber. (HHF)

Atmosphere, Chamber. The environment inside the chamber. (HHF)

Automatic. Self-acting, operating by its own mechanism when actuated by some impersonal influence as, for example, a change in current, voltage, pressure, temperature, or mechanical configuration. (EES)

Bends. Decompression sickness, caisson worker's disease. (See *Appendix C-10-1.3.3.2.*) (HHF)

Branch Circuit. The circuit conductors between the final overcurrent device protecting the circuit and the outlet(s). (SUE)

Cannula, Nasal. Device consisting of two short tubes to be inserted into the nostrils to administer oxygen or other therapeutic gases. (RT)

Catheter, Nasal. A flexible tube for insertion through the nose into the nasopharynx to administer oxygen or other therapeutic gases. (RT)

Cold Room. A refrigerated area large enough for personnel to enter. (LAB)

Combustible. A substance that will react with oxygen, if ignited, and burn. (AA)

Combustible Liquid. See definition of Liquids and Appendix C-7-2.1. (LAB)

Combustion. A chemical process (such as oxidation) accompanied by the rapid evolution of heat and light. (AA)

NOTE: Combustion is not limited to a chemical reaction always involving oxygen. Certain metals, such as calcium and aluminum, will burn in nitrogen; nitrous oxide will support the combustion of phosphorous and carbon; etc. However, this document deals with the more common process of fuels burning in air.

Combustion Products. The gases, volatilized liquids and solids, particulate matter and ash generated by combustion. (AA)

Conductive. Adjective describing not only those materials, such as metals, which are commonly considered as electrically conductive, but also that class of materials which, when tested in accordance with this document, have a resistance not exceeding 1,000,000 ohms. Such materials are required where electrostatic interconnection is necessary. (AA)

Container. A low-pressure, vacuum insulated vessel containing oxygen in liquid form at approximately -300°F (-184.4°C). (RT)

Critical Branch. A subsystem of the Emergency System consisting of feeders and branch circuits supplying energy to task illumination, special power circuits, and selected receptacles serving areas and functions related to patient care, and which can be connected to alternate power sources by one or more transfer switches during interruption of normal power source. (EES)

Critical Equipment. That equipment essential to the safety of the occupants of the facility. (HHF)

Critical System. A system of feeders and branch circuits in nursing homes and residential custodial care facilities arranged for connection to the alternate power source to restore service to certain critical receptacles, task illumination and equipment. (EES)

Cylinder. A supply tank containing high-pressure gaseous oxygen or oxygen mixtures at pressures which may be in excess of 2000 psig (13.8 kPa). (RT)

Decompression Sickness. A syndrome due to evolved gas in the tissues resulting from a reduction in ambient pressure. (HHF)

Detonation. An exothermic reaction wherein the reaction propagates through the unrelated material at a rate exceeding the velocity of sound, hence the explosive noise. (AA)

Direct Electrical Pathway to the Heart. An externalized conductive pathway, insulated except at its ends, one end of which is in direct contact with heart muscle and the other outside the body, and is accessible for inadvertent or intentional contact with grounded objects or energized, ground-referenced sources. Catheters filled with conductive fluids and electrodes, such as may be used for pacing the heart, are examples of direct electrical pathways to the heart. (SUE)

Double-Insulated Appliances. Appliances having an insulation system comprising both the basic insulation necessary for the functioning of the appliance and for basic protection against electric shock, and the supplementary insulation. The supplementary insulation is independent insulation provided in addition to the basic insulation to ensure protection against electric shock in case of failure of the basic insulation. (SUE)

Electrical Life Support Equipment. Electrically powered equipment whose continuous operation is necessary to maintain a patient's life. (EES)

Electrode. A device intended to provide an electrically conductive connection through a cable to a patient. Some electrodes of interest are: (SUH)

Active Electrode. An electrode intended to generate a surgical effect at its point of application to the patient. (SUH)

Dispersive Electrode. An electrode intended to complete the electrical path between patient and appliance,

and at which no surgical effect is intended. It is often called the "indifferent electrode," the "return electrode," the "patient plate," or the "neutral electrode." (SUH)

Emergency System. A system of feeders and branch circuits in meeting the requirements of Article 700 of NFPA 70, *National Electrical Code*, and intended to supply alternate power to a limited number of prescribed functions vital to the protection of life and safety, with automatic restoration of electrical power within 10 seconds of power interruption. (EES)

Equipment Grounding Bus. A grounding terminal bus in the feeder circuit of the branch circuit distribution panel which serves a particular area. (SUE)

Equipment System. A system of feeders and branch circuits arranged for automatic or manual connection to the alternate power source and which serves primarily three-phase power equipment. (RT)

Essential Electrical System. A system comprised of alternate sources of power and all connected distribution systems and ancillary equipment, designed to assure continuity of electrical power to designated areas and functions of a health care facility during disruption of normal power sources, and also designed to minimize disruption within the internal wiring system. (EES)

Exposed Conductive Surfaces. Those surfaces which are capable of carrying electric current and which are unprotected, uninsulated, unenclosed or unguarded, permitting personal contact. (SUE)

Failure. An incident which increases the hazard to personnel or patients or affects the safe functioning of electric appliances or devices. It includes failure of a component, loss of normal protective paths such as grounding, and short circuits or faults between energized conductors and the chassis. (SUE)

Fault Current. A current in an accidental connection between an energized and a grounded or other conductive element resulting from a failure of insulation, spacing, or containment of conductors. (SUE)

Feeder. All circuit conductors between the service equipment, or the generator switchboard of an isolated plant, and the final branch circuit overcurrent device. (SUE)

Flame Resistant. Where flame resistance of a material is required by this standard, that material shall pass successfully the small scale test described in NFPA 701, *Standard Methods of Fire Tests for Flame-Resistant Textiles and Films*, except that the test shall be conducted in the gaseous composition and maximum pressure at which the chamber will be operated. (HHF)

NOTE: A source of ignition alternate to the gas burner specified in NFPA 701 may be required for this test if it is to be performed in 100 percent oxygen at several atmospheres pressure.

Flame Retardant. (See definition of *Flame Resistant*.) (HHF)

Flammable. An adjective describing easy ignition, intense burning and rapid rate of flamespread during combustion. It may also be used as a noun to mean a "flammable substance." Many substances nonflammable in air become flammable if the oxygen content of the gaseous medium is increased above 0.235 ATA. (AA)

Flammable Anesthetizing Location. Any area of the facility which has been designated to be used for the administration of any flammable inhalation anesthetic agents in the normal course of examination or treatment. (AA)

Flammable Gas. Any gas that will burn when mixed in any proportion with air, oxygen, or nitrous oxide. (LAB)

Flammable Liquid. See definition of Liquids and Appendix C-7-2.1. (LAB)

Flash Point. The minimum temperature at which a liquid gives off vapor in sufficient concentration to form an ignitable mixture with air near the surface of the liquid within the vessel, as specified by appropriate test procedures and apparatus. (See Appendix C-7-2.2.) (LAB)

Flow Control Valve. A valve, usually a needle valve, which precisely controls flow of gas. (RT)

Flowmeter. A device for measuring volumetric flow rates of gases and liquids. (RT)

Flowmeter, Pressure Compensated. A flowmeter indicating accurate flow of gas whether the gas is discharged into ambient pressure or into a system at non-ambient pressure. (DIS)

Frequency. The number of oscillations, per unit time, of a particular current or voltage waveform. (Note: The waveform may consist of components having many different frequencies, in which case it is called a complex or nonsinusoidal waveform.) The unit of frequency is the hertz. Formerly the unit of frequency was cycles per second, a terminology no longer preferred. (SUE)

Governing Body. The governing body is the person or persons who have the overall legal responsibility for the operation of the hospital. (See "Accreditation Manual for Hospitals," Joint Commission on Accreditation of Hospitals, Chicago, 1980.) (AA)

Ground Fault Circuit Interrupter. A device whose function is to interrupt the electric circuit to the load when a fault current to ground exceeds some predetermined value that is less than that required to operate the overcurrent protective device of the supply circuit. (SUE)

Grounding. A system of conductors which provides a low-impedance return path for leakage and fault currents. It coordinates with, but may be locally more extensive than, the grounding system described in Article 250, NFPA 70, *National Electrical Code*. (SUE)

Grounding System. A system of conductors which provides a low-impedance return path for leakage and fault

currents. It coordinates with, but may be locally more extensive than, the grounding system described in Article 250 of NFPA 70, *National Electrical Code*. (AA)

Hazard Current. For a given set of connections in an isolated power system, the total current that would flow through a low impedance if it were connected between either isolated conductor and ground. The various hazard currents are: (AA)

Fault Hazard Current. The hazard current of a given isolated power system with all devices connected except the Line Isolation Monitor. (AA)

Monitor Hazard Current. The hazard current of the Line Isolation Monitor alone. (AA)

Total Hazard Current. The hazard current of a given isolated system with all devices, including the Line Isolation Monitor, connected. (AA)

Hazardous Area in a Flammable Anesthetizing Location.* The space extending 152 cm (5 ft) above the floor in a flammable anesthetizing location. (See 3-3.2 and Appendix A-2-2.) (AA)

Hazardous Area in Laboratories. The area inside fume hoods or enclosures where tests or procedures are being conducted under the conditions listed in 7-4.4.1. (LAB)

Hazardous Chemical.* A chemical with one or more of the following hazard ratings as defined in NFPA 704, *Standard System for the Identification of Fire Hazards of Materials*: Health — 2, 3, or 4; Flammability — 2, 3, or 4; Reactivity — 2, 3, or 4. (See Appendices A-2-2 and C-7-2.3.) (LAB)

Hazardous Location. An anesthetizing location or any location where flammable agents are used or stored. (AA)

Health Care Facilities. Buildings or portions of buildings that contain, but are not limited to, occupancies such as: hospitals; nursing homes; residential-custodial care; supervisory care; clinics, medical and dental offices; and ambulatory health care facilities, whether permanent or movable. (EES)

Hood, Oxygen. A device encapsulating the patient's head, and used for a purpose similar to a mask. (See definition of Mask.) (HHF)

Hospital-based. In the interpretation and application of this document, physically connected to a hospital. (AA)

Hospital Facility. A building or part thereof used for the medical, psychiatric, obstetrical or surgical care, on a 24-hour basis, of four or more inpatients. Hospital, wherever used in this standard, shall include general hospitals, mental hospitals, tuberculosis hospitals, children's hospitals, and any such facilities providing inpatient care. (SUE)

Humidifier. A device used for adding water vapor to the inspired gas. (RT)

Hyperbaric. An adjective referring to pressures above atmospheric pressure. (HHF)

Hyperbaric Oxygenation. The application of pure oxygen or an oxygen-enriched gaseous mixture to a subject at elevated pressure. (HHF)

Hypobaric. An adjective referring to pressures below atmospheric pressure. (HHF)

Hypoxia. A state of inadequate oxygenation of the blood and tissue. (HHF)

Immediate Restoration of Service. Automatic restoration of operation with an interruption of not more than 10 seconds. (EES)

Impedance. Impedance is the ratio of the voltage drop across a circuit element to the current flowing through the same circuit element. The circuit element may consist of any combination of resistance, capacitance or inductance. The unit of impedance is the ohm. (SUH)

Intermittent Positive Pressure Breathing (IPPB). Ventilation of the lungs by application of intermittent positive pressure to the airway. (RT)

Intrinsically Safe. As applied to equipment and wiring, equipment and wiring which are incapable of releasing sufficient electrical energy under normal or abnormal conditions to cause ignition of a specific hazardous atmospheric mixture. Abnormal conditions may include accidental damage to any part of the equipment or wiring, insulation or other failure of electrical components, application of over-voltage, adjustment and maintenance operations and other similar conditions. (HHF)

Isolated Patient Lead. A patient lead whose impedance to ground or the power line is sufficiently high that connecting the lead to ground, or to either conductor of the power line, results in current flow in the lead which is below a hazardous limit. (SUE)

Isolated Power System. A system comprising an isolating transformer or its equivalent, a Line Isolation Monitor and its ungrounded circuit conductors. (See *NFPA 70, National Electrical Code.*) (AA)

Isolation Transformer. A transformer of the multiple-winding type, with the primary and secondary windings physically separated, which inductively couples its ungrounded secondary winding to the grounded feeder system that energizes its primary winding. (AA)

Laboratory. A building, space, room or group of contiguous rooms located in any part of a hospital or health care-related facility and intended to serve activities involving procedures for investigation, diagnosis or treatment in which flammable, combustible or oxidizing materials are to be used. These laboratories are not intended to include

isolated frozen section laboratories; areas in which oxygen is administered; blood donor rooms in which flammable, combustible or otherwise hazardous materials normally used in laboratory procedures are not present; and clinical service areas not using hazardous materials. (LAB)

Laboratory Equipment. See definition of Apparatus. (LAB)

Laboratory Hood. An enclosure designed to transform the suction of an exhaust system into an air flow across the face of the enclosure to prevent the release of hazardous materials back into the laboratory work area. This definition does not include canopy hoods or recirculating laminar flow biological safety cabinets which may not be designed for use with flammable materials. (LAB)

Laboratory Unit. An enclosed space used for experiments or tests. A laboratory unit may or may not include offices, lavatories, and other contiguous rooms maintained for or used by laboratory personnel and corridors within the units. It may contain one or more separate laboratory work areas. It may be an entire building. (LAB)

Laboratory Unit Separation. All walls, partitions, floors, and ceilings, including openings in them, which separate a laboratory unit from adjoining areas. (LAB)

Laboratory Work Area. A room or space for testing, analysis, research, instruction, or similar activities which involve the use of chemicals. This work area may or may not be enclosed. (LAB)

Leakage Current. Any current, including capacitively coupled current, not intended to be applied to a patient but which may be conveyed from exposed metal parts of an appliance to ground or to other accessible parts of an appliance. (SUE)

Life Safety Branch. A subsystem of the Emergency System consisting of feeders and branch circuits, meeting the requirements of Article 700 of *NFPA 70, National Electrical Code*, and intended to provide adequate power needs to ensure safety to patients and personnel, and which can be automatically connected to alternate power sources during interruption of the normal power source. (EES)

Line Isolation Monitor. An instrument which continually checks the hazard current from an isolated circuit to ground. (HHF)

Liquids. Any material which has a fluidity greater than that of 300 penetration asphalt when tested in accordance with ASTM D5-73, *Test for Penetration of Bituminous Materials*. When not otherwise identified, the term liquid shall include both flammable and combustible liquids. (See *Appendix C-7-2.1.*) (LAB)

Macroshock. The effect of large electric currents (milliamperes or larger) on the body. (AA)

Manifold. A device for connecting two or more high-pressure gas cylinders to a common header, with appropriate CGA connections and check valves. (AA)

Mask. A device that fits over the mouth and nose (oronasal) or nose (nasal), used to administer gases to a patient. (AA)

Mask, Oronasal. A device which fits over the mouth and nose, to deliver therapeutic gases to the user. (HHF)

Medical Laboratory. As used in this standard means limited suction usage rooms in routine, direct support of patient therapy (as contrasted with laboratories used extensively or exclusively for analysis, research, and teaching). (MSVS)

Medical-Surgical Vacuum System. A system consisting of central vacuum producing equipment with pressure and operating controls, shutoff valves, alarm warning systems, gauges, and a network of piping extending to and terminating with suitable terminals (inlets) at locations where patient suction may be required. (MSVS)

Microshock. The effect of small electric currents (as low as 10 microamperes) on the body. To be hazardous, such currents must be applied to a conductor inside or in very close proximity to the heart. (AA)

Mixed Facility. A facility wherein flammable anesthetizing locations and nonflammable anesthetizing locations coexist within the same building, allowing interchange of personnel or equipment between flammable and nonflammable anesthetizing locations. (AA)

Nebulizer. A device used for producing an aerosol of water and/or medication within inspired gas supply. (RT)

Negative Pressure. Pressure less than atmospheric. (RT)

Nitrogen. An element which, at atmospheric temperatures and pressures, exists as a clear, colorless, and tasteless gas; it comprises approximately four-fifths of the earth's atmosphere. (AA)

Nitrogen Narcosis. A condition resembling alcoholic inebriation, which results from breathing nitrogen in the air under significant pressure. (See C-10-1.3.1.2.) (HHF)

Nitrogen, Oil-Free, Dry. Nitrogen complying, as a minimum, with Grade "D" in CGA Pamphlet G-10.1, *Commodity Specification for Nitrogen*, as used for cleaning pipelines. (AA)

Nitrous Oxide. An inorganic compound, one of the oxides of nitrogen; it exists as a gas at atmospheric pressure and temperature, possesses a sweetish smell and is capable of inducing the first and second stages of anesthesia when inhaled; the oxygen in the compound will be released under conditions of combustion, creating an oxygen-enriched atmosphere. (AA)

Noncombustible (Hyperbaric). Within the context of Chapter 10, Hyperbaric Facilities, an adjective describing a substance that will not burn in 95 ± 5 percent oxygen at pressures up to 3 ATA (44.1 psia). (HHF)

Noncombustible (Hypobaric). Within the context of Chapter 11, Hypobaric Facilities, an adjective describing a substance that will not burn in 95 ± 5 percent oxygen at pressures of 760 mmHg. (HHF)

Nonflammable. An adjective describing a substance that will not burn under the conditions set forth in the definition of Flame Resistant. (HHF)

Nonflammable Anesthetic Agent.* Refers to those inhalation agents which, because of their vapor pressure at 98.6°F (37°C) and at atmospheric pressure, cannot attain flammable concentrations when mixed with air, oxygen, or mixtures of oxygen and nitrous oxide. (AA)

Nonflammable Anesthetizing Location. Any anesthetizing location designated for the exclusive use of nonflammable anesthetizing agents. (AA)

Nonflammable Medical Gas System. A system of piped oxygen, nitrous oxide, compressed air or other nonflammable medical gases. (See NFPA 56F, *Standard for Nonflammable Medical Gas Systems*.) (AA)

Oxidizing Gas. A gas which supports combustion. Oxygen and nitrous oxide are examples of oxidizing gases. There are many others including halogens. (HHF)

Oxygen. An element which, at atmospheric temperatures and pressures, exists as a colorless, odorless, tasteless gas. Its outstanding property is its ability to sustain life and to support combustion. Although oxygen is nonflammable, materials which burn in air will burn much more vigorously and create higher temperatures in oxygen or in oxygen-enriched atmospheres. (AA)

Oxygen Delivery Equipment. Any device used to transport and deliver an oxygen-enriched atmosphere to a patient. (RT)

Oxygen Index. The minimum concentration of oxygen, expressed as percent by volume, in a mixture of oxygen and nitrogen which will just support combustion of a material under conditions of ASTM Method D-2863. (HHF)

Oxygen Toxicity (Hyperbaric). Physical impairment resulting from breathing gaseous mixtures containing oxygen-enriched atmospheres at elevated pressures for extended periods of time. Under the pressures and times of exposure normally encountered in hyperbaric treatments, toxicity is a direct function of concentration and time of exposure. (See Appendix C-10.1.3.1.3.) (HHF)

Oxygen Toxicity (Hypobaric). Physical impairment usually resulting from breathing gaseous mixtures containing oxygen-enriched atmospheres at elevated pressures for extended periods of time; it may occur under the pressures and duration of exposure normally encountered in long-duration hypobaric exposures, since toxicity is a direct function of concentration and time of exposure, and involves toxicity of the lung. (HHF)

Oxygen, Gaseous. A colorless, odorless and tasteless gas; and the physical state of the element at atmospheric temperature and pressure. (RT)

Oxygen, Liquid. Exists at cryogenic temperature, approximately -300°F (-184.4°C) at atmospheric pressure. It retains all of the properties of gaseous oxygen, but, in addition, when allowed to warm to room temperature at atmospheric pressure, it will evaporate and expand to fill a volume 860 times its liquid volume. If spilled, the liquid can cause frostbite on contact with skin. (RT)

Oxygen-Enriched Atmosphere.* Any atmosphere containing a percentage of oxygen, or oxygen and nitrous oxide, greater than the quotient of 23.45 divided by the square root of the total pressure in atmospheres, i.e.,

$$\frac{23.45}{\sqrt{T.P._{atmos.}}} \text{ where } T.P._{atmos.} = \text{total pressure in atmospheres}$$

(See Appendix A-2-2.) (HHF)

Psia. Pounds per square inch absolute, a unit of pressure measurement with zero pressure as the base or reference pressure. (HHF)

Psig. Pounds per square inch gauge, a unit of pressure measurement with atmospheric pressure as the base or reference pressure (under standard conditions, 0 psig is equivalent to 14.7 psia). (HHF)

Patient Care-Related Electrical Appliance. An electrical appliance that is intended to be used for diagnostic, therapeutic or monitoring purposes in a patient care area. (SUE)

Patient Equipment Grounding Point. A jack or terminal which serves as the collection point for redundant grounding of electric appliances serving a patient vicinity or for grounding other items in order to eliminate electromagnetic interference problems. (SUE)

Patient Lead. Any deliberate electrical connection which may carry current between an appliance and a patient. This may be a surface contact (e.g., an ECG electrode); an invasive connection (e.g., implanted wire or catheter); or an incidental long-term connection (e.g., conductive tubing). It is not intended to include adventitious or casual contacts such as pushbutton, bed surface, lamp, hand-held appliance, etc. (SUE)

NOTE: Also see definition of Isolated Patient Lead.

Patient Vicinity. In an area in which patients are normally cared for, the patient vicinity is the space with surfaces likely to be contacted by the patient or an attendant who can touch the patient. Typically in a patient room, this encloses a space within the room 6 ft (1.8 m) beyond the perimeter of the bed in its nominal location and extending vertically within 7 ft 6 in. (2.3 m) of the floor. (SUE)

Piping. The tubing or conduit of the vacuum system. There are three general classes of piping, as follows: (MSVS)

Branch (Lateral) Lines. Those sections or portions of the vacuum piping system which serve a room or group of rooms on the same story of the facility. (MSVS)

Risers. The vertical pipes connecting the vacuum system main line(s) with the branch lines on the various levels of the facility. (MSVS)

Main Lines. Those parts of the vacuum system that connect the vacuum source (pumps, receivers, etc.) to the risers or branches, or both. (MSVS)

Plug (Attachment Plug, Cap). A device which, by insertion in a receptacle, establishes connection between the conductors of the attached flexible cord and the conductors connected permanently to the receptacle. (SUE)

Positive Pressure. Pressure greater than ambient atmospheric. (RT)

Positive-Negative Pressure Breathing. Ventilation of the lungs by the application of intermittent positive-negative pressure to the airway. (RT)

Pressure Reducing Regulator. A device which automatically reduces gas under high pressure to a usable lower working pressure. In hospitals, the term "regulator" is frequently used to describe a regulator which incorporates a flow measuring device. (RT)

Pressure, Absolute. The total pressure in a system with reference to zero pressure. (HHF)

Pressure, Ambient. Refers to total pressure of the environment referenced. (HHF)

Pressure, Gauge. Refers to total pressure above (or below) atmospheric. (HHF)

Pressure, High. A pressure exceeding 200 psig (1.38 kPa)(215 psia). (RT)

Pressure, Partial. The pressure, in absolute units, exerted by a particular gas in a gas mixture (the pressure contributed by other gases in the mixture is ignored). For example, oxygen is one of the constituents of air; the partial pressure of oxygen in standard air, at a standard air pressure of 14.7 psia, is 3.06 psia or 0.208 ATA or 158 mmHg. (HHF)

Pressure, Working. A pressure not exceeding 200 psig (11.6 kg/cm²). A pipeline working pressure of 50 to 55 psig (2.9 to 3.2 kg/cm²) is conventional because medical gas equipment is generally designed and calibrated for use at this pressure. (RT)

Quiet Ground. A system of grounding conductors, insulated from portions of the conventional grounding of the power system, which interconnects the grounds of electric appliances for the purpose of improving immunity to electromagnetic noise. (SUE)

Reactance. The component of impedance contributed by inductance or capacitance. The unit of reactance is the ohm. (SUH)

Reactive Material. A material that, by itself, is readily capable of detonation, explosive decomposition, or explosive reaction at normal or elevated temperatures and pressures. (See Appendix C-7-2.3 for definitions of Reactivity 3 and Reactivity 4.) (LAB)

Reference Grounding Point. A terminal bus which is the equipment grounding bus, or an extension of the equipment grounding bus, and is a convenient collection point for installed grounding wires or other bonding wires where used. (SUE)

Refrigerating Equipment. Any mechanically operated equipment used for storing, below normal ambient temperature, hazardous materials having flammability ratings of 3 or 4. It includes refrigerators, freezers, and similar equipment. (LAB)

Relative Analgesia. A state of sedation and partial block of pain perception produced in the patient by the inhalation of concentrations of nitrous oxide insufficient to produce loss of consciousness (conscious sedation). (AA)

SCFM. Standard cubic feet per minute. The unit used to express the measure of the volume of a gas flowing at standard conditions — a temperature of 68°F (20°C) and a pressure of one atmosphere (29.92 in. of Hg). (MSVS)

Safety Can. An approved container, of not more than 5 gal (15.5 L) capacity, having a spring-closing lid and spout cover and so designed that it will safely relieve internal pressure when subjected to fire exposure. (LAB)

Selected Receptacles. Minimal electrical receptacles to accommodate appliances ordinarily required for local tasks or likely to be used in patient care emergencies. (EES)

Self-Extinguishing. A characteristic of a material such that once the source of ignition is removed, the flame is quickly extinguished without the fuel or oxidizer being exhausted. (HHF)

Slow Burning. As used in this standard, the term "slow burning" refers to an Underwriters Laboratories, Inc. test procedure. In this small-scale test, conducted in air at atmospheric pressure, a sample 6 in. (15.24 cm) long, ½

in. (1.27 cm) wide, and of ¼ in. (0.32 cm) nominal thickness is suspended with longitudinal axis horizontal and transverse axis 45 degrees to the horizontal. A Bunsen burner flame is held against one end for 30 seconds and then removed, after which the time is measured for flame to spread along the bottom edge of a 4 in. (10.16 cm) segment between marks 1 in. (2.54 cm) from each end. If the rate of burning is not more than 1½ in. (3.81 cm) per minute, the sample is classified as "slow burning." (RT)

Storage Cabinet.* A cabinet for the storage of flammable and combustible liquids constructed in accordance with Section 4-2 of NFPA 30, *Flammable and Combustible Liquids Code*. (See Appendix A-2-2.) (LAB)

Storage Location for Flammable Inhalation Anesthetics. Any room within a consuming facility (hospital) used for the storage of flammable anesthetic or flammable disinfecting agents (see NFPA 30, *Flammable and Combustible Liquids Code*) or inhalation anesthetic apparatus to which cylinders of flammable gases are attached. Such a storage location shall be considered a hazardous area throughout. (AA)

Task Illumination. Provisions for the minimum lighting required to carry out necessary tasks in the described areas, including safe access to supplies and equipment, and access to exits. (EES)

Tube, Endotracheal. A tube for insertion through the mouth or nose into the upper portion of the trachea (windpipe). Endotracheal tube may be equipped with an inflatable cuff. (RT)

Tube, Tracheotomy. A curved tube for insertion into the trachea (windpipe) below the larynx (voice box) during the performance of an appropriate operative procedure (tracheotomy). A tracheotomy tube may be equipped with an inflatable cuff. (RT)

Unattended Laboratory Operation. A laboratory procedure or operation at which there is no person present who is knowledgeable regarding the operation and emergency shutdown procedures. Absence for even short periods without coverage by a knowledgeable person constitutes an unattended laboratory operation. (LAB)

Chapter 3 Use of Inhalation Anesthetics (Flammable and Nonflammable)

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A-3.

Information on referenced publications can be found in Chapter 12 and Appendix B.

3-1 Introduction.

3-1.1 Scope. The purpose of this chapter is to establish performance and maintenance criteria for anesthetizing locations and for equipment and facilities ancillary thereto, for safeguarding patients and health care personnel from fire, explosion, electrical, and related hazards associated with the administration of both flammable and nonflammable inhalation anesthetics.

This chapter covers all anesthetizing locations and related storage areas within hospitals in which inhalation anesthetics are administered.

This chapter covers ambulatory care facilities which are part of a hospital as well as an ambulatory care facility in which flammable inhalation anesthetics are administered. This chapter does not apply to anesthetizing locations situated in freestanding ambulatory care facilities in which only nonflammable anesthetics are administered (see Chapter 4).

This chapter is intended to provide requirements to protect against explosions or fires, electric shock, mechanical injury from compressed gases or compressed gas cylinders, or anoxia from erroneous gas connections and similar hazards, without unduly limiting the activities of the surgeon or anesthesiologist. This principle, without minimizing any of the aforementioned dangers, recognizes that the physicians shall be guided by all the hazards to life that are inherent to surgical procedures carried out in anesthetizing locations.

This chapter does not cover animal operative facilities unless the animal operative facility is integral to a hospital and uses flammable anesthetics.

The provisions of this chapter do not apply to the manufacture, storage, transportation, or handling of inhalation anesthetics prior to delivery to the consuming health care facility. They do not apply to any use other than in an anesthetizing location and related storage areas.

3-1.2 Intended Use. This chapter is intended for use by those persons involved in the manufacture, supply and testing of equipment and material for use in anesthetizing locations and in the design, construction, inspection or operation of hospitals, including the ambulatory care facilities using flammable inhalation anesthetics.

3-1.3 Responsibility of the Governing Body. It shall be the responsibility of the governing body of the health care facility to designate anesthetizing locations. In order to discharge this obligation, the governing body shall be permitted to delegate appropriate authority to its staff, consultants, architects, engineers, and others.

3-1.4* Application of this Chapter. This chapter shall be applied only to new construction and new equipment. It shall not require the alteration or replacement of existing

construction or equipment. Existing construction or equipment shall be permitted to be continued in use when such use does not constitute a distinct hazard to life. Variations in existing facilities are acceptable when wiring arrangements, electrical power distribution systems, equipment, or construction are in accordance with prior editions of this chapter (formerly NFPA 56A, *Standard on Inhalation Anesthetics*) or afford a comparable degree of performance.

3-1.5 Interpretations. The National Fire Protection Association does not approve, inspect, or certify any installation, procedure, equipment, or material. In determining the acceptability of installations, procedures, or material the authority having jurisdiction may base acceptance on compliance with this standard. To promote uniformity of interpretation and application of its standards, NFPA has established interpretation procedures. These procedures are outlined on the inside front cover of this standard. Refer to Section 16 of the NFPA "Regulations Governing Committee Projects" for complete details.

3-1.6 Organization. This chapter is concerned with certain features of the construction and arrangement of operating rooms, delivery rooms, other anesthetizing locations, and facilities ancillary thereto. This chapter with equal emphasis deals with the design, maintenance, performance and use of equipment within anesthetizing locations and ancillary facilities thereto.

This chapter is divided into five sections, with additional material contained in Appendices A-3 and C-3:

Section 3-1 contains introductory material.

Section 3-2 sets forth the requirements for the construction, equipment, operation and maintenance of all anesthetizing locations, flammable and nonflammable, and rooms ancillary thereto.

Section 3-3 states the requirements, in addition to those of Section 3-2, for the construction, equipping, operation and maintenance of flammable anesthetizing locations and flammable agent storage facilities.

Section 3-4 contains the requirements, in addition to those contained in Section 3-2, for nonflammable anesthetizing locations.

Section 3-5 contains the requirements particular to mixed facilities.

Appendix A-3 contains supporting material and deals with the background information explaining the reasons for many of the requirements.

Appendix C-3-1 delineates the hazards of fire, explosion, electric shock and the use of compressed gases.

Appendices C-3-2 through C-3-5 contain other informative material and recommendations for safe practices.

The five parts of the chapter and Appendix A-3 are interdependent. For the informed development of an effective operating room safety program, it is necessary that thorough reference be made to all sections of these requirements.

A serious behavioral hazard exists in a "mixed facility," i.e., where there are some rooms where flammable agents are prohibited. In the latter situation, inadvertent use of a flammable agent in the "nonflammable" room could be disastrous. It is important to understand the regulations recommended in Appendix C-3-3.

3-1.7 Foreword. When this chapter was first published in 1941 as a separate document, the majority of inhalation anesthetics were administered with flammable agents, and fires and explosions in operating rooms occurred with disturbing frequency. Promulgation of this chapter by NFPA and the use of this chapter by hospitals has lowered the incidence of such tragedies significantly.

Since 1950, nonflammable inhalation anesthetics possessing relatively safe properties have been developed. The increasing use of these agents has curtailed, and in most institutions completely eliminated, the use of flammable agents. This change in anesthetic practice has made it desirable to delineate standards of construction and operation of rooms in locations where flammable agents will never be used. It must be emphasized that many safety recommendations pertain to hazards other than those related to fires and explosions, e.g., electric shock. It must also be recognized that these agents may possess toxicologic hazards to patients and personnel.

This chapter has been formulated in the belief that, although materials and mechanical equipment must be relied upon to the fullest possible extent for the mitigation of fire, explosion, and electric shock hazards, such physical safeguards are most effective only when augmented by safety precautions conscientiously applied by operating room and supporting personnel. This chapter emphatically calls attention to the need for constant human diligence in the maintenance of safe practices because of the peculiar intermixing of flammable anesthetic hazards and electric shock hazards, together with the mental strain in the environment of surgical operations.

Studies of these operating room hazards by many investigators over more than 30 years have pointed to the conclusion that the greatest degree of safety possible within the limitations of our present knowledge is secured only through a completely coordinated program rather than by the application of individual and unrelated safeguards. Compliance with certain of the requirements of this chapter will be effective, or even permissible, only when accompanied by compliance with the full program of precautionary measures.

It is necessary that all personnel having any responsibility for safety in anesthesia collaborate in the precautionary program. In the case of hospitals, this will apply to members of the governing body, physicians, administrative personnel, nursing staff, and maintenance staff. Not only must such personnel achieve an understanding of the hazards involved, but, in addition, they must be reminded periodically of the dangers posed by electric shock, compressed gases and their cylinders, the explosive nature of all flammable agents, and the hazards created by oxygen-enriched atmospheres. (*See NFPA 53M, Fire Hazards in Oxygen-Enriched Atmospheres.*)

For further discussion on the nature of the hazards, see Appendix C-3-1.

3-2 Requirements for All Facilities.

3-2.1 Ventilation, Humidification and Cooling.

3-2.1.1* Anesthetizing Locations.

3-2.1.1.1 Relative humidity of not less than 50 percent, at a temperature range of 64.4°F (19°C) to 80.6°F (27°C), shall be maintained in flammable inhalation anesthetizing locations.

3-2.1.1.2 The mechanical ventilation system supplying nonflammable anesthetizing locations shall have the capability of controlling the relative humidity within the range of 35 to 50 percent.

NOTE: It is recognized that there may be numerous medical hazards associated with the maintenance of relative humidity below 50 percent. These include the danger of producing hypothermia in patients, especially during long operative procedures; the fact that floating particulate matter increases in conditions of low relative humidity; and the fact that the incidence of wound infections is minimized following procedures performed in those operating rooms in which the relative humidity is maintained at the level of 50 to 55 percent.

3-2.1.1.3 Supply and exhaust systems for windowless anesthetizing locations shall be arranged to automatically vent smoke and products of combustion.

3-2.1.1.4 Ventilating systems for anesthetizing locations shall be provided with automatically controlled dampers actuated by devices intended to sense smoke to (a) prevent recirculation of smoke originating within the surgical suite, and (b) prevent the circulation of smoke entering the system intake, without in either case interfering with the exhaust function of the system.

3-2.1.1.5 The electric supply to the ventilating system shall be served by the equipment system of the essential electrical system specified in Chapter 8, Essential Electrical Systems for Health Care Facilities.

3-2.1.1.6 Window-type temperature regulating units (air conditioners) may be installed in exterior windows or exterior walls of anesthetizing locations (*see also 3-3.1.1.3 and 3-3.1.1.4*). Where such units are employed, the provisions of 3-2.1.1.1 or 3-2.1.1.2 shall be met.

3-2.1.1.7 Scavenging apparatus, if installed, shall exhaust the waste anesthetic gases to the outside of the facility in a manner that will preclude their reentry.

3-2.1.2 Storage Locations or Manifold Enclosures for Oxygen and Nitrous Oxide.

3-2.1.2.1 The location and ventilation of storage rooms or manifold enclosures for oxygen and nitrous oxide shall comply with NFPA 56F, *Standard for Nonflammable Medical Gas Systems*.

3-2.1.2.2 Sources of heat in storage locations shall be protected or located so that cylinders or compressed gases shall not be heated to the activation point of integral safety devices. In no case shall the temperature of the cylinders exceed 130°F (54.5°C). Care shall be exercised in handling cylinders that have been exposed to freezing temperature to prevent injury to the skin.

3-2.2 Nonflammable Medical Gases.

3-2.2.1 Construction of Cylinder Storage or Manifold Enclosures.

3-2.2.1.1 Cylinder storage or manifold enclosures shall be provided for oxidizing agents (nitrous oxide, oxygen mixtures and compressed air). Such enclosures shall be constructed of an assembly of building materials with a fire-resistive rating of at least one hour and shall not communicate directly with anesthetizing locations. Other

nonflammable (inert) medical gases may be stored in the enclosure. Flammable gases shall not be stored with oxidizing agents. Storage of full or empty cylinders is permitted. Such enclosures shall serve no other purpose.

NOTE 1: Conductive flooring is not required in cylinder storage locations which are not a part of a surgical or obstetrical suite.

NOTE 2: Conductive flooring is not required for those cylinder storage locations or manifold enclosures used only for nonflammable medical gases (see 3-3.1.2.6).

3-2.2.1.2 Provisions shall be made for racks or fastenings to protect cylinders from accidental damage or dislocation.

3-2.2.1.3 The electric installation in storage locations or manifold enclosures for nonflammable medical gases shall comply with the standards of NFPA 70, *National Electrical Code*, for ordinary locations. Electric wall fixtures, switches and receptacles shall be installed in fixed locations not less than 152 cm (5 ft) above the floor as a precaution against their physical damage.

3-2.2.1.4 Storage locations for oxygen and nitrous oxide shall be kept free of flammable materials (see also 3-2.7.5.6).

3-2.2.2 Nonflammable Medical Gas Piping Systems.

3-2.2.2.1 Oxygen and nitrous oxide manifolds and piping systems which supply anesthetizing locations shall comply with NFPA 56F, *Standard for Nonflammable Medical Gas Systems*.

3-2.2.2.2 The main supply line shall be provided with a shutoff valve so located as to be accessible in an emergency. This valve shall be identified.

3-2.2.2.3 A shutoff valve shall be located outside each anesthetizing location in each oxygen or nitrous oxide line, so located as to be readily accessible at all times for use in an emergency. These valves shall be so arranged that shutting off the supply of gas to any one operating room or anesthetizing location will not affect the others. Valves shall be of an approved type, mounted on a pedestal or otherwise properly safeguarded against physical damage and marked to prohibit tampering or inadvertent closing, such as: "Oxygen — Do Not Close."

Exception: This paragraph does not apply when provisions of 3-2.2.2.4 are met.

3-2.2.2.4 A shutoff valve located immediately outside anesthetizing locations, specified in 3-2.2.2.3, is not required if service valves for oxygen and nitrous oxide are located within the anesthetizing locations and are equipped with pipes extending at least 6 ft (183 cm) and terminating with female members of noninterchangeable quick couplers for oxygen and nitrous oxide. The male member of quick couplers shall be attached to (1) length of hose leading to yoke inserts suitable for oxygen or nitrous oxide on anesthesia machines or other dispensing equipment, or (2) lengths of hose leading to noninterchangeable quick couplers or specifically designed noninterchangeable threaded connections complying with CGA Pamphlet V-5, *Diameter-Index Safety System*, of the Compressed Gas Association, Inc.

3-2.2.2.5* Each yoke insert shall be drilled with two

holes of a size and in locations specified in the "Pin-Index Safety System," in ANSI B57.1, *Compressed Gas Cylinder Valve Outlet and Inlet Connections* (CGA Pamphlet V-1) (Canadian Standard CSA-B96) for the gas contained in the pipeline to which it is attached.

3-2.2.2.6 Each yoke insert or noninterchangeable quick coupler or specifically designed noninterchangeable threaded connection complying with CGA V-5, *Diameter-Index Safety System* shall be equipped with a backflow check valve designed to prevent flow of gas from the anesthesia apparatus into the pipeline system. Each backflow check valve shall be designed to function properly at pressures up to 190 kg/cm² gauge (2700 psig).

3-2.2.2.7 Cylinder valve outlet connections shall conform with ANSI B57.1 (see 3-2.6.1.2 and Appendix A-3-2.2.2.5).

3-2.2.2.8 Piping systems shall not be used for the distribution of flammable anesthetic gases.¹

3-2.3 Electrical Distribution System.

3-2.3.1 Grounded Electrical Distribution System. A grounded electrical distribution system shall be permitted to be installed in facilities which have a written policy prohibiting the use of flammable inhalation anesthetizing agents.

3-2.3.1.1 Raceway. Such distribution systems shall be run in metal raceways along with a green grounding wire sized no smaller than the energized conductors.

3-2.3.1.2 Grounding. Each device connected to the distribution system shall be effectively grounded to the metal raceway at the device.

3-2.3.1.3 Installation. Methods of installation shall conform to Articles 250 and 517 of NFPA 70, *National Electrical Code*.

3-2.3.2* Grounding System.

3-2.3.2.1* A grounding system shall be installed and maintained in each inhalation anesthetizing location such that under normal conditions no voltage greater than 20 millivolts rms at 60 Hz shall be measured across an impedance of 1000 ohms, typical at 60 Hz, connected between any combination of exposed conductive surfaces or grounding conductors that may contact patients and personnel (see Appendix A-3 for measuring circuits).

Exception: In existing inhalation anesthetizing locations a voltage not exceeding 40 millivolts rms at 60 Hz shall be permitted.

3-2.3.2.2 The grounding system shall be initially tested prior to use. Thereafter, measurements shall be taken at intervals to be determined by the hospital. A permanent record of the readings shall be kept.

NOTE: A minimum testing interval of one year is recommended.

3-2.3.3 Grounding of Appliances. Patient-connected electric appliances shall be grounded by an identified

¹These requirements do not restrict the distribution of helium or other inert gases through piping systems.

grounding conductor in the power cord connected to the appropriate terminal in the attachment plug or, for fixed equipment, to the equipment grounding bus in the distribution panel by an insulated grounding conductor run with the power conductors.

Exception: Listed double-insulated appliances with two-wire cords shall be permitted.

3-2.3.4 Wiring.

3-2.3.4.1 Installed wiring shall be in metal raceway or shall be as required in NFPA 70, *National Electrical Code*, Sections 517-100 through 517-104. In addition, devices, appliances, fixtures or equipment, if of a type incorporating sliding contacts, arcing or sparking parts, including switches and overcurrent devices, shall be of the totally enclosed type or shall have all openings guarded or screened so as to prevent the dispersion of hot particles.

Exception No 1: Receptacles located in nonflammable anesthetizing locations shall not be required to be totally enclosed or have openings guarded or screened to prevent dispersion of particles.

Exception No 2: Wiring for low-voltage control systems and nonemergency communications and signaling systems need not be installed in metal raceways in nonflammable anesthetizing locations, or when outside or above the hazardous area in flammable anesthetizing locations. (See also 3-3.4.4.)

3-2.3.4.2 All exposed metal of permanently installed equipment shall be grounded in accordance with the requirements of 3-2.3.2.

3-2.3.4.3 Approved permanently installed equipment may be supplied through a grounded single-phase or three-phase distribution system if installed in accordance with 3-3.3.1.2.

3-2.3.4.4 High-voltage wiring for X-ray equipment shall be effectively insulated from ground and adequately guarded against accidental contact.

3-2.3.5 Service Equipment. Requirements for service equipment are listed in 3-3.4.1.3 and 3-3.4.1.4.

3-2.4 Electric Switches, Receptacles and Fixtures.

3-2.4.1 Electric Switches.

3-2.4.1.1 Electric switches shall comply with 3-2.3.4.1 and 3-2.4.1.2. Specifications for switches used in hazardous locations shall comply with 3-3.4.1.7 and 3-3.4.1.8.

3-2.4.1.2 Switches controlling ungrounded circuits within or partially within an inhalation anesthetizing location shall have a disconnecting pole for each conductor.

3-2.4.2 Receptacles and Attachment Plugs.

3-2.4.2.1 Receptacles and attachment plugs for use in nonflammable anesthetizing locations and nonhazardous areas of flammable anesthetizing locations shall be listed for the use.

Exception: Wall-mounted receptacles installed above the hazardous area in flammable anesthetizing locations shall not be required to be totally enclosed or have openings guarded or screened to prevent dispersion of particles.

3-2.4.2.2 Plugs and receptacles for use with 250-volt, 50-ampere and 60-ampere ac service shall be designed for use in nonhazardous areas of flammable anesthetizing locations and nonflammable anesthetizing locations and shall be so designed that the 60-ampere receptacle will accept either the 50-ampere or the 60-ampere plug. Fifty-ampere receptacles are to be designed so as not to accept the 60-ampere attachment plug. These plugs shall be of the two-pole, three-wire design with a third contact connecting to the (green or green with yellow stripe) grounding wire of the electric system.

3-2.4.2.3 Receptacles provided for other services having different voltages, frequencies or types on the same premises shall be of such design that attachment plugs and caps used in such receptacles cannot be connected to circuits of a different voltage, frequency or type, but shall be interchangeable within each classification and rating required for two-wire, 125-volt, single-phase ac service.

3-2.4.3 Ceiling-Suspended Fixtures. Ceiling-suspended fixtures for illumination of the operative field, if installed, shall comply with the following requirements:

(a) *Fixture.* The light source of the fixture shall be suitably protected against physical damage.

(b) *Supports.* Boxes, box assemblies or fittings used for these fixtures shall be approved for the purpose, and so supported that the supporting means does not become disengaged from its fastening during or as a result of movement of the fixture. The fixture shall be suspended by suitable rigid stems or other approved means. For stems longer than 12 in. (30.5 cm), flexibility in the form of a fitting or flexible connector approved for the purpose shall be provided not more than 12 in. (30.5 cm) from the point of attachment to the supporting box or fitting.

3-2.5 Portable Electric Equipment.

3-2.5.1 Line Voltage Equipment.

3-2.5.1.1 Photographic lighting equipment for use in anesthetizing locations shall be of the totally enclosed type or so constructed as to prevent the escape of sparks or hot metal particles. The exposed metal parts of photographic lighting equipment shall be grounded as specified in 3-2.5.1.2.

3-2.5.1.2 Exposed metal parts of electric equipment such as the frames or metal exteriors of motors, portable lamps and appliances, fixtures, cabinets and cases, intended for use in anesthetizing locations, shall be grounded as provided in Article 250, and in Section 501-16 of NFPA 70, *National Electrical Code* (see 3-2.3.2).

3-2.5.1.3 Flexible cord for portable lamps or portable electric appliances operating at more than eight volts between conductors, intended for use in all anesthetizing locations, shall be continuous and without switches from the appliance to the attachment plug and of a type designated for extra-hard usage in accordance with Section 501-11 of NFPA 70, *National Electrical Code*. Such flexible cord shall contain one extra insulated conductor to form a grounding connection between the ground terminal of the polarized plug and metal lamp guards, motor frames, and all other exposed metal portions of portable lamps and appliances. Cords shall be protected at the

entrance to equipment by a suitable insulating grommet. The flexible cord shall be of sufficient length to reach any position in which the portable device is to be used and the attachment plug shall be inserted only in a fixed, approved receptacle. For correct use and maintenance of adapters, the provisions of 9-3.3.4 in Chapter 9 shall apply.

Exception No. 1: Foot treadle-operated controllers are permitted in any anesthetizing location if appended to portable electric appliances in an approved manner or if integral with the supply cord and equipped with a connector containing a flammable anesthetizing location receptacle approved for use in Class I, Group C, Division 1 hazardous locations into which the equipment plug (see 3-3.4.1.4, 3-3.4.2.1 and 3-3.4.2.2) may be inserted.

Exception No. 2: Foot treadle-operated controllers and their connector shall be splashproof but need not be explosionproof if used in a nonflammable anesthetizing location.

Exception No. 3: Listed double-insulated appliances with two-wire cords shall be permitted.

Exception No. 4: Small metal parts not likely to become energized (e.g., name plates, screws) shall not be required to be grounded.

Exception No. 5: Two or more power receptacles supplied by a flexible cord may be used to supply power to plug-connected components of a movable equipment assembly that is rack-, table-, or pedestal-mounted in a nonflammable anesthetizing location provided:

(a) the receptacles are an integral part of the equipment assembly, permanently attached; and

(b) the sum of the ampacity of all appliances connected to the receptacles shall not exceed 75 percent of the ampacity of the flexible cord supplying the receptacles.

NOTE: Whole body hyperthermia/hypothermia units should be powered from a separate branch circuit.

(c) the ampacity of the flexible cord is suitable and in accordance with the current edition of NFPA 70; and

(d) the electrical and mechanical integrity of the assembly is regularly verified and documented through an ongoing maintenance program.

NOTE: See 3-2.4.2.1 for criteria of receptacles.

Exception No. 6: Overhead power receptacles, not in a hazardous location, may be supplied by a flexible cord (ceiling drop) which is connected at a ceiling-mounted junction box either:

(a) permanently; or

(b) utilizing a locking-type plug cap and receptacle combination, or other method of retention. In either connection mode, suitable strain relief shall be provided.

NOTE 1: The disconnection means is permitted only to facilitate replacement; as such, ceiling drop cords may not be disconnected for alternative usage.

NOTE 2: See 3-2.4.2.1 for criteria of receptacles.

3-2.5.1.4 Portable equipment shall be provided with a storage device for its flexible cord which is designed to minimize damage to the cord during storage.

3-2.5.2 Low-Voltage Equipment and Instruments.

3-2.5.2.1 Low-voltage equipment which is frequently in

contact with the bodies of persons or has exposed current-carrying elements shall:

(a) operate on an electrical potential of 10 volts or less, or

(b) be approved as intrinsically safe or double-insulated equipment, and

(c) be moisture resistant.

3-2.5.2.2 Power shall be supplied to low-voltage equipment from:

(a) an individual isolating transformer (autotransformers shall not be used) connected to an outlet receptacle by means of a listed cord and plug (see 3-2.4.2.1 through 3-2.4.2.3), or

(b) a common isolating transformer installed in a nonhazardous location, or

(c) individual dry cell batteries, or

(d) common batteries made up of storage cells located in a nonhazardous location.

3-2.5.2.3 Battery-powered appliances shall not be capable of being charged while in operation unless their charging circuitry incorporates an integral isolating-type transformer.

3-2.6 Cylinders, Regulators, Anesthetic Apparatus.

3-2.6.1 Cylinders and Regulators.

3-2.6.1.1 Approved regulators or other gas flow control devices shall be used to reduce the cylinder pressure of every cylinder used for medical purposes. All such devices shall have connections so designed that they can be attached only to cylinders of gas for which they are designated.

3-2.6.1.2 Equipment which will permit the intermixing of different gases, either through defects in the mechanism or through error in manipulation in any portion of the high-pressure side of any system in which these gases may flow, shall not be used for coupling cylinders containing compressed gases. It is particularly important that the intermixing of oxidizing and flammable gases under pressure be scrupulously avoided, as such mixing may result in violent explosion.

3-2.6.1.3 Cylinder valve outlet connections for oxygen shall be Connection No. 540 as described in ANSI B57.1, *Compressed Gas Cylinder Valve Outlet and Inlet Connections*.

3-2.6.1.4 Cylinder valve outlet connections for nitrous oxide shall be Connection No. 326 as described in ANSI B57.1, *Compressed Gas Cylinder Valve Outlet and Inlet Connections*.

3-2.6.1.5 Yoke-type connections between anesthesia apparatus and flush-type cylinder valves (commonly used with anesthetic gas cylinders) shall be Connection No. 860 as described in ANSI B57.1, *Compressed Gas Cylinder Valve Outlet and Inlet Connections* (see Appendix A-3-2.2.2.5).

3-2.6.2 Anesthetic Apparatus.

3-2.6.2.1 Anesthetic apparatus shall be subject to approval by the authority having jurisdiction.

3-2.6.2.2 Each yoke on anesthetic apparatus constructed to permit attachment of small cylinders equipped with flush-type valves shall have two pins installed as specified in ANSI B57.1 (*Pin-Index Safety System*) (see 3-2.2.2.7 and Appendix A-3-2.2.2.5).

3-2.6.2.3 After any adjustment or repair involving use of tools, or any modification of the gas piping supply connections or the pneumatic power supply connections for the anesthesia ventilator, or other pneumatically powered device if one is present, and before use on patients, the gas anesthesia apparatus shall be tested at the final common path to the patient to determine that oxygen and only oxygen is delivered from the oxygen flow meters, and oxygen flush valve if any. Interventions requiring such testing shall include, but not be limited to:

- (a) alteration of pipeline hoses or fittings;
- (b) alteration of internal piping;
- (c) adjustment of selector switches or flush valves;
- (d) replacement or repair of flow meters or bobbins.

Before the gas anesthesia apparatus is returned to service, each fitting and connection shall be checked to verify its proper indexing to the respective gas service involved.

A paramagnetic or polarographic oxygen analyzer, or a similar device, known to be accurate at 0 percent, 21 percent and 100 percent oxygen is a suitable test instrument (see Appendix C-3-2).

3-2.7 Administration and Maintenance.

3-2.7.1 Purpose. This section contains the requirements for administration and maintenance which shall be followed as an adjunct to physical precautions specified in 3-2.1 through 3-2.6.

3-2.7.2 Recognition of Hazards and Responsibility.

3-2.7.2.1 The hazards involved in the use of inhalation anesthetic agents can be successfully mitigated only when all of the areas of hazard are fully recognized by all personnel, and when the physical protection provided is complete and is augmented by attention to detail by all personnel of administration and maintenance having any responsibility for the functioning of anesthetizing locations. Since 3-2.7 is expected to be used as a text by those responsible for the mitigation of associated hazards, the requirements set forth herein are frequently accompanied by explanatory text.

3-2.7.2.2 Responsibility for the maintenance of safe conditions and practices in anesthetizing locations falls mutually upon the governing body of the hospital, all physicians using the anesthetizing locations, the administration of the hospital, and those responsible for hospital licensing, accrediting, or other approved programs.

3-2.7.2.3 Inasmuch as the ultimate responsibility for the care and safety of patients in a hospital is that of the governing board of the hospital, that body in its responsibility for enforcement of requirements contained in this chapter shall determine that adequate regulations with respect to anesthesia practices and conduct in anesthetizing locations have been adopted by the medical staff of the

hospital and that adequate regulations for inspection and maintenance are in use by the administrative, nursing and ancillary personnel of the hospital.

3-2.7.2.4 By virtue of its responsibility for the professional conduct of members of the medical staff of the hospital the organized medical staff shall adopt adequate regulations with respect to the use of inhalation anesthetic agents and to the prevention of electric shock and burns (see Appendix C-3-3) and through its formal organization shall ascertain that these regulations are regularly adhered to.

3-2.7.2.5 In meeting its responsibilities for safe practices in anesthetizing locations, the hospital administration shall adopt or correlate regulations and standard operating procedures to assure that both the physical qualities and the operating maintenance methods pertaining to anesthetizing locations meet the standards set in this chapter. The controls adopted shall cover the conduct of professional personnel in anesthetizing locations, periodic inspection to ensure the proper grounding of dead metal (see 3-2.3.2), and inspection of all electrical equipment, including testing of Line Isolation Monitors.

3-2.7.3 Rules and Regulations.

3-2.7.3.1 Hospital authorities and professional staff shall jointly consider and agree upon necessary rules and regulations for the control of personnel concerned with anesthetizing locations. Upon adoption, rules and regulations shall be prominently posted in the operating room suite. Positive measures are necessary to acquaint all personnel with the rules and regulations established and to assure enforcement.

3-2.7.3.2 This chapter recognizes that some hospitals contain operating and delivery rooms designed and maintained for the use of flammable anesthetic agents. It also recognizes that there may be some operating rooms and even entire operating suites designed for the exclusive use of nonflammable agents. A particular hazard exists where personnel elect to employ a flammable agent in a room not designed for it, or where a flammable agent is employed in a nonflammable anesthetizing location without taking the proper administrative steps.

3-2.7.3.3 Appendix C-3-3 contains three steps of proposed regulations applying to the specific types of inhalation anesthetizing locations as defined in Section 2-2.

Set (1) contains regulations for flammable anesthetizing locations which may be adopted by hospitals for all anesthetizing locations designed for the safe administration of flammable inhalation anesthetic agents.

Set (2) contains regulations for nonflammable anesthetizing locations which may be adopted by hospitals for all anesthetizing locations designed for the exclusive administration of nonflammable inhalation anesthetic agents.

Set (3) contains regulations for mixed facilities which may be adopted by hospitals in which flammable anesthetizing locations and nonflammable anesthetizing locations co-exist within the same building, allowing interchange of personnel and equipment between flammable and nonflammable anesthetizing locations.

3-2.7.3.4 Anesthetizing locations shall be identified as noted in 3-5.5.1.

3-2.7.3.5 The hazard symbols contained in NFPA 704, *Identification of the Fire Hazards of Materials*, shall be employed throughout the hospital, as appropriate. Such use is particularly important in the operating suite and in gas and volatile liquid storage facilities.

3-2.7.3.6 All pieces of equipment used in anesthetizing locations shall be labeled to indicate that they comply with applicable safety regulations.

NOTE: A generally recognized mark or symbol will meet the intent of this requirement.

3-2.7.3.7* Transportation of patients while an inhalation anesthetic is being administered by means of a mobile anesthesia machine shall be prohibited, unless deemed essential for the benefit of the patient in the combined judgment of the surgeon and anesthetist.

3-2.7.3.8 Germicides.

(a) Medicaments, including those dispersed as aerosols, may be used in anesthetizing locations for germicidal purposes, for affixing plastic surgical drape materials, for preparation of wound dressing, or for other purposes.

(b) Liquid germicides used in anesthetizing locations, whenever the use of cautery or electrosurgery is contemplated, shall be nonflammable.

(c) Whenever flammable aerosols are employed, sufficient time shall be allowed to elapse between deposition and application of drapes to permit complete evaporation and dissipation of any flammable vehicle remaining.

NOTE: Inhibited 1,1,1 trichloroethane and 1,1,1 trifluoro 2,2,2 trichloroethane are suitable defatting agents. Ether and tinctures of disinfecting agents are flammable and often are improperly used during surgical procedures. Tipping containers, accidental spillage and the pouring of excessive amounts of such flammable agents on patients expose them to injury in the event of accidental ignition of the flammable solvent.

3-2.7.3.9 Smoking and open flames shall be prohibited in all anesthetizing locations.

3-2.7.4 Ventilation and Humidification.

3-2.7.4.1 Ventilating and humidifying equipment for anesthetizing locations shall be kept in operable condition and continually operating during surgical procedures (see *Appendix A-3-2.1.1*).

3-2.7.4.2 All gas storage locations or manifold enclosures shall be routinely inspected to assure that the ventilation requirements stated in 3-2.1.2 are not obstructed.

3-2.7.5* Handling of Gases.

3-2.7.5.1 Hospital administrative authorities shall provide regulations to assure that standards for safe practice in the specifications for cylinders, marking of cylinders, regulators and valves, and cylinder connections have been met by vendors of cylinders containing compressed gases supplied to the hospital.

3-2.7.5.2 Cylinder contents shall be identified by attached labels or stencils naming the components and giving their proportions. Labels and stencils shall be lettered in accordance with ANSI Z48.1 (CGA Pamphlet C-4), *Standard Method of Marking Portable Compressed Gas Containers to Identify the Material Contained*.

3-2.7.5.3 Before piping systems are initially put into use, the hospital authority shall be responsible for ascertaining that the gas delivered at the outlet is that shown on the outlet label and that the proper connecting fittings are checked against their labels.

3-2.7.5.4 Hospital authorities, in consultation with medical staff and other trained personnel, shall provide and enforce regulations for the storage and handling of containers of oxygen and nitrous oxide in storage rooms of approved construction, and for the safe handling of these agents in anesthetizing locations. Storage locations for flammable inhalation anesthetic agents, established in any operating or delivery suite, shall be limited by space allocation and regulation to not more than 48-hour normal requirement for any such suite. In storage locations, cylinders shall be properly secured in racks or adequately fastened. No cylinders containing oxygen or nitrous oxide, other than those connected to anesthetic apparatus, shall be kept or stored in anesthetizing locations.

NOTE: Electric wiring and equipment in storage rooms for oxygen and nitrous oxide are not required to be explosionproof.

3-2.7.5.5 Cylinders containing compressed gases and cans containing volatile liquids shall be kept away from radiators, steam pipes, and like sources of heat. Oxygen and nitrous oxide cylinders may be stored in the same room.

3-2.7.5.6 Combustible materials, such as paper, cardboard, plastics and fabrics, shall not be stored or kept near cylinders containing oxygen or nitrous oxide. An exception to the rule may be made in the case of cylinder shipping crates or cartons. Racks for cylinder storage may be of wooden construction. Wrappers shall be removed prior to storage.

3-2.7.6 Special Precautions — Oxygen Cylinders and Manifolds.

3-2.7.6.1 Great care shall be exercised in handling oxygen to prevent contact of oxygen under pressure with oils, greases, organic lubricants, rubber, or other materials of an organic nature. The following regulations, based on those of the Compressed Gas Association Pamphlet G-4, *Oxygen* shall be observed:

(a) Oil, grease or readily flammable materials shall never be permitted to come in contact with oxygen cylinders, valves, regulators, gauges, or fittings.

(b) Regulators, fittings, or gauges shall never be lubricated with oil or any other flammable substance.

(c) Oxygen cylinders or apparatus shall never be handled with oily or greasy hands, gloves or rags.

(d) Particles of dust and dirt shall be cleared from cylinder valve openings by slightly opening and closing the valve before applying any fitting to the cylinder.

(e) The high-pressure valve on the oxygen cylinder shall be opened before bringing the apparatus to the patient.

(f) The cylinder valve shall be opened slowly, with the face of the gauge on the regulator pointed away from any person.

(g) An oxygen cylinder shall never be draped with any materials such as hospital gowns, masks or caps.

(h) Oxygen fittings, valves, regulators or gauges shall never be used for any service other than that of oxygen.

(i) Gases of any type shall never be mixed in an oxygen or any other cylinder.

(j) Oxygen shall always be dispensed from a cylinder through a pressure regulator.

(k) Regulators which are in need of repair or cylinders having valves which do not operate properly shall never be used.

(l) Oxygen equipment which is defective shall not be used until it has been repaired by competent personnel. If competent in-house repairs cannot be made, such equipment shall be repaired by the manufacturer or his authorized agent; or it shall be replaced.

(m) Oxygen cylinders shall be protected from abnormal mechanical shock which is liable to damage the cylinder, valve, or safety device. Such cylinders shall not be stored near elevators, gangways or in locations where heavy moving objects may strike them or fall on them.

(n) Cylinder valve protection caps, when provided, shall be kept in place and be hand tightened, except when cylinders are in use or connected for use.

(o) Cylinders shall be protected from the tampering of unauthorized individuals.

(p) Storage shall be planned so that cylinders may be used in the order in which they are received from the supplier.

(q) If stored within the same enclosure, empty cylinders shall be segregated from full cylinders. Empty cylinders shall be marked to avoid confusion and delay if a full cylinder is needed hurriedly.

(r) Cylinders stored in the open shall be protected against extremes of weather and from the ground beneath to prevent rusting. During winter, cylinders stored in the open shall be protected against accumulations of ice or snow. In summer, cylinders stored in the open shall be screened against continuous exposure to direct rays of the sun in those localities where extreme temperatures prevail.

(s) Valves shall be closed on all empty cylinders in storage.

(t) Oxygen shall be referred to by its proper name "OXYGEN," not "AIR." Liquid oxygen shall be referred to by its proper name, not "LIQUID AIR."

(u) Oxygen shall never be used as a substitute for compressed air.

(v) Cylinders or cylinder valves shall not be repaired, painted or altered.

(w) Safety relief devices in valves or cylinders shall never be tampered with. Sparks and flame shall be kept away from cylinders; a torch flame shall never be permitted under any circumstances to come in contact with cylinder valves or safety devices. Valve outlets clogged with ice shall be thawed with warm — not boiling — water.

(x) The markings stamped on cylinders shall not be tampered with. It is against federal statutes to change these markings without written authority from the Bureau of Explosives.

(y) Markings which are used for identification of contents of cylinder shall not be defaced or removed,

including decals, tags, stencilled marks and upper half of shipping tag.

(z) The owner of the cylinder shall be notified if any condition has occurred which might permit any foreign substance to enter cylinder or valve, giving details and cylinder number.

(aa) Even if they are considered to be empty, cylinders shall never be used as rollers, supports, or for any purpose other than that for which they are intended by the supplier.

3-2.7.6.2 Transfer of gas from one cylinder to another on the hospital site or by hospital personnel shall be prohibited.

3-2.7.7 Electrical Safeguards.

3-2.7.7.1 Physical safeguards built into the anesthetizing locations or storage areas will not provide protection unless safe practices are followed and good maintenance is provided.

3-2.7.7.2 Scheduled inspections and written reports shall be maintained.

3-2.7.7.3 Rules to require prompt replacement of defective electrical equipment shall be adopted and rigidly enforced.

3-2.7.7.4 Maintenance employees shall be properly acquainted with the importance of the work they are expected to do in storage locations for flammable anesthetic agents and anesthetizing locations, in order that their informed cooperation may be assured.

3-2.7.7.5 All electrical equipment used in inhalation anesthetizing locations and areas ancillary thereto, or in other areas using conductive floors constructed in accordance with this chapter, shall be periodically tested for electrical safety. (*See Appendix C-3-1.2.1.2.*)

3-2.7.7.6 Members of the professional staff shall be required to submit for inspection and approval any special equipment they wish to introduce into anesthetizing locations. Such equipment shall meet the requirements for the protection against electric shock as given in this chapter (*see 3-2.3.3 and 3-2.5.1*).

3-2.7.7.7 Line-powered equipment which introduces current to the patient's body shall have the output circuit isolated from ground to ensure against an unintentional return circuit through the patient.

Exception: Equipment whose output circuit is grounded, or ground-referenced shall be permitted, provided that the design provides equivalent safety to an isolated output.

3-2.7.8 Electric Connections and Testing.

3-2.7.8.1 Administrative authorities shall ascertain that electric maintenance personnel are completely familiar with the function and proper operation of ungrounded electric circuits required by 3-3.3.1. The significance of the signal lamps and audible alarms installed to indicate accidental grounds shall be explained to all personnel affected. A permanent sign shall be installed close to the

position of the signal lamps to indicate their significance. Circuits in the panel boxes shall be clearly labeled, distinguishing between grounded and ungrounded, emergency and normal circuits, so that immediate recognition is possible.

3-2.7.8.2 Extension cords shall not be connected to lighting fixtures in anesthetizing locations under any circumstances.

3-3 Requirements for Flammable Inhalation Anesthetizing Locations and Flammable Inhalation Anesthetic Agent Storage Locations.

3-3.1 Ventilation, Humidification and Cooling.

3-3.1.1 Anesthetizing Locations.

3-3.1.1.1 Requirements for ventilation, humidification and cooling of flammable anesthetizing locations are set forth in 3-2.1.1.

3-3.1.1.2 Duct Work for Air Handling. It is not required that duct work be fabricated of nonsparking material.

3-3.1.1.3 If a window-type temperature regulating unit (air-conditioner) is installed so that any part is less than 5 ft (152 cm) from the floor of a flammable anesthetizing location, such unit shall comply with the requirements set forth in 3-3.1.1.4.

3-3.1.1.4 Such a window-type temperature regulating unit shall be provided with a vertical divider which effectively prevents air flow from the room side to the outside side, and all electric equipment on the room side of this divider shall meet the requirements of 3-3.4.1.1. The installed unit shall tightly fit the opening in the window or wall. Openings in the divider for shafts of fans, other moving parts or wiring shall be gasketed unless the local air pressure on the room side of the opening when the unit is in operation is less than that on the outdoor side. A fresh air port may be provided in the divider if it is automatically closed when the unit is not in operation. The rotating parts of fans on the room side of the divider shall not cause percussion sparks if they accidentally contact surrounding objects.

3-3.1.2 Storage Locations for Flammable Inhalation Anesthetic Agents.

3-3.1.2.1 Enclosures in which flammable inhalation anesthetic agents are stored shall be individually and continuously ventilated by gravity or by mechanical means at a rate of not less than eight air changes per hour. The fresh air inlet and the exhaust air outlet within the enclosure shall be located as far apart as feasible consistent with the enclosure layout. The fresh air inlet shall be located at or near the ceiling, and the bottom of the exhaust air outlet shall be located 3 in. (7.6 cm) above the floor. The fresh air supply may be heated. Exhaust air shall be discharged to the exterior of the building at least 12 ft (3.6 m) above grade in a manner to prevent its re-entry to the building.

3-3.1.2.2 Exhaust fans shall have nonsparking blades. The fan motor shall be connected into the equipment

system (either automatic or delayed restoration) (see *Chapter 8, Essential Electrical Systems for Health Care Facilities*). All electric installations shall conform to NFPA 70, *National Electrical Code*, and, when inside the storage area or exhaust duct, shall be approved for use in Class I, Group C, Division 2 locations. A visual signal which indicates failure of the exhaust system shall be installed at the entrance to the storage area.

NOTE: Exhaust fans in all new installations, and whenever possible in existing installations, should be located at the discharge end of the exhaust duct.

3-3.1.2.3 Approved fire dampers shall be installed in openings through the required fire partition in accordance with the requirements of NFPA 90A, *Air-Conditioning and Ventilating Systems*.

3-3.1.2.4 The electric installation in storage locations for flammable inhalation anesthetic agents shall comply with the requirements of 3-3.4.1.

3-3.1.2.5 This chapter prohibits the piping of flammable anesthetic gases (see also NFPA 56F, *Standard on Non-flammable Medical Gas Systems*).

3-3.1.2.6 Enclosures shall not be used for purposes other than for storage of flammable inhalation anesthetic agents.

3-3.1.2.7 Flooring shall comply with 3-3.6.2.1.

3-3.2 Areas Adjoining Flammable Inhalation Anesthetizing Locations and Flammable Anesthetizing Storage Locations.

3-3.2.1 An adjoining area connected by a closable doorway, such as a corridor, sterilizing room, scrub room, X-ray control room, or monitoring room, where it is not intended to store or administer flammable inhalation anesthetics, is not considered a hazardous area.

3-3.2.2 Areas described in 3-3.2.1 may be ventilated in accordance with the applicable sections of NFPA 70, *National Electrical Code*, for ordinary locations.

3-3.2.3 Conductive flooring is required in these adjoining areas to remove static charges from personnel or objects before they enter the flammable inhalation anesthetizing location or agent storage location (see 3-3.6.2).

3-3.2.4 Post-anesthesia recovery rooms are not considered to be hazardous areas unless specifically intended for the induction of inhalation anesthesia with flammable anesthetic agents (see 3-3.7.2.2).

3-3.2.5 All doorways leading to flammable inhalation anesthetic agent storage locations shall be identified with NFPA 704, *Identification of Fire Hazards of Materials* symbols as appropriate.

3-3.3* Electric Distribution.

3-3.3.1 Isolated Power Systems.

3-3.3.1.1 A local ungrounded electric system shall be provided.

Exception: An area in a health care facility which does not use flammable inhalation anesthetics and is dedicated to brief, superficial procedures carried out under inhalation anesthesia or analgesia, such as dental operatories.

NOTE 1: The isolated system reduces the ignition hazard from arcs and sparks between a live conductor and grounded metal and mitigates the hazard of shock or burn from electric current flowing through the body to ground. The latter hazard usually follows inadvertent contact with one live conductor or results from unrecognized failure of insulation.

NOTE 2: Such a system provides protection from spark and electric shock hazards due to most common types of insulation failure. It does not, however, prevent all electric sparks or completely eliminate the possibility of electric shock from insulation failure. Electric shock hazards are particularly aggravated in operating rooms because of the physiological predisposition to injury of persons in such locations and because of the generally low electric resistance resulting from moisture on the floors or the use of conductive shoes and the installation of conductive floors necessary for dissipation of static electricity. Patients and personnel often are wet with prepping solutions, blood, urine and other conductive fluids which greatly reduce resistance to the passage of unintended electrical current. More than ordinary care is crucially necessary in the use and maintenance of all electric systems and equipment.

3-3.3.1.2 Power for Fixed Equipment. Approved, fixed, therapeutic and diagnostic equipment, permanently installed in nonflammable anesthetizing locations or outside the hazardous area of a flammable anesthetizing location, may be supplied by a grounded single or three-phase system of less than 600 volts provided (a) the equipment complies with 3-3.4.1.10, (b) cord-connected accessories (such as positioning controls, aiming lights and fiberoptic light sources, slaved monitors, motorized cameras and video cameras, dosimeters, and exposure triggers) likely to come in contact with patients or personnel are supplied by isolated power at line voltage or operate at 24 volts or less supplied by an isolating transformer, and (c) wiring is installed in accordance with NFPA 70, *National Electrical Code*, Section 517-104.

NOTE: It is intended that this section apply to positioning motors for patient tables associated with radiographic and other imaging equipment, and to sometimes massive equipment for radio-therapy or for the delivery of other forms of energy.

3-3.3.1.3 Fixed Lighting. Branch circuits supplying only fixed lighting may be supplied by a conventional grounded system provided (a) such fixtures are located at least 2.4 m (8 ft) above the floor; (b) switches for the grounded circuits are wall-mounted and installed in accordance with NFPA 70, *National Electrical Code*, Section 517-104; and (c) wiring for grounded and ungrounded circuits is installed in accordance with NFPA 70, *National Electrical Code*, Section 517-104.

NOTE: Wall-mounted remote control stations for lighting controls switches operating at 24 volts or less may be installed in any anesthetizing location.

3-3.3.2 Isolation Transformer.

3-3.3.2.1 The isolation transformer shall be approved for the purpose.

3-3.3.2.2 The primary winding shall be connected to a power source so that it is not energized with more than 600 volts (nominal). The neutral of the primary winding shall be grounded in an approved manner. If an electrostatic shield is present, it shall be connected to the reference grounding point.

3-3.3.2.3 An isolation transformer shall not serve more than one operating room except as provided in 3-3.3.2.5. For purposes of this section, anesthetic induction rooms are considered part of the operating room or rooms served by the induction rooms. If an induction room serves more than one operating room, the isolated circuits of the induction room may be supplied from the isolation transformer or any one of the operating rooms served by that induction room.

Exception: In existing hospitals where one isolation transformer is serving more than one inhalation anesthetizing location, provided the system has been installed in accordance with previous editions of this chapter (formerly NFPA 56A) where such systems were permitted.

3-3.3.2.4 Wiring of isolated power systems shall be in accordance with Article 517-104 of NFPA 70, *National Electrical Code*.

3-3.3.2.5 Isolation transformers may serve single receptacles in several patient areas when the receptacles are reserved for supplying power to equipment requiring 150 volts or higher, to such items as portable X-ray units, and when the receptacles and mating plugs are not interchangeable with the receptacles on the local isolated power system.

3-3.3.3 Impedance of Isolated Wiring.

3-3.3.3.1 The impedance (capacitive and resistive) to ground of either conductor of an isolated system shall exceed 200,000 ohms when installed. The installation at this point may include receptacles but not lighting fixtures or components of fixtures. This value shall be determined by energizing the system and connecting a low impedance ac milliammeter (0-1 mA scale) between the reference grounding point and either conductor in sequence. This test may be performed with the Line Isolation Monitor (see 3-3.3.4) connected, provided the connection between the Line Isolation Monitor and the reference grounding point is open at the time of the test. After the test is made, the milliammeter shall be removed and the grounding connection of the Line Isolation Monitor shall be restored. When the installation is completed, including permanently connected fixtures, the reading of the meter on the Line Isolation Monitor, which corresponds to the unloaded line condition, shall be made. This meter reading shall be recorded as a reference for subsequent line impedance evaluation.

NOTE 1: Before conducting this test it shall be determined in a safe manner that there is no gross fault between either conductor or ground.

NOTE 2: It is desirable to limit the size of the isolation transformer to 10 kVA or less and to use conductor insulation with low leakage to meet the impedance requirements. Keeping branch circuits short, using insulation with a dielectric constant less than 3.5 and insulation resistance constant greater than 6,100 megohm-meters (20,000 megohm-kilofeet) at 60°F (16°C) reduces leakage from line to ground.

NOTE 3: Keeping branch circuits short, using insulation with a dielectric constant less than 3.5 and insulation resistance constant greater than 6,100 megohm-meters (20,000 megohm-kilofeet) at 60°F (16°C) reduces the monitor hazard current.

NOTE 4: To correct milliammeter reading to line impedance:
 Line impedance (in ohms) = $V \times 1000$ divided by I
 where V = isolated power system voltage
 I = milliammeter reading made during impedance test.

3-3.3.3.2 An approved capacitance suppressor may be used to improve the impedance of the permanently installed isolated system; however, the resistive impedance to ground of each isolated conductor of the system shall be at least one megohm prior to the connection of the suppression equipment. Capacitance suppressors shall be installed so as to prevent inadvertent disconnection during normal use.

3-3.3.4 Line Isolation Monitor.

3-3.3.4.1 In addition to the usual control and protective devices, each isolated power system shall be provided with an approved continually operating Line Isolation Monitor that indicates possible leakage or fault currents from either isolated conductor to ground.

NOTE: Protection for the patient is provided primarily by a grounding system. The ungrounded secondary of the isolation transformer reduces the maximum current in the grounding system in case of a single fault between either isolated power conductor and ground. The Line Isolation Monitor provides warning when a single fault occurs, or when excessively low impedance to ground develops, that may expose the patient to an unsafe condition should an additional fault occur. Excessive current in the grounding conductors will not result from a first fault. A hazard exists if a second fault occurs before the first fault is cleared.

3-3.3.4.2 The Monitor shall be designed so that a green signal lamp, conspicuously visible to persons in the anesthetizing location, remains lighted when the system is adequately isolated from ground; and adjacent red signal lamp and an audible warning signal (remote if desired) shall be energized when the total hazard current (consisting of possible resistive and capacitive leakage currents) from either isolated conductor to ground reaches a threshold value of 5.0 milliamperes under normal line voltage conditions. The Line Isolation Monitor is not to alarm for a fault hazard current of less than 3.7 milliamperes.

NOTE: A 120 volt (nominal) 60 Hz ac system of moderate ampacity is assumed for the description of the specification of the Line Isolation Monitor in 3-3.3.4.1. If other systems are considered, modifications are required e.g., for other voltages or frequencies, installed impedance and sensitivity (alarm) levels differ.

3-3.3.4.3 The Line Isolation Monitor shall have sufficient internal impedance that when properly connected to the isolated system the maximum internal current that can flow through the Line Isolation Monitor, when any point of the isolated system is grounded, shall be one milliamperes.

Exception: The Line Isolation Monitor may be of the low-impedance type such that the current through the Line Isolation Monitor, when any point of the isolated system is grounded, will not exceed twice the alarm threshold value for a period not exceeding 5 milliseconds.

NOTE: It is desirable to reduce this monitor hazard current provided this reduction results in an increased "not alarm" threshold value for the fault hazard current.

3-3.3.4.4 An ammeter connected to indicate the total hazard current of the system (contribution of the fault hazard current plus monitor hazard current) shall be mounted in a plainly visible place on the Line Isolation Monitor with the "alarm on" (total hazard current = 5.0 milliamperes) zone at approximately the center of the scale.

NOTE: The Line Isolation Monitor may be a composite unit, with a sensing section cabled to a separate display panel section, on which the alarm and test functions are located, if the two sections are within the same electric enclosure.

It is desirable to locate the ammeter so that it is conspicuously visible to persons in the anesthetizing location.

3-3.3.4.5 Means shall be provided for shutting off the audible alarm while leaving the red warning lamp activated. When the fault is corrected and the green signal lamp is reactivated, the audible alarm silencing circuit shall reset automatically, or an audible or distinctive visual signal shall indicate that the audible alarm is silenced.

3-3.3.4.6 A reliable test switch shall be mounted on the Line Isolation Monitor that will test its capability to operate (i.e., cause the alarms to operate and the meter to indicate in the "alarm on" zone). This switch shall transfer the grounding connection of the Line Isolation Monitor from the reference grounding point to a test impedance arrangement connected across the isolated line. The test impedance(s) shall be of appropriate magnitude to produce a meter reading corresponding to a total hazard current of 5.0 milliamperes at the nominal line voltage. The operation of this switch shall break the grounding connection of the Line Isolation Monitor to the reference grounding point before transferring this grounding connector to the test impedance(s), so that making this test will not add to the hazard of a system in actual use, nor will the test include the effect of the line to ground stray impedance of the system. The test switch shall be of a self-restoring type.

3-3.3.4.7 The Line Isolation Monitor shall not generate energy of sufficient amplitude and/or frequency, as measured by a physiological monitor with a gain of at least 10^4 with a source impedance of 1,000 ohms connected to the balanced differential input of the monitor, to create interference or artifact on human physiological signals. The output voltage from the amplifier shall not exceed 30 millivolt when the gain is 10^4 . The 1,000 ohms impedance shall be connected to the ends of typical unshielded electrode leads (which are a normal part of the cable assembly furnished with physiological monitors). A 60 Hz notch filter shall be used to reduce ambient interference (as is typical in physiological monitor design).

3-3.3.4.8 Hospitals complying with NFPA 56A, *Standard for the Use of Inhalation Anesthetics*, prior to 1970 shall not be required to change ground detectors to a Line Isolation Monitor.

3-3.3.5 Isolated Power System. The isolated electric system specified for flammable inhalation anesthetizing locations shall only be required to be explosionproof if installed in the hazardous areas of a flammable inhalation anesthetizing location.

3-3.4 Wiring, Receptacles, and Fixtures.

3-3.4.1 Electric Wiring and Equipment.

3-3.4.1.1 Electric wiring and fixed equipment installed in the hazardous area of a flammable inhalation anesthetizing location shall comply with the requirements of NFPA 70, *National Electrical Code*, Article 501, Class I, Division 1. Equipment installed therein shall be approved for use in Class I, Group C, Division 1 hazardous areas.

3-3.4.1.2 Wiring for fixed equipment installed outside the hazardous area of a flammable inhalation anesthetizing location shall comply with 3-3.4.1.10.

3-3.4.1.3 All service equipment, switchboards, or panelboards shall be installed outside hazardous areas.

3-3.4.1.4 Control Devices. Devices or apparatus such as motor controllers, thermal cutouts, switches, relays, the switches and contactors or auto-transformer starters, resistance and impedance devices, which tend to create arcs, sparks, or high temperatures, shall not be installed in hazardous areas unless devices or apparatus are of a type approved for use in Class I, Group C atmospheres in accordance with Sections 501-6(a), 501-7(a) or Sections 501-6(b) and 501-7(b) of NFPA 70, *National Electrical Code*.

NOTE: It is recommended that control devices for such purposes be installed in a nonhazardous area and actuated by some suitable mechanical, hydraulic, or other nonelectric remote control device which may be operated from any desired location. This recommendation applies particularly to foot and other switches which must be operated from a location at or near the floor.

3-3.4.1.5 Electric wiring and equipment in storage locations for flammable anesthetic agents shall comply with the requirements of NFPA 70, *National Electrical Code*, Article 500, Class I, Division 2 and equipment used therein shall be approved for use in Class I, Group C, Division 1 hazardous areas (see 3-2.3.2 for grounding requirements).

3-3.4.1.6 The provisions of 3-3.3.1 for ungrounded electric distribution systems do not apply to storage locations for flammable agents.

3-3.4.1.7 Electric switches installed in hazardous areas of flammable anesthetizing locations shall comply with the requirements of Section 501-6(a) of NFPA 70, *National Electrical Code*.

3-3.4.1.8 Electric switches installed in other than hazardous areas shall comply with 3-3.4.1.9.

3-3.4.1.9 Identification of Conductors for Isolated (Ungrounded) Systems. The isolated conductors shall be identified in accordance with 517-104(a)(5) of NFPA 70, *National Electrical Code*.

3-3.4.1.10 Ceiling-suspended surgical lighting fixtures shall be supplied from an ungrounded electric distribution system (see 3-3.3.1.1) which shall be monitored by a Line Isolation Monitor as required by 3-3.3.4.1. Switching or dimmer devices shall control secondary circuit conductors only.

Exception No. 1: Where interruption of illumination is acceptable, as with single filament lights, ceiling-suspended surgical lighting fixtures may be connected to a grounded source of supply, protected by approved individual ground fault circuit interrupters.

Exception No. 2: The secondary circuit of the ceiling-mounted surgical lighting fixture supplied by a step down isolation transformer need not be equipped with a Line Isolation Monitor provided that the step down transformer is located in the same enclosure as the lamp fixture, or that the conductors carrying the current from the transformer to

the lamp fixture are contained in metallic conduit that forms an integral electrical (ground) pathway between the transformer enclosure and the lamp fixture, and provided that the voltage in the secondary (lamp) circuit is not greater than 30 volts.

3-3.4.2 Receptacles and Attachment Plugs.

3-3.4.2.1 Receptacles and attachment plugs in hazardous areas shall comply with the requirements of Section 501-12 of NFPA 70, *National Electrical Code*. They shall be a part of an approved unit device with an interlocking switch arranged so that the plug cannot be withdrawn or inserted when the switch is in "on" position.

NOTE: It should be recognized that any interruption of the circuit, even of circuits as low as eight volts, either by any switch or loose or defective connections anywhere in the circuit, may produce a spark sufficient to ignite a flammable anesthetic agent.

3-3.4.2.2 Non-explosionproof plugs shall not engage, and be energized by, the poles of Class I, Group C, Division 1 receptacles.

NOTE: It is desirable to promote "one-way" interchangeability by using attachment plugs in hazardous areas which can also mate with the non-explosionproof receptacles in nonhazardous areas.

3-3.4.3 Ceiling-Suspended Fixtures.

3-3.4.3.1 The light source of ceiling-suspended surgical lighting fixtures installed above hazardous areas shall not enter the hazardous area, and, if in an enclosure, the enclosure shall not enter the hazardous area in its lowest position, unless it is approved for hazardous areas.

3-3.4.3.2 If installed above a hazardous area, fixtures with sliding contacts, or arcing or sparking parts shall be installed so that in any position of use, no sliding contacts or arcing or sparking parts shall extend within the hazardous areas.

3-3.4.3.3 Integral or appended switches, if installed on ceiling-suspended surgical lighting fixtures, shall be approved for use in Class I, Group C, Division 1 hazardous areas if a switch is installed in, or can be lowered into, the hazardous area.

3-3.4.3.4 Lamps installed in fixed position in hazardous areas shall be enclosed in a manner approved for use in Class I, Group C, Division 1 hazardous areas and shall be properly protected by substantial metal guards or other means where exposed to breakage. Lamps shall not be of the pendant type unless supported by and supplied through hangers of rigid conduit or flexible connectors approved for use in Class I, Group C, Division 1 hazardous areas in accordance with Section 501-9(a) or Section 501-9(b) of NFPA 70, *National Electrical Code*.

3-3.4.3.5 Tube heads and cable of permanently installed X-ray equipment in flammable anesthetizing locations shall be approved for use in Class I, Group C atmospheres.

3-3.4.3.6 Viewing Box Lighting. Film viewing boxes in hazardous areas shall either comply with the requirements of Section 501-9(a) of NFPA 70, *National Electrical Code*, or they shall be of a type which excludes the atmosphere of the room. If located above the 5 ft (152 cm) level in a flammable anesthetizing location or mixed facility, or in a

nonflammable anesthetizing location, the film viewing box may be of the totally enclosed type or so constructed as to prevent the escape of sparks or hot metal. Such viewing boxes may be connected to a conventional grounded supply circuit if the device is protected by an approved system of double insulation. Where such an approved system is employed, the equipment shall be distinctly marked.

3-3.4.3.7 Control units and other electric apparatus installed or intended for use in a flammable anesthetizing location shall comply with the requirements of 3-3.4.1 (*see also 3-3.4.3.3 and 3-5.6.4*).

3-3.4.4 Signaling and Communications Systems. All equipment of signaling and communications systems in hazardous areas, irrespective of voltage, shall be of a type approved for use in Class I, Group C, Division 1 hazardous areas in accordance with Section 501-14(a) or Section 501-14(b) of NFPA 70, *National Electrical Code*.

3-3.5 Portable Electric Equipment.

3-3.5.1 Line Voltage Equipment.

3-3.5.1.1 All equipment intended for use in anesthetizing locations shall be labeled by the manufacturer to indicate whether it may be used in a flammable anesthetizing location. Electric equipment presently in use shall be so labeled by the user. Labeling shall be permanent, conspicuous and legible when the equipment is in the normal operating position (*see 3-3.5.1.6*).

3-3.5.1.2 Suction, pressure, or insufflation equipment, involving electric elements and located within the hazardous area, shall be of a type approved for use in Class I, Group C, Division 1 hazardous areas. Means shall be provided for liberating the exhaust gases from such apparatus in such a manner that gases will be effectively dispersed without making contact with any possible source of ignition.

NOTE: Suction of pressure apparatus serving flammable anesthetizing locations but located outside such flammable anesthetizing locations need not be approved for Class I, Group C, Division 1 hazardous areas, providing the discharge from suction machines is kept away from sources of ignition.

3-3.5.1.3 Portable X-ray equipment intended for use in flammable anesthetizing locations shall be approved for use in Class I, Group C, Division 1 hazardous areas and may be provided with an approved positive pressure system for the tube head and cables within the hazardous area [*see 3-3.5.1.6(b)*]. All devices and switches for X-ray equipment within the hazardous area shall conform to requirements of 3-3.4.1.3, 3-3.4.3.5 and 3-3.4.3.7. X-ray equipment shall be provided with an approved method of eliminating electrostatic accumulation (*see 3-2.3.4.3 and 3-3.4.3.5*).

3-3.5.1.4 High-frequency equipment intended for use in flammable anesthetizing locations shall be approved for use in Class I, Group C, Division 1 hazardous areas.

NOTE 1: Remote control switches are recommended (*see 3-3.4.1.4 and 3-3.7.2.3*).

NOTE 2: For recommendations in connection with the use of cautery and high-frequency equipment in flammable anesthetizing locations, *see 3-3.5.2 and Appendix C-3-3, Regulation Set (1), 4(d) and Set (3), 4(e), and Appendix E, Safe Use of High-Frequency Electricity in Health Care Facilities.*

3-3.5.1.5 Portable electric equipment, such as incubators, lamps, heaters, motors and generators, used in flammable anesthetizing locations in which anesthesia equipment is present or in operating condition, shall comply with requirements of Articles 500, 501 and 517 of NFPA 70, *National Electrical Code*, for Class I, Division 1 locations and shall be approved for Class I, Group C, Division 1 hazardous areas except as permitted in 3-3.5.1.6.

NOTE: The resistance and capacitive reactance between the conductors and the noncurrent-carrying metallic parts must be high enough to permit the use of the equipment on an ungrounded distribution system having a Line Isolation Monitor specified in 3-3.3.4.

3-3.5.1.6 The following shall be considered exceptions to 3-3.5.1.1 and 3-3.5.1.5.

(a) Equipment designed to operate on circuits of ten volts or less shall comply with 3-2.5.2.

(b) Portable electric or electronic equipment mounted within an enclosure and protected by an approved positive-pressure ventilating system which conforms with the following requirements shall otherwise comply with the standards of NFPA 70, *National Electrical Code*, for ordinary locations. The enclosure of such a system shall be supplied with air taken from a nonhazardous area and circulated to maintain within the enclosure a pressure of at least 1 in. (2.5 cm) of water above that of the hazardous area, and shall be provided with means to de-energize the equipment if the air temperature exceeds 140°F (60°C), or if the pressure differential drops below 1 in. (2.5 cm) of water. The positive pressure shall be continuously maintained whether or not the equipment is in use, or means shall be provided to ensure that there are at least ten changes of air within the enclosure before any electric equipment within the enclosure that does not comply with the requirements of 3-3.4.1.5 is energized. The enclosure with its equipment shall be approved for use in Class I, Group C, Division 1 hazardous areas.

(c) Portable electric or electronic equipment, if it is mounted on a floor-borne movable assembly which will not overturn (a) when it is tilted through an angle of 20 degrees or (b) when in a normal operating position a horizontal force of 25 lb (11.3 kg) is applied at a height of 5 ft (152 cm) above the floor, and if the equipment, together with its enclosure, cannot be lowered within 5 ft (152 cm) of the floor without tilting the assembly, need not be approved for use in Class I, Group C, Division 1 hazardous areas, but shall comply with the requirements of 3-3.5.1.5. The entire assembly shall be approved for use in anesthetizing locations as defined in Section 2-2.

(d) Intrinsically safe electric or electronic equipment which is incapable of releasing sufficient electric energy under normal or abnormal conditions to cause ignition of flammable anesthetic mixtures may be approved for use in Class I, Group C, Division 1 hazardous areas as provided in Section 500-1 of NFPA 70, *National Electrical Code*.

3-3.5.1.7 Photographic lighting equipment used in flammable anesthetizing locations shall comply with provisions of 3-3.5.1 to prevent ignition of flammable gases (*see 3-2.5.1.7*). Lamps used above the hazardous area shall be suitably enclosed to prevent sparks and hot particles falling into the hazardous area. Photoflash and photoflood lamps which are not suitably enclosed shall not be used within an anesthetizing location. Neither flash tubes nor their

auxiliary equipment shall be used within the hazardous area. Flash-tube operation may be accompanied by sparking at switches, relays and socket contacts, and by corona discharge of flashovers from high-voltage circuits.

3-3.5.1.8 The exposed metal parts of photographic lighting equipment shall be grounded as specified in 3-2.5.1.2.

3-3.5.1.9 Administrative vigilance is required to prohibit the use of portable electric equipment and appliances—such as electric drills—of a type unsuitable for use in hazardous areas in flammable anesthetizing locations during their occupancy by patients or near anesthesia equipment in operating condition and in storage locations containing flammable inhalation anesthetic agents.

3-3.5.2 High-Frequency Equipment. Potential sources of ignition, such as electrosurgical units, shall be prohibited during the administration of flammable anesthetizing agents.

3-3.5.3 Low-Voltage Equipment.

3-3.5.3.1 Specifications for portable equipment operating on low-voltage power supplies and not stated in 3-3.5.1.6(a) and 3-3.5.2 are stated in 3-2.5.2.

3-3.6 Reduction in Electrostatic Hazard.

3-3.6.1 Purpose.

3-3.6.1.1 The requirements of this section have been promulgated to reduce the possibility of electrostatic spark discharges, with consequent ignition of flammable gases (*see C-3-1.3.1*).

3-3.6.1.2 The prevention of the accumulation of static charges revolves about a number of safeguards which shall be complied with in flammable anesthetizing locations, in corridors and passageways adjacent thereto, in rooms connecting directly to anesthetizing locations, such as scrub rooms and sterilizing rooms, and in storage locations for flammable anesthetics located in an operating suite.

3-3.6.1.3 The methods employed to prevent such accumulation include the installation of conductive flooring (*see 3-3.6.2*), the maintenance of the relative humidity at 50 percent at least, and the use of certain items of conductive equipment, accessories and wearing apparel.

3-3.6.2* Conductive Flooring.

3-3.6.2.1 Conductive flooring shall be installed in those areas specified in 3-3.6.1.2. Conductive flooring installed in corridors or passageways in compliance with 3-3.6.1.2 shall extend the width of the corridor and along the corridor a minimum of 9.84 ft (3 m) on each side of door frames.

3-3.6.2.2 A conductive floor shall meet the resistance provisions through its inherent conductive properties. The surface of the floor in the locations specified by 3-3.6.1.2 and 3-3.6.2.1 shall provide a patch of moderate electric conductivity between all persons and equipment making contact with the floor to prevent the accumulation of dangerous electrostatic charges. No point on a nonconductive element in the surface of the floor shall be more than ¼ in. (6.4 mm) from a conductive element of the surface, except for insulated floor drains.

3-3.6.2.3 The resistance of the conductive floor shall be less than an average of 1,000,000 ohms as measured in 3-3.6.2.7.

3-3.6.2.4 The resistance of the floor shall be more than an average of 25,000 ohms, as measured in 3-3.6.2.7.

3-3.6.2.5 A deliberate connection of the conductive floor to the room ground shall not be required.

3-3.6.2.6 The resistance of conductive floors shall be initially tested prior to use. Thereafter measurements shall be taken at intervals of not more than one month. A permanent record of the readings shall be kept.

3-3.6.2.7 The following test method shall be used (*see 3-3.7.5*).

(a) The floor shall be clean and dry and the room shall be free of flammable gas mixtures.

(b) Each electrode shall weigh 5 lb (2.268 kg) and shall have a dry, flat, circular contact area 2½ in. (6.35 cm) in diameter, which shall comprise a surface of aluminum or tin foil .0005 in. (.013 mm) to .001 in. (.025 mm) thick, backed by a layer of rubber ¼ in. (6.4 mm) thick and measuring between 40 and 60 durometer hardness as determined with a Shore Type A durometer (ASTM D-2240-68).

(c) Resistance shall be measured by a suitably calibrated ohmmeter which shall have a nominal open circuit output voltage of 500 volts dc and a nominal internal resistance of not less than 100,000 ohms, with tolerance defined as follows:

1. Short-circuit current of from 2.5 ma to 5 ma.
2. At any value of connected resistance, R_x , the terminal voltage V shall be

$$\left[\frac{R_x}{R_x + \text{internal resistance}} \right] \times 500V \pm 15\%$$

(d) Measurements shall be made between five or more pairs of points in each room and the results averaged. For compliance with 3-3.6.2.3 the average shall be within the limits specified and no individual measurement value shall be greater than five megohms, as measured between two electrodes placed 3 ft (91 cm) apart at any points on the floor. For compliance with 3-3.6.2.4 the average value shall be no less than 25,000 ohms with no individual measurements value less than 10,000 ohms as measured between a ground connection and an electrode placed at any point on the floor, and also as measured between two electrodes placed 3 ft (91 cm) apart at any points on the floor. There is no upper limit of resistance for a measurement between a ground connection and an electrode placed on the conductive floor.

NOTE: If the resistance changes appreciably with time during a measurement, the value observed after the voltage has been applied for about five seconds shall be considered to be the measured value.

3-3.6.3 Accessories.

3-3.6.3.1 Coverings of operating tables, stretcher pads, pillows and cushions, etc., shall be fabricated from conductive materials throughout. Conductive sheeting shall be tested on a nonconductive surface. The resistance

between two electrodes placed 3 ft (91 cm) apart, or as close to this distance as the size of the material will permit, on the same surface, and between two electrodes placed in the middle of opposite surfaces, shall not exceed one megohm. Individual items covered with conductive sheeting shall be tested on a metal surface. The resistance between an electrode placed on the upper surface of the covered item and another electrode placed on the metal surface shall not exceed one megohm. Electrodes and ohmmeter used for these tests shall be of the type specified in 3-3.6.2.7(b) and (c) respectively.

3-3.6.4 Interconnecting Conductive Accessories.

3-3.6.4.1 All accessories which are required to be resilient or flexible on the anesthesia machine, and which form part of an interconnecting electrically conductive pathway, such as tubing, inhalers, rebreathing bags, headstraps, retainers, face masks, handbulbs and similar items, shall be of conductive material throughout. Electric resistance of such accessories shall be not greater than one megohm when tested as specified in 3-3.6.5.1.

High-pressure flexible tubing used to interconnect the gas anesthesia apparatus with the central piping station outlets shall be antistatic and shall be conductive throughout with a maximum resistance of 100,000 ohms per linear foot during the specified life of the material.

NOTE: When a nonconductive endotracheal catheter is in use, the conductive path from the patient to the anesthesia machine should be maintained by the use of a conductive headstrap.

3-3.6.4.2 Tubing and connectors used for suctioning shall provide a continuous electrically conductive pathway to the vacuum bottle and to the vacuum outlet. The materials used shall be conductive throughout or, where it is necessary for visual monitoring, may be of antistatic material with antistatic properties good for the specified life¹ of the material provided tubing or connector embodies a continuous integral conductive pathway designed so that in normal use the conductive pathway shall make and maintain conductive contact with conducting materials. Electric resistance of such tubing and connectors shall be not greater than one megohm when tested as specified in 3-3.6.5.

3-3.6.4.3 All belting used in connection with rotating machinery shall have incorporated in it sufficient material to prevent the development of electrostatic charges. A conductive pulley shall be used.

NOTE: The conductivity of the path from the pulley to the ground should be considered. If ball bearings are used, the contact between the balls and the races will probably be sufficient when bearings are lubricated with graphited oil or grease. If sleeve bearings are used, some means of conducting the charge from the pulley should be provided.

3-3.6.4.4 Wherever possible, items which are not parts of a machine shall be of conductive materials throughout, particularly where the item is depended on to provide a conductive pathway between other conductive items and/or the patient (*see Note after 3-3.6.4.1*).

NOTE: For essential elements in surgery, such as prosthetic and therapeutic devices, bacterial barriers, instruments, gloves (ther-

moplastic: for example, PVC), or biomechanical equipment, antistatic materials should be used if conductive materials are not available or are impractical. Regular materials may be used in approved devices shown by test to be nonhazardous.

3-3.6.4.5 Nonconductive nonantistatic parts shall be used where necessary as electric insulators or heat insulating handles on approved devices. Where exposed metal parts of machines of necessity are insulated from each other by other nonconductive parts, they shall be electrically interconnected. The resistance of the grounding path between these metal parts shall not exceed 0.1 ohm.

3-3.6.4.6 Antistatic materials are not acceptable where they are relied upon to provide an interconnecting electrically conductive pathway.

3-3.6.5 Testing for Conductivity.

3-3.6.5.1 An ohmmeter of the type specified in 3-3.6.2.7(c) shall be used for testing. Where possible, electrodes shall be of the type to make contact with metal positions across which it is desired to ensure a conductive pathway provided by the accessory, but care must be taken to ensure that the placing of the electrodes has not inadvertently provided an alternate conductive path to that under test; or, electrodes shall be of the type specified in 3-3.6.2.7(b), where applicable; or, equivalent electrode contact shall be employed as practical. All items which are parts of a machine such as tubing, bags, face masks, etc., shall be tested either in place or detached from the machine in accordance with one of the methods listed under 3-3.6.5.2 through 3-3.6.5.8.

3-3.6.5.2 When tested in place on the machine, it is first necessary to purge the entire system of flammable or explosive gases. The anesthesia jar and cylinders of flammable gases shall be removed from the machine and all the remaining parts purged by flowing air through them in sufficient quantity to assure that all residual anesthetic gases have been removed. All parts shall be tested and each part shall be tested separately.

3-3.6.5.3 For interconnecting parts that are to be classed as conductive throughout, one electrode shall be attached in a satisfactory manner to the metal frame of the machine, and the conductivity shall be determined by measuring the resistance between this first electrode and a second electrode consisting of a metal band snugly fitted around the midpart of the item being tested or, for face masks and similar objects, between the first electrode and a second electrode [*see 3-3.6.2.7(b)*] resting on the item.

3-3.6.5.4 For interconnecting parts that are to be classed as antistatic with a continuous integral conductive pathway, the conductivity test shall be performed as given in 3-3.6.5.1 above except that, in place of the metal band electrode or the standard electrode of 3-3.6.2.7(b), there shall be a suitable second electrode making contact with the part in a manner that simulates the actual second contact area made when the part is connected for use.

3-3.6.5.5 Metal parts of machines which are of necessity apparently insulated from each other by other nonconductive parts shall be suitably tested for electric interconnection; this may be an ohmmeter test. The resistance of the grounding path between these metal parts shall not exceed 0.1 ohm.

¹"Specified life" refers to the permanence of the antistatic property with respect to the stated life of the material, including storage, and is of particular importance if the material is expected to be used and cleaned (e.g., washed) several times.

3-3.6.5.6 When tubing and other accessories are tested for conductivity while detached from a machine, each part shall be fitted with a clean brass nipple of the same outside diameter as the connector by which the part is normally connected to the machine. A nipple shall be inserted into each such opening of the part. When two or more nipples are involved, satisfactory conductivity shall be determined by measuring the resistance between nipples. If only one nipple is involved, as in the case of a face mask or breathing bag, the resistance shall be measured between the nipple and another electrode suitably connected elsewhere (e.g., a standard electrode resting on the part).

3-3.6.5.7 While the above are given as standard test methods, where these methods cannot be applied, an equivalent test method may be used. Interconnecting conductivity is acceptable if the measured resistance is not greater than one megohm.

3-3.6.5.8 Conductive items containing antistatic material shall have the antistatic properties tested as given in 3-3.6.6.3 and 3-3.6.6.4.

3-3.6.6 Antistatic Accessories and Testing.

3-3.6.6.1 For conductive accessories containing antistatic material see 3-3.6.4.1 and 3-3.6.4.2; the antistatic material of these accessories shall be tested as given in 3-3.6.6.3 and 3-3.6.6.4. For other individual items which may be of antistatic material see 3-3.6.4.4.

3-3.6.6.2 Plastic sheeting, film and other nontextile, nonmetal materials, if not required to form a conductive interconnecting pathway between machines, objects and persons, need not be conductive but shall be of antistatic material except as given in 3-3.6.4.4. They shall be of antistatic material throughout their specified life when tested as given in 3-3.6.6.3 and 3-3.6.6.4.

3-3.6.6.3 Antistatic sheeting, film and textiles shall meet the specified requirements of at least one of the following test methods when preconditioned at 50 percent $\pm$ 2 percent RH at 23° $\pm$ 1°C for 25 hours or until equilibrium is reached, and tested at 50 percent $\pm$ 2 percent RH at 23° $\pm$ 1°C.

(a) *Method 4046 of Federal Test Method Standard 101B.* After the specimen has received its maximum charge from the application of 5000 volts, the time for the indicated specimen potential to drop to 10 percent of its maximum value shall not exceed $\frac{1}{2}$ second.

NOTE: The static detector head should be of a type which is adequately shielded to minimize responses to potentials on the electrodes, and other stray pickup. The sample is held between electrically interconnected electrodes. The 5000 volts is applied to the electrodes for 10 seconds after the indicated potential of the sample reaches equilibrium before the charge decay rate is measured.

(b) *Method 76-1972 of the AATCC (ANSI L14.112).* Applied voltage should be 102 volts per in. (40 volts per cm) of interelectrode spacing. The measured resistivity shall be less than 1×10^{11} ohms per unit square of material.

3-3.6.6.4 Antistatic items other than sheeting, film, and textiles shall be tested in a manner as closely as possible equivalent to that given in 3-3.6.6.3.

3-3.6.6.5 The supplier of conductive and antistatic accessories shall certify that item or items supplied meet the requirements of one of the tests specified in 3-3.6.6.3. The supplier shall certify the conditions of storage, shelf life and, in the case of reusable items, the methods of reparation necessary to allow the product or device to return to its antistatic or conductive properties.

3-3.6.7 Conductive Footwear.

3-3.6.7.1 The resistance of any static conductive footwear or any equivalent static conductive device used in conjunction with nonconductive footwear shall have a value before the item is first put in use not exceeding 500,000 ohms when tested in the following manner. The static conductive shoe or any equivalent static conductive device attached to a nonconductive shoe shall have clean contact surfaces. It shall be placed on a nonoxidizing metal plate wetted with water. A brass electrode having a contact area of 1 sq in. (6.5 sq cm) shall be placed on the inside of the sole or heel of the shoe after the surface under the electrode has been wetted by water. The resistance shall be measured between the plate and the electrode using a dc ohmmeter supplying a potential in excess of 100 volts [e.g., see 3-3.6.2.7(c)].

3-3.6.7.2 In the case of static conductive booties, the test shall be made as follows: The bootie shall be laid flat on an insulating surface. Two brass electrodes, each 1.5 in. (3.8 cm) long, having a contact area of 1 sq in. (6.5 sq cm), shall be used. One electrode shall be placed on the bootie near the toe and on the part of the bootie that normally comes in contact with the floor. The other electrodes shall be placed on the ankle section. The booties shall be wetted under the electrodes only.

3-3.6.7.3 If the tests as here described are not technically feasible for the device under consideration, an alternative equivalent means of testing shall be used. The static conductive footwear and any static conductive device used with nonconductive footwear shall also meet, during use, the requirements of 3-3.7.3.1, 3-3.7.3.2, 3-3.7.3.3 and 3-3.7.6.3.

3-3.6.7.4 For protection of personnel against electric shock and high-frequency burns, static conductive footwear and equivalent static conductive devices shall not have any metal parts (nails, etc.) which normally come in contact with the floor.

3-3.6.8 Textiles. (See also 3-3.7.3.4, 3-3.7.3.5 and 3-3.7.3.6.)

3-3.6.8.1 Silk, wool, synthetic textile materials, blends of synthetic textile materials with unmodified cotton or rayon, or nonwoven materials shall not be permitted in hazardous locations as outer garments or for nonapparel purposes, unless such materials have been tested and found to be antistatic by meeting the requirements of 3-3.6.6.3.

In the case of reusable materials the manufacturer shall certify that the antistatic properties shall be maintained through 50 wash-autoclave cycles or throughout the useful life of the material, whichever is greater.

In the case of nonreusable material the manufacturer shall certify that the antistatic properties shall be maintained throughout the useful life of the material.

NOTE: It is preferable to use only one textile material because static electricity is more readily generated by contact between articles of different materials than by contact between articles of the same material.

3-3.6.9* Furniture.

3-3.6.9.1 If the furniture is conductive but not made of metal, then it shall have casters, tires, or legs of metal, conductive rubber, or equivalent conductive material with a floor contact surface having one dimension of at least $\frac{3}{8}$ in. (1.58 cm). Approved equivalent means of making conductive contact between the piece of furniture and the floor is acceptable, provided the contact device is securely bonded to the piece of furniture and is of material which will not oxidize under conditions of normal use to decrease the conductivity of the circuit, and if uninterrupted contact with the floor is at least $\frac{3}{8}$ in. (1.6 cm) in one dimension (*see also 3-3.7.6.4*).

3-3.6.9.2 Surfaces on which movable objects may be placed shall be without insulating paint, lacquer, or other nonconductive finish.

3-3.6.9.3 The resistance between the conductive frame of the furniture referred to in 3-3.6.9.2 and a metal plate placed under one supporting member but insulated from the floor shall not exceed 250,000 ohms, measured with an ohmmeter of the type described in 3-3.6.2.7(c).

3-3.7 Administration and Maintenance.

3-3.7.1 Storage of Flammable Agents.

3-3.7.1.1 Hospital administrative authorities, in consultation with the medical staff and others of training and expertise, shall determine the adequacy of storage space for flammable anesthetic and disinfecting agents and medications (*see 3-3.7.2*), and shall provide and enforce regulations for the storage and handling of containers of such agents. Said regulations also shall provide for the periodic inspection and maintenance of said storage locations.

3-3.7.1.2 Storage locations for flammable anesthetics shall meet the construction requirements stated in 3-2.2.1.1 and 3-2.2.1.2, and shall be ventilated as provided in 3-3.1.2.1.

3-3.7.1.3 Flammable inhalation anesthetizing agents shall be stored only in such locations. Flammable inhalation anesthetizing agents shall not be stored in anesthetizing locations, other than cylinders of flammable anesthetic agents connected to a gas anesthesia apparatus.

3-3.7.1.4 Cylinders containing flammable gases (i.e., ethylene and cyclopropane) and containers of flammable liquids (i.e., diethyl ether, divinyl ether, ethyl chloride) shall be kept out of proximity to cylinders containing oxidizing gases (i.e., oxygen or nitrous oxide) through the use of separate rooms.

3-3.7.1.5 Storage locations for flammable inhalation agents shall be kept free of cylinders of nitrous oxide, compressed air, oxygen and mixtures of oxygen.

¹An economical way to make painted furniture conform to this requirement is to attach unpainted sheet metal to the furniture's shelf or top with screws, rivets, or similar fasteners that provide electrical continuity to the frame and casters of the furniture.

3-3.7.1.6 Sources of illumination and ventilation equipment in storage locations for flammable inhalation anesthetic agents, wherever located, and especially in storage locations which are remote from the operative suite shall be inspected and tested on a regular schedule. Such procedures shall determine that adequate ventilation is maintained under supervision.

3-3.7.2 General Requirements for Flammable Anesthetizing Locations.

3-3.7.2.1 Hospital authorities in consultation with others as noted in 3-3.7.1.1 shall adopt regulations to control apparel and footwear allowed, the periodic inspection of conductive materials, the control of purchase of static conductive and antistatic materials, and the testing of conductive floors.

3-3.7.2.2* All required precautions shall apply to all anesthetizing locations in which flammable inhalation anesthetics are used.

3-3.7.2.3 Hospital regulations shall be established and enforced to control the use of electronic equipment such as television equipment, diathermy equipment, public address systems, monitoring equipment, and similar electronic and high-frequency apparatus in the presence of flammable inhalation anesthetic agents.

3-3.7.2.4 Hospital regulations shall prohibit the use of X-ray equipment in flammable anesthetizing locations if such equipment is not approved for operation in hazardous locations (*see 3-3.4.3.5, 3-3.4.3.7 and 3-3.5.1.3*).

3-3.7.2.5 Covers of fabric or of any form of sheeting shall not be used on anesthesia equipment capable of utilizing flammable anesthetizing agents because a cover will confine gas that may leak from a cylinder. When the cover is removed from the anesthesia machine under such conditions a static charge may be created which could ignite the gas confined beneath the cover.

3-3.7.2.6 The use of rebreathing techniques in administering flammable anesthetic agents at all times is highly desirable. Through the use of these techniques the escape of flammable mixtures is substantially limited.

3-3.7.2.7 Residual ether remaining in ether vaporizers at the end of each day shall be returned to original containers for disposal or laboratory use only. The ether vaporizer, container, and such shall be thoroughly washed and dried before being returned to use (*see Appendix C-3-1.3.2.1*).

3-3.7.2.8 Waste liquid ether and other flammable volatile liquid inhalation anesthetic agents shall be disposed of outside of the hospital building according to the recommendations of the authority having jurisdiction. One method is to allow the agent to evaporate in a shallow pan, well removed from possible sources of ignition under supervision.

3-3.7.2.9 Members of the professional staff shall be required to submit for inspection and approval any special equipment they wish to introduce into flammable anesthetizing locations (*see 3-2.7.7.6*). Such equipment shall be

approved for use in Class I, Group C, Division 1 hazardous areas or comply with 3-3.5.1.5. It shall be equipped with approved cords and attachment plugs (see 3-2.5.1.3 through 3-2.5.1.4, 3-3.2.1, and 3-3.2.2).

3-3.7.2.10 High-frequency electric and electronic equipment, such as electrosurgery amplifiers, monitors, recorders, television cameras, portable electrical tools, maintenance equipment, and certain sterilizing equipment which does not comply with the provisions of 3-3.5.1.5, shall not be used when flammable inhalation anesthetic agents are being administered.

Cautery and electric surgical equipment shall not be used during procedures involving flammable inhalation anesthetic agents unless the equipment complies with the requirements of 3-3.5.1.4 and Appendix E, Safe Use of High-Frequency Electricity in Health Care Facilities (see 3-3.5.2).

3-3.7.3 Electrostatic Safeguards.

NOTE: Section 3-3.6 of this chapter deals with the elements required to be incorporated into the structure and equipment to reduce the possibility of electrostatic spark discharges which are a frequent source of the ignition of flammable anesthetic agents. The elimination of static charges is dependent on the vigilance of administrative activities in materials, selection, maintenance supervision, and periodic inspection and testing. It cannot be too strongly emphasized that an incomplete chain of precautions will generally increase the electrostatic hazard. For example, conductive flooring (see 3-3.6.2) may contribute to the hazard unless all personnel wear conductive shoes and unless all objects in the room are electrically continuous with the floor.

3-3.7.3.1* All personnel entering flammable anesthetizing locations, mixed facilities or storage locations for flammable anesthetics located in the surgical suite shall be in electrical contact with the conductive floor through the wearing of conductive footwear or an alternative method of providing a path of conductivity. The provision of conductive floors in corridors and rooms directly communicating with flammable anesthetizing locations (see 3-3.6.2) will minimize the possibility of static discharge from patients or personnel entering such anesthetizing locations.

3-3.7.3.2 Electric connection of the patient to the operating table shall be assured by the provision of a high-impedance strap in contact with the patient's skin, with one end of the strap fastened to the metal frame of an operating table.

3-3.7.3.3 Because of the possibility of percussion sparks, shoes having ferrous nails which may make contact with the floor shall not be permitted in flammable anesthetizing locations or mixed facilities nor in storage locations for flammable anesthetic agents in the surgical suite.

3-3.7.3.4 Silk, wool, or synthetic textile materials, except rayon, shall not be permitted in flammable anesthetizing locations or mixed facilities as outer garments or for nonapparel purposes, unless these materials have been approved as antistatic in accordance with the requirements of 3-3.6.6.3 and 3-3.6.6.4.

NOTE: Rayon refers to regenerated cellulose and not cellulose acetate. Cotton and rayon must be unmodified; i.e., must not be glazed, permanently starched, acetylated, or otherwise treated to reduce their natural hygroscopic quality. Fabrics of intimate blends of unmodified cotton or rayon with other textile materials are not acceptable unless tested and found to be antistatic.

3-3.7.3.5 Hosiery and underclothing in which the entire garment is in close contact with the skin may be of silk, wool, or synthetic material.

3-3.7.3.6 Undergarments with free-hanging skirts, such as slips or petticoats, shall be of cotton, rayon, or other materials demonstrated to be antistatic by the requirements of 3-3.6.6.3 and 3-3.6.6.4.

3-3.7.3.7 Antistatic materials for use in flammable anesthetizing locations shall be handled and used in the following manner:

(a) Antistatic materials shall be stored at the temperature and humidity required for flammable anesthetizing locations or they shall be allowed to equilibrate to the humidity and temperature of the flammable anesthetizing location prior to use.

(b) Antistatic materials shall be stored in such a manner that will ensure that the oldest stocks will be used first.

(c) Controls shall be established to ensure that manufacturers' recommendations as to use are followed in the case of antistatic materials.

3-3.7.3.8 All antistatic accessories intended for replacement, including belting, rubber accessories, plastics, sheeting and the like, shall meet pertinent requirements for conductivity as specified in 3-3.6.6.

3-3.7.4 Discretionary Use of Nonconforming Materials.

3-3.7.4.1 Suture material, alloplastic or therapeutic devices, bacterial barriers, instruments, gloves (thermoplastic), surgical dressings, and biologic interfaces of these otherwise prohibited materials may be used at the discretion of the surgeon.

3-3.7.4.2 Disposable supplies which contribute to the electrostatic hazard shall be so labeled on the unit package.

3-3.7.5 Maintenance of Conductive Floors.

3-3.7.5.1 The surface of conductive floors shall not be insulated by a film of oil or wax. Any waxes, polishes, or dressings used for maintenance of conductive floors shall not adversely affect the conductivity of the floor.

3-3.7.5.2 Floors which depend upon applications of water, salt solutions, or other treatment of a nonpermanent nature for their conductivity are not acceptable.

Exception: Treatment of the floor to modify conductivity shall be considered permanent provided the floor meets the requirements of this chapter for a period of not less than two years during which no change or modification beyond normal washing is performed.

3-3.7.5.3 Cleaning procedures for conductive floors shall be established, then carefully followed to assure that conductivity characteristics of the floor are not adversely affected by such treatment.

3-3.7.5.4 Conductive floors shall be tested as specified in 3-3.6.2.

3-3.7.6 Other Conductive Equipment.

3-3.7.6.1 The resistance of conductive accessories shall be tested prior to use as described in 3-3.6.3 or 3-3.6.4. Thereafter, measurements shall be taken at intervals of not more than one month. A permanent record of the readings shall be kept.

3-3.7.6.2 Antistatic plastics shall meet the requirements of 3-3.6.6.2. It shall be the responsibility of the hospital to ensure that antistatic sheeting, etc., is used in accordance with the manufacturer's instructions. Failure to do so could in some cases lead to loss of antistatic properties. Antistatic materials which are reused (e.g., such as antistatic tubing incorporating a continuous conductive pathway as described in 3-3.6.4.1) shall be tested (*see 3-3.6.6.1*) periodically to ensure retention of conductive properties.

3-3.7.6.3 Conductive footwear and other personnel-to-floor connective devices shall be tested on the wearer each time they are worn. An approved resistance measuring device having a short-circuit current not exceeding 0.5 milliamperes shall be used.

NOTE: The reading may be taken between two insulated, nonoxidizing, metal plates so located that the wearer can stand in a normal manner with a foot on each, in which case the indicated resistance shall not exceed 1,000,000 ohms (1 megohm). (*See also Appendix A-3-3.7.3.1.*)

3-3.7.6.4 The resistance of furniture (*see 3-3.6.9 and Appendix A-3-3.6.9*) and equipment shall be tested prior to use as described in 3-3.6.9.3. Thereafter, measurements shall be taken at intervals of not more than one month. A permanent record of the readings shall be kept. The monthly tests can conveniently consist of measurements of the resistance between an electrode placed on the floor and an electrode placed successively on each article of furniture in the room. Additional tests of any individual item shall be made if the measured resistance exceed five megohms.

3-3.7.6.5 Periodic inspection shall be made of leg tips, tires, casters, or other conductive devices on furniture and equipment to ensure that they are maintained free of wax, lint or other extraneous material which may insulate them and defeat the purpose for which they are used, and also to avoid transporting to conductive floors such materials from other areas.

3-3.7.6.6 Excess lubrication of casters shall be avoided to prevent accumulation of oil on conductive caster wheels and sides. Dry graphite or graphited oil are preferable lubricants.

3-3.8 Testing the Line Isolation Monitor. The proper functioning of each Line Isolation Monitor circuit shall be assured by the following:

(a) The LIM circuit shall be tested after installation, and prior to being placed in service, by successively grounding each line of the energized distribution system through a resistor of $200 \times V$ ohms, where V = measured line voltage. The visual and audible alarms (*see 3-3.3.4.2*) shall be activated.

(b) The LIM circuit shall be tested at intervals of not more than one month by actuating the LIM test switch (*see 3-3.3.4.6*). Actuation of the test switch shall activate both visual and audible alarm indicators.

(c) After any repair or renovation to an electrical distribution system and at intervals of not more than six months, the LIM circuit shall be tested in accordance with paragraph (a) above and only when the circuit is not otherwise in use.

(d) A permanent record shall be kept of the results of each of the tests.

3-4 Nonflammable Anesthetizing Locations.

3-4.1 Requirements contained in this part are in addition to those contained in Section 3-2.

3-4.2 All nonflammable anesthetizing locations shall be identified by prominently posted permanent signs at all entrances to the location and within the location indicating that only nonflammable anesthetic agents may be employed.

NOTE: Suggested explanatory text of such a sign is as follows:

**RESTRICTED TO NONFLAMMABLE
INHALATION ANESTHETIC AGENTS**

3-4.3 Each operating suite containing only nonflammable anesthetizing locations shall contain prominently posted regulations similar to those contained in Appendix C-3-3, Set (2).

3-4.4* Flooring in nonflammable anesthetizing locations shall not be required to be conductive. If conductive flooring exists, the monthly testing of floors shall not be required provided that at least one test of the floors, as detailed in 3-3.6.2.7, is carried out and which in no case will show a single reading of less than 10,000 ohms. At least five readings shall be taken in each room. In the event that the check shows any reading of less than 10,000 ohms, the facility shall revert to the monthly check of the flooring specified in 3-3.6.2.6 until the flooring again exceeds 10,000 ohms resistance. There is no need to average the readings. Conductive floors are permitted to be rendered nonconductive by means which will modify their conductive properties. (*See 3-3.7.5.2.*)

NOTE: No requirements on upper limit.

3-4.5 In nonflammable facilities the requirements of 3-3.7.3, Electrostatic Safeguards, do not apply. Antistatic clothing and conductive footwear shall not be required. Furniture in nonflammable anesthetizing locations shall not be required to be tested.

3-5 Mixed Facilities.

3-5.1 General. The mixed facility is defined in Chapter 2.

3-5.2 Construction of Anesthetizing Locations and Storage Locations.

3-5.2.1 Flammable anesthetizing locations shall be designed, constructed and equipped as stated in Sections 3-2 and 3-3 of this chapter.

3-5.2.2 The requirements for nonflammable anesthetizing locations are stated in Sections 3-2 and 3-4 of this chapter.

3-5.2.3 Storage locations for flammable anesthetics shall be constructed as provided in 3-3.4.1.2. Storage locations for nonflammable medical gas cylinders shall be constructed as provided in 3-2.2.1.

3-5.3 Conductive Flooring. The provisions of 3-4.4 shall apply to permanently designated and posted nonflammable anesthetizing locations which exist within a mixed facility.

3-5.4 Provision for Connection of Patient to Operating Table. Electric connection of the patient to the operating table shall be assured by the provision of a high-resistance (conductive) strap in contact with the patient's skin, with one end of the strap fastened to the metal frame of an operating table.

3-5.5 Precautionary Signs.

3-5.5.1 The entrances to all anesthetizing locations shall be identified by prominently posted signs denoting individually whether the anesthetizing location is designed for flammable inhalation anesthetic agents or for nonflammable anesthetic agents.

NOTE: Suggested explanatory texts of such signs are as follows:

SUITABLE FOR USE WITH FLAMMABLE
INHALATION ANESTHETIC AGENTS

or

RESTRICTED TO NONFLAMMABLE
INHALATION ANESTHETIC AGENTS

3-5.5.2 In addition, a removable sign shall be posted to all entrances to the anesthetizing location indicating whether a flammable inhalation anesthetic agent is being employed.

NOTE: Suggested explanatory text of such a sign is as follows:

CAUTION
FLAMMABLE INHALATION ANESTHETIC
IN USE
OBSERVE AND OBEY ALL SAFETY
REGULATIONS

It shall be the responsibility of the anesthesiologist or nurse anesthetist to ensure that the room is suitably

designated for use of the particular agent, whether flammable or nonflammable.

3-5.5.3 Regulations for the conduct of personnel, administration and maintenance in mixed facilities shall be posted in at least one prominent location within the operating and, if applicable, delivery suite (see 3-2.7.3.3). Suggested text of such regulations is contained in Appendix C-3-3, Set (3).

3-5.6 Movable Equipment and Furniture.

3-5.6.1 All equipment intended for use in both flammable and nonflammable anesthetizing locations shall meet the antistatic requirements of 3-3.6.

3-5.6.2 Equipment intended for use only in nonflammable anesthetizing locations shall be labeled in accordance with 3-3.5.1.1, and shall not be introduced into flammable anesthetizing locations. This equipment is not required to meet the antistatic requirements of 3-3.6.

3-5.6.3 No portable equipment, including X-ray equipment, shall be introduced into mixed facilities unless it complies with requirements of 3-3.5.1.3 and is approved for use in Class I, Group C, Division 1 hazardous areas, or unless it is prominently labeled for use only in the presence of nonflammable anesthetic agents and then restricted to such use.

3-5.6.4 Portable electric equipment, such as incubators, lamps, heaters, motors and generators used in mixed facilities in which flammable anesthetics are being employed shall comply with the requirements of Articles 500, 501 and 517 of NFPA 70, *National Electrical Code*, for Class I, Division 1 locations and shall be approved for Class I, Group C, Division 1 hazardous areas, except as permitted in 3-3.5.1.6.

NOTE: The resistance and capacitive reactance between the conductors and the noncurrent-carrying metallic parts must be high enough to permit the use of the equipment on an ungrounded distribution system having a Line Isolation Monitor specified in 3-3.3.4.

3-5.6.5 Furniture intended for use in both flammable and nonflammable anesthetizing locations of mixed facilities shall meet the antistatic requirements of 3-3.6.9.

3-5.6.6 Furniture intended for use only in nonflammable anesthetizing locations of mixed facilities shall comply with 3-3.6.9 or shall be conspicuously labeled and not be introduced into flammable anesthetizing locations.

Chapter 4 Use of Inhalation Anesthetics in Ambulatory Care Facilities

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A-4.

Information on referenced publications can be found in Chapter 12 and Appendix B.

4-1 Introduction.

4-1.1 History. A significant number of general anesthetic agents, especially nitrous oxide, are employed in ambulatory care facilities, both as an adjunct for the production of general anesthesia and for the production of relative analgesia. This chapter was prepared because of the variety of hazards attendant upon the use of some of these agents in the out-patient setting.

4-1.2 Scope.

4-1.2.1 This chapter states the composite methods whereby the hazards of fire and the handling of compressed gases, when these agents are employed in the ambulatory care facility, can be mitigated.

4-1.2.2 This chapter applies to nonhospital-based facilities wherein general anesthesia or relative analgesia are administered to ambulatory patients.

4-1.2.3 This chapter does not apply to the administration of flammable agents. In ambulatory care facilities wherein flammable agents are employed, the provisions of Chapter 3, Use of Inhalation Anesthetics, shall apply.

4-1.2.4 This chapter is intended to provide requirements to protect against fires, electric shock, mechanical injury from compressed gases or compressed gas cylinders, and anoxia from erroneous gas connections, without unduly limiting the activities of the practitioner, be he/she a surgeon, oral surgeon, dentist, anesthetist, or anesthesiologist.

4-1.2.5 Provisions of this chapter do not apply to the manufacture, storage, transportation or handling prior to the delivery to the consuming facility of any of these gases. This chapter does not apply to any use other than in an anesthetizing location.

4-1.2.6 Although neither nitrous oxide nor oxygen will burn, both support combustion quite readily and pose a potential fire hazard even when flammable agents are not employed concurrently. Additionally, cylinders containing these gases pose a threat to life, because of the large amount of pneumatic energy contained therein, and the danger of accidental cross connection between supplies of nitrous oxide and oxygen.

4-1.3 Foreword.

4-1.3.1 This chapter has been formulated in the belief that, although material and mechanical equipment must be relied upon to the fullest possible extent for the mitigation of fire and electric shock hazards, such physical safeguards are most effective only when augmented by safety precautions conscientiously applied by personnel staffing ambulatory care facilities. This chapter emphatically calls atten-

tion to the need for constant human diligence in the maintenance of safe practices, because of the hazards cited, together with the mental strain in the environment of surgical, dental, and similar procedures.

4-1.3.2 Studies of hazards associated with hospital operating rooms by many investigators for more than 30 years have pointed to the conclusion that the greatest degree of safety possible, within the limitations of our present knowledge, is secured only through a completely coordinated program, rather than by the application of individual and unrelated safeguards. Compliance with certain of the requirements of this chapter will be effective, or even permissible, only when accompanied by compliance with the full program of precautionary measures.

4-1.3.3 It is necessary for all ambulatory care personnel having any responsibility for safety in anesthesia to collaborate in the precautionary program. Not only must such personnel achieve an understanding of the hazards involved, but in addition, they must be reminded periodically of the dangers posed by electrical shock, compressed gases and their cylinders, and the fire hazards created by oxygen-enriched atmospheres.

4-1.4 Organization.

4-1.4.1 This chapter is concerned with certain features in the construction of ambulatory care facilities. This chapter, with equal emphasis, deals with the installation, maintenance, performance and use of equipment within these facilities.

4-1.4.2 This chapter is divided into four sections and has associated appendix material.

Section 4-1 contains introductory material.

NOTE: Definitions are included in Chapter 2 of this document.

Section 4-2 delineates the hazards of fire, electric shock and the use of compressed gases.

Section 4-3 sets forth the standards for the installation and testing of systems.

Section 4-4 contains the requirements for administration and maintenance of ambulatory care facilities.

Appendix A-4 contains supporting material and deals with the background information explaining the reasons for many of the requirements.

Appendix B contains a list of sources of related documents cited in this chapter.

Appendix C-4-1 contains a table showing the properties and dimensions of cylinders of various sizes.

Appendix C-4-2 contains recommendations for safe practices.

4-1.4.3 The four sections of the chapter and Appendix A-4 are interdependent. For the informed development of an effective ambulatory care safety program, it is necessary that thorough reference be made to all sections of these requirements.

4-1.4.4 The requirements in this chapter are intended as minimums. References to NFPA 70, *National Electrical Code*, are to the applicable requirements contained in the edition referenced in Chapter 12.

4-1.4.5 This chapter does not apply to hospital-based ambulatory care facilities. In such facilities, appropriate provisions of Chapter 3, Use of Inhalation Anesthetics, Chapter 5, Respiratory Therapy, and NFPA 56F, *Nonflammable Medical Gas Systems*, shall apply.

4-2 Nature of Hazards.

4-2.1 Fire Hazards.

4-2.1.1 Oxygen and nitrous oxide, the gases normally used for relative analgesia and as a component of general anesthesia, are strong oxidizing gases, and individually or as a mixture support combustion quite readily.

4-2.1.2 Inhalation gases or vapors introduce fire, chemical, mechanical, and electrical hazards which are all interrelated. Any mixture of inhalation gases will support combustion. In an oxygen-enriched atmosphere, materials that are flammable and combustible in air ignite more easily and burn more vigorously. The materials which may be found on or near patients include hair oils, oil-base lubricants, skin lotions, clothing, linens, paper, rubber, alcohols, acetone, and some plastics.

4-2.1.3 A hazard exists if any of the components of an oxygen or nitrous oxide supply system become contaminated with oil or grease.

4-2.1.4 Sources of ignition may include open flames, burning tobacco, electric heating coils, defective electrical equipment, and adiabatic heating of gases.¹

NOTE: The use of carpeting is a matter of concern. It is recognized that some carpeting contributes to the possible generation of high energy static charges. Until more experience is obtained, it is advisable that carpeting not be used.

4-2.1.5 A hazard exists if either oxygen or nitrous oxide leaks into a closed space, creating an oxygen-enriched atmosphere.

4-2.1.6 A hazard exists if improper components are employed to connect equipment containing pressurized oxygen or nitrous oxide.

4-2.2 Toxicologic Hazards.

4-2.2.1 The use of some modern nonflammable inhalation anesthetic agents with high flow techniques and in the absence of venting of the exhaled gases to the atmosphere may create low grade toxicity in personnel who work regularly in the facility.

4-2.2.2 Many substances, when subjected to a fire, may undergo a chemical change resulting in a new toxic product. This is especially true of many plastic substances. Many highly toxic combustion products may cause sudden unconsciousness, cardiovascular collapse, and severe injury or death, even though the person injured is relatively remote from the fire. These combustion products have been found to cause injury after passing through halls, ventilating systems, and even through electrical conduit.

¹Sudden compression or recompression of a gas to high pressure can generate large increase in temperature [up to 2000°F (1093°C)] which can ignite any organic material present including grease. See also NFPA 53M, *Fire Hazards in Oxygen-Enriched Atmospheres*.

4-2.3 Mechanical Hazards.

4-2.3.1 A large amount of energy is stored in a cylinder of compressed gas. If the valve of a cylinder is struck (or strikes something else) hard enough to break off the valve, the contents of the cylinder may be discharged with sufficient force to impart dangerous reactive movement to the cylinder.

4-2.3.2 A hazard exists if ambulatory care facility personnel attempt to transfer the contents of one compressed gas cylinder into another.

4-2.4 Electrical Hazards.

4-2.4.1 The major hazard of concern is electric shock resulting from failure in normally safe electric systems or appliances. The defects may be in wiring, faulty component, deteriorated insulation, or mechanical abuse.

4-2.4.2 Electric shock may cause undesired muscular contractions that may cause further injury to the patient or, in the case of health care personnel, may harm others coming under the health care personnel's management, i.e., during surgery. Additionally, anesthetics remove the feeling of pain, including that of electrical shock, and normal reflex action will not take place.

4-2.4.3 Electric shock may cause burns by virtue of the electrical energy supplied by the defective system.

4-2.4.4 Electric shock may cause cardiac disturbance which may lead to death, i.e., ventricular fibrillation.

4-2.4.5 A defective electrical system can cause severe sparks that may serve as a source of ignition.

4-2.4.6 Normally the dry skin poses a formidable barrier to the passage of electrical current. Currents must approach ampere strength before the danger of electrical fibrillation of the heart occurs. If a patient has a cardiac pacemaker with externalized conductors, there is a direct conductive pathway to the heart. If stray electrical currents in the microampere range (millionths of an ampere) come in contact with one of these conductors, it is possible that ventricular fibrillation will occur (*see definition of Microshock in Section 2-2 of Chapter 2*).

4-2.4.7 Patients with externalized pacemakers normally would not be expected to be treated in ambulatory care facilities (*see 4-4.4.4*).

4-3 Equipment.

4-3.1 Central Supply Systems. Central supply systems shall be installed and tested in accordance with Chapter 6 of NFPA 56F, *Standard for Nonflammable Medical Gas Systems*.

4-3.2 Portable Supply Systems. If the sole source of supply of nonflammable medical gases, such as nitrous oxide and oxygen, is a system of cylinders attached directly to and supported by the device (such as a gas anesthesia apparatus) used to administer these gases, it is recommended that two cylinders of each gas be attached to the administering device.

4-3.3 Electrical Circuits. Receptacles and cord connectors used in ambulatory care facilities shall be equipped with grounding contacts.

Exception: Cord connectors attached to double-insulated devices need not be equipped with a grounding conductor.

4-3.4 Anesthetic Apparatus.

4-3.4.1 Anesthetic apparatus shall be subject to approval by the authority having jurisdiction.

4-3.4.2* Yoke-type connections between anesthesia apparatus and flush-type cylinder valves (commonly used with anesthetic gas cylinders) shall be Connection No. 860 as described in CGA Pamphlet V-1, *Compressed Gas Cylinder Valve Outlet and Inlet Connections*.

4-3.4.3* Each yoke on anesthetic apparatus constructed to permit attachment of small cylinders equipped with flush-type valves shall have two pins installed as specified in CGA Pamphlet V-1, *Compressed Gas Cylinder Valve Outlet and Inlet Connections*.

4-3.4.4 After any adjustment or repair involving use of tools, and before use on patients, the gas anesthesia apparatus shall be tested at the final common path to the patient to determine that oxygen and only oxygen is delivered from the oxygen flow meters, and oxygen flush valve if any. Interventions requiring such testing shall include, but not be limited to:

- (a) alteration of pipelines, hoses or fittings;
- (b) alteration of internal piping;
- (c) adjustment of selector switches or flush valves;
- (d) replacement or repair of flow meters or bobbins.

4-4 Administration and Maintenance.

4-4.1 Purpose. This section contains the requirements for administration and maintenance which shall be followed as an adjunct to physical precautions specified in Section 4-3.

4-4.2 Recognition of Hazards and Responsibility. The hazards involved in the use of anesthetic agents, whether used for general anesthesia or relative analgesia, can be successfully mitigated only when all of the areas of hazard are fully recognized by all personnel, and when the physical protection provided is complete and is augmented by attention to detail by all personnel of administration and maintenance having any responsibility for the functioning of anesthetizing locations.

4-4.3 Special Precautions—Oxygen Cylinders, Manifolds and Cylinder Storage Facilities.

4-4.3.1 Great care shall be exercised in handling oxygen to prevent contact of oxygen under pressure with oils, greases, organic lubricants, rubber, or other materials of an organic nature. The following regulations, based on those of CGA Pamphlet G-4, *Oxygen*, shall be observed:

(a) Oil, grease, or readily flammable material shall never be permitted to come in contact with oxygen cylinders, valves, regulators, gauges, or fittings.

(b) Regulators, fittings, or gauges shall never be lubricated with oil or any other flammable substance.

(c) Oxygen cylinders or apparatus shall never be handled with oily or greasy hands, gloves or rags.

(d) Particles of dust and dirt shall be cleared from cylinder valve openings by slightly opening and closing the valve before applying any fitting to the cylinder.

(e) The high-pressure valve on the oxygen cylinder shall be opened before bringing the apparatus to the patient or the patient to the apparatus.

(f) The cylinder valve shall be opened slowly, with the face of the gauge on the regulator pointed away from any person.

(g) An oxygen cylinder shall never be draped with any materials such as hospital gowns, masks or caps.

(h) Oxygen fittings, valves, regulators or gauges shall never be used for any service other than that of oxygen.

(i) Gases of any type shall never be mixed in an oxygen or any other cylinder.

(j) Oxygen shall always be dispensed from a cylinder through a pressure regulator.

(k) Regulators which are in need of repair, or cylinders having valves which do not operate properly, shall never be used.

(l) Oxygen equipment which is defective shall not be used until it has been repaired by competent personnel.

(m) Oxygen cylinders shall be protected from abnormal mechanical shock which is liable to damage the cylinder, valve or safety device. Such cylinders shall not be stored near elevators, gangways, or in locations where heavy moving objects may strike them or fall on them.

(n) Cylinder valve protection caps, when provided, shall be kept in place and be hand tightened, except when cylinders are in use or connected for use.

(o) Cylinders shall be protected from the tampering of unauthorized individuals.

(p) Storage shall be planned so that cylinders may be used in the order in which they are received from the supplier.

(q) Empty and full cylinders shall be stored separately. Empty cylinders shall be marked, to avoid confusion and delay if a full cylinder is needed hurriedly.

(r) Cylinders stored in the open shall be protected against extremes of weather and from the ground beneath to prevent rusting. During winter, cylinders stored in the open shall be protected against accumulations of ice or snow. In summer, cylinders stored in the open shall be screened against continuous exposure to direct rays of the sun in those localities where extreme temperatures prevail.

(s) Valves shall be closed on all empty cylinders in storage.

(t) Oxygen shall be referred to by its proper name, "OXYGEN," not "AIR." Liquid oxygen shall be referred to by its proper name, not "LIQUID AIR."

(u) Oxygen shall never be used as a substitute for compressed air.

(v) Cylinders or cylinder valves shall not be repaired, painted or altered.

(w) Safety relief devices in valves or cylinders shall never be tampered with. Sparks and flame shall be kept

away from cylinders; a torch flame shall never be permitted under any circumstances to come in contact with cylinder valves or safety devices. Valve outlets clogged with ice shall be thawed with warm—not boiling—water.

(x) The markings stamped on cylinders shall not be tampered with. It is against federal statutes to change these markings without written authority from the Bureau of Explosives.

(y) Markings which are used for identification of contents of cylinder shall not be defaced or removed, including decals, tags, stenciled marks and upper half of shipping tag.

(z) The owner of the cylinder shall be notified if any condition has occurred which might permit any foreign substance to enter cylinder or valve, giving details and cylinder number.

(aa) Even if they are considered to be empty, cylinders shall never be used as rollers, supports, or for any purpose other than that for which they are intended by the supplier.

4-4.3.2 Transfer of gas from one cylinder to another at the site of the ambulatory facility or by a member of its staff shall be prohibited.

4-4.4 Electrical Safeguards.

4-4.4.1 Physical safeguards built into the anesthetizing locations or storage areas will not provide protection unless safe practices are followed and good maintenance is provided.

4-4.4.2 Scheduled inspections shall be maintained.

4-4.4.3 Defective electrical equipment shall be replaced promptly or repaired by competent personnel.

4-4.4.4 If patients with externalized cardiac pacemakers are treated in ambulatory care facilities, care shall be taken to prevent contact of the exposed leads with conductive surfaces.

4-4.5 Posted Regulations.

4-4.5.1 Rules and regulations necessary for the implementation of this chapter (*see Appendix C-4-2 for suggested text*), where appropriate, shall be posted in the ambulatory care facility.

4-4.5.2 Smoking shall be prohibited in all anesthetizing locations.

Chapter 5 Respiratory Therapy

NOTICE: Information on referenced publications can be found in Chapter 12 and Appendix B.

5-1 Introduction.

5-1.1 Respiratory therapy is an allied health specialty employed with medical direction in the treatment, management, control, diagnostic evaluation and care of patients with deficiencies and abnormalities of the cardiopulmonary system.¹

5-1.2 Respiratory therapy includes the therapeutic use of the following: medical gases and administration apparatus, environmental control systems, humidification, aerosols, medications, ventilatory support, broncho-pulmonary drainage, pulmonary rehabilitation, cardiopulmonary resuscitation and airway management.¹

5-1.3 There is a continual need for human diligence in the establishment and maintenance of safe practices for respiratory therapy.

5-1.3.1 It is essential for personnel having responsibility for respiratory therapy to establish and enforce appropriate programs to fulfill provisions of this chapter.

5-1.3.1.1 It is the responsibility of the administrative and professional staff of the hospital, or safety director if one is appointed, to adopt and enforce appropriate regulations for the hospital. In other facilities, responsibility may be assigned to a safety director or other responsible person, who is, in turn, responsible to the administration.

5-1.3.1.2 In institutions having a respiratory therapy service, it is recommended that this service be directly responsible for the administration of this chapter.

5-1.4 Hazards can be mitigated only when there is continual recognition and understanding.

5-2 Scope.

5-2.1 This chapter applies to the use of nonflammable medical gases, vapors and aerosols, and the equipment required for their administration, at normal atmospheric pressure.

5-2.1.1 When used in this chapter, the term "oxygen" is intended to mean 100 percent oxygen as well as mixtures of oxygen and air.

5-2.1.2 This chapter does not apply to special atmospheres, such as those encountered in hyperbaric chambers. (See Chapter 10, *Hyperbaric Facilities*.)

5-2.2 This chapter applies to all facilities in which respiratory therapy and resuscitative procedures are administered.

5-3 Nature of Hazards.

5-3.1 General. Respiratory therapy applications introduce fire, chemical, electrical, and mechanical hazards.

5-3.2 Fire Hazards.

5-3.2.1 The occurrence of a fire requires the presence of combustible or flammable materials, an atmosphere of oxygen or other oxidizing agents and a source of ignition. Combustible materials may be unavoidably present when oxygen is being administered, but flammable liquids and gases and ignition sources are avoidable.

5-3.2.1.1 Any mixture of breathing gases used in respiratory therapy will support combustion. In an oxygen-enriched atmosphere, materials that are combustible and flammable in air ignite more easily and burn more vigorously.

5-3.2.1.2 Materials not normally considered to be combustible may be so in an oxygen-enriched atmosphere.

5-3.2.2 Combustible materials which may be found near patients who are to receive respiratory therapy include hair oils, oil-base lubricants, skin lotions, facial tissues, clothing, bed linen, tent canopies, rubber and plastic articles, gas supply and suction tubing, cyclopropane, ether, alcohols and acetone.

5-3.2.2.1 Cellulose nitrate (nitrocellulose) base plastic is highly flammable even in air. Eyeglass frames, mechanical pens and pencils, combs, toothbrushes, and toys occasionally are made of this plastic.

5-3.2.3 A particular hazard exists when high-pressure oxygen equipment becomes contaminated with oil, grease, or other combustible materials. Such contaminants will ignite readily and burn more rapidly in the presence of high oxygen concentrations and make it easier to ignite less combustible materials with which they come in contact.

5-3.2.3.1 An oxygen-enriched atmosphere normally exists in an oxygen tent, croup tent, incubator and similar devices when supplemental oxygen is being employed in them. These devices are designed to maintain a concentration of oxygen higher than that found in the atmosphere.

5-3.2.3.2 Oxygen-enriched atmospheres may exist in the immediate vicinity of all oxygen administration equipment. (See definition of Site of Administration in Section 2-2 of Chapter 2.)

The transfer of liquid oxygen from one container to another container may create an oxygen-enriched atmosphere within the vicinity of the containers.

5-3.2.3.3 If oxygen is supplied by a container which stores the oxygen as a liquid, there will be a small amount of oxygen vented into the vicinity of the container after a period of non-use of the equipment. Larger amounts of oxygen will be vented if the container is accidentally tipped over or placed on its side. This venting may create an oxygen-enriched atmosphere if the container is stored in a confined space (see 5-5.4.3.1).

¹Courtesy of the American Association for Respiratory Therapy, 1720 Regal Row, Dallas, TX 75235.

5-3.2.4 Sources of ignition include not only the usual ones in ordinary atmospheres but others which become significant hazards in oxygen-enriched atmospheres (*see 5-3.2.1.1*).

5-3.2.4.1 Open flames, burning tobacco and electric radiant heaters are sources of ignition.

5-3.2.4.2 The discharge of a cardiac defibrillator may serve as a source of ignition.

5-3.2.4.3 Arcing and excessive temperatures in electrical equipment are sources of ignition. Electrically powered oxygen apparatus and electrical equipment intended for use in an oxygen-enriched atmosphere are sources of ignition if electrical defects are present.

5-3.2.4.4 Electrical equipment not conforming to the requirements of 5-4.4.2, which may include, but is not limited to electric razors, electric bed controls, hair dryers, remote television controls and telephone handsets, may create a source of ignition if introduced into an oxygen-enriched atmosphere (*see 5-5.1.5*).

5-3.2.4.5 A static discharge having an energy content which can be generated under normal conditions in respiratory therapy will not constitute an ignition source as long as easily ignited substances (such as ether, cyclopropane, alcohols, acetone, oils, greases, or lotions) are not present (*see 5-5.2.4*).

NOTE: Experience and research indicate that static accumulating materials such as plastics, synthetic fibers and wool may be used under these conditions. The use of carpeting in patient care areas of hospitals is a relatively new innovation. It is recognized that some carpeting contributes to the generation of significant static charges on personnel. Until more experience is obtained with this potential problem, it is advisable that carpeting of wool and acrylic, nylon and other synthetic fibers not be used in the area of administration unless treated to render them permanently antistatic.

5-3.2.4.6 Rapid opening of cylinder valves can cause sudden increase in downstream gas pressure and temperature caused by the adiabatic heat of recompression with consequent ignition of combustible materials in contact with the hot gas downstream including the valve seat.

5-3.3 Chemical Hazards.

5-3.3.1 Chemical hazards may be associated with the presence of residual sterilant in high-pressure equipment.

5-3.3.2 Some breathing mixtures may decompose in contact with hot surfaces and produce toxic or flammable substances (*see 5-3.3*).

5-3.3.3 Smoldering combustion of flammable substances may occur with the production of significant amounts of toxic gases and fumes.

5-3.4 Mechanical Hazards.

5-3.4.1 Cylinders and containers may be heavy and bulky and can cause personal injury or property damage (including the cylinder or container) if improperly handled.

5-3.4.1.1 In cold climates, cylinders or containers stored outdoors or in unheated ventilated rooms may become extremely cold (*see 5-5.4.7 and 5-5.4.8*). A hazardous situation could develop if these cylinders or containers are heated (*see 5-5.4.6.2*).

5-3.4.2 Improper maintenance, handling or assembly of equipment may result in personal injury, property damage or fire.

5-3.4.3 A hazardous condition exists if cylinders or containers are improperly located so that they may become overheated or tipped over. If a container is tipped over or placed on its side, liquid oxygen may be spilled. The liquid can cause frostbite on contact with skin.

5-3.4.4 A hazardous condition exists if there is improper labeling of cylinders or containers or inattention to the manufacturer's label or instructions.

5-3.4.5 A hazardous condition exists if care is not exercised in making slip-on and other interchangeable connections when setting up equipment.

5-3.4.6 Safety features, including relief devices, valves, and connections, are provided in equipment and gas supply systems. Altering or circumventing these safety features by means of adapters creates a hazardous condition.

5-3.4.7 **Extreme danger to life and property can result when compressed gases are mixed or transferred from one cylinder to another.**

5-3.4.8 A hazardous condition exists if devices, such as fixed or adjustable orifices and metering valves, are directly connected to cylinders or systems without a pressure-reducing regulator.

5-3.4.9 Hazardous conditions are created when pressure-reducing regulators or gauges are defective.

5-3.5 Electrical Hazards. Electrical equipment, such as those items detailed in 5-5.1.5, is often employed on patients who are receiving respiratory therapy. Aside from the fire ignition hazard (*see 5-3.2.4.3*), there may be a serious shock hazard if such equipment is defective and generates leakage currents, or if it is employed without careful thought, and particularly if more than one item of electrical equipment is being used simultaneously.

NOTE 1: Therapy gases containing nebulized mists and vapors render the therapy equipment conductive. If the equipment is connected to a nonflammable medical gas system, the patient may be grounded through the therapy apparatus, and leakage currents may pass through the patient to the grounded therapy equipment.

NOTE 2: See Chapter 9, Safe Use of Electricity in Patient Care Areas of Hospitals, for further information.

5-4 Equipment.

5-4.1 Gas Supply.

5-4.1.1 Nonflammable medical gas systems used as supply of gases for respiratory therapy shall be installed in accordance with NFPA 56F, *Standard for Nonflammable Medical Gas Systems*.

5-4.1.2 Cylinders or supply containers shall be constructed, tested and maintained in accordance with the US Department of Transportation Specifications and Regulations.¹

5-4.2 Dispensing Equipment.

5-4.2.1 Oxygen tent circulation/conditioning apparatus, pressure breathing apparatus and other equipment intended to rest on the floor shall be equipped with a base designed to render the entire assembly stable during storage, transport and use. If casters are used, they shall conform to Class C of Commercial Standard 223-59, "Casters, Wheels and Glides for Hospital Equipment."²

5-4.2.2 Oxygen tent canopies having flexible components shall be fabricated of materials having a maximum burning rate classification of "slow burning." (See definition of *Slow Burning* in Section 2-2 of Chapter 2.)

5-4.2.2.1 Oxygen enclosures of rigid materials shall be fabricated of noncombustible materials.

5-4.2.3 Equipment supplied from cylinders or containers shall be designed and constructed for service at full cylinder or container pressure, or constructed for use or equipped with pressure reducing regulators.

5-4.2.4 Humidification or reservoir jars containing liquid to be dispersed into a gas stream shall be made of clear, transparent material, impervious to contained solutions and medications, and shall permit observation of the liquid level and consistency.

5-4.2.5 Humidifiers and nebulizers shall be equipped with provisions for overpressure relief or alarm if the flow becomes obstructed.

5-4.3 Gas Supply Connections.

5-4.3.1 Cylinder valve outlet connections shall conform to ANSI B57.1, *Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections* (includes Pin-Index Safety System for medical gases). (See 5-1.2.)

5-4.3.2 When low-pressure threaded connections are employed, they shall be in accordance with the Compressed Gas Association standards for noninterchangeable, low-pressure connections for medical gases, air and suction, Pamphlet V-5, *Diameter-Index Safety System*.

5-4.3.3 Low-pressure quick coupler connections shall be noninterchangeable between gas services.

5-4.3.4 Regulators and gages intended for use in high-pressure service shall be listed for such service.

5-4.3.5 Pressure-reducing regulators shall be used on high-pressure cylinders to reduce the pressure to working pressures.

5-4.4 Electrical Equipment.

5-4.4.1 Electrical equipment, apparatus, and wiring in ordinary and hazardous locations shall be in accordance with NFPA 70, *National Electrical Code*.

5-4.4.2 Electrical equipment used within or in the vicinity of an oxygen-enriched atmosphere shall comply with 5-4.4.2.1 through 5-4.4.2.3. (See Chapter 2, definitions of "Site of Administration," "Area of Administration" and "Oxygen-Enriched Atmosphere," and see 5-5.1.5.)

5-4.4.2.1 Electrical equipment used within an oxygen-enriched atmosphere shall be listed for such use.

5-4.4.2.2 Electrical equipment used within the site of administration shall comply with 5-4.4.2.1 or 5-4.4.2.3.

5-4.4.2.3 Electrical equipment not complying with 5-4.4.2.1 may be used if affixed to the bed or wall at such a location that it will not be subjected to an oxygen-enriched atmosphere. Controls for such equipment, which can be brought into the site of administration, shall be listed for use in an oxygen-enriched atmosphere.

5-4.4.3 When high-energy delivering probes (such as defibrillator paddles) or other electrical devices that do not comply with 5-4.4.2 are deemed essential to the care of an individual patient and must be used within a site of administration or within oxygen delivery equipment, they shall be used with extreme caution.

NOTE: Where possible, combustible materials such as hair, fabric and paper should be removed from the vicinity of where the energy is delivered. Water-soluble surgical jelly has been shown to dramatically reduce the combustibility of these materials.

5-4.4.4 Electrical equipment, apparatus and wiring for respiratory therapy equipment used in anesthetizing locations shall be in accordance with Chapter 3, Use of Inhalation Anesthetics.

5-4.5 Carts and Hand Trucks.

5-4.5.1 Carts and hand trucks for cylinders and containers shall be constructed for the intended purpose and shall be self-supporting. They shall be provided with appropriate chains or stays to retain cylinders or containers in place.

5-4.5.2 Carts and hand trucks which are intended to be used in anesthetizing locations or cylinder and container storage rooms communicating with anesthetizing locations shall comply with the appropriate provisions of Chapter 3, Use of Inhalation Anesthetics.

5-4.6 Labeling.

5-4.6.1 Equipment listed for use in oxygen-enriched atmospheres shall be so labeled.

5-4.6.2 Oxygen metering equipment and pressure-reducing regulators shall be conspicuously labeled: "OXYGEN — USE NO OIL."

¹Regulations of the US Department of Transportation (formerly US Interstate Commerce Commission) outline specifications for transportation of explosives and dangerous articles (*Code of Federal Regulations*, Title 49, Parts 171-190). In Canada, the regulations of the Canadian Transport Commission, Union Station, Ottawa, Ontario, apply.

²See Chapter 12.

5-4.6.3 Flowmeters and pressure-reducing regulators and oxygen dispensing apparatus shall be clearly and permanently labeled, designating the gas or mixture of gases for which they are intended. Apparatus whose calibration or function is dependent on gas density shall be labeled as to the proper supply gas pressure (psig/kPa) for which it is intended.

5-4.6.4 Canopies or enclosures intended to contain patients shall be labeled advising that oxygen is in use and that precautions related to the hazard shall be observed. The labels shall be located on the enclosure interior in a position to be read by the patient and on two or more opposing sides of the enclosure exterior.

5-4.6.4.1 A suggested minimum text for labels is:

**CAUTION
OXYGEN IN USE
KEEP FLAMES AWAY
NO SMOKING
NO ELECTRICAL APPLIANCES**

5-4.6.5 Oxygen metering equipment, pressure-reducing regulators, humidifiers and nebulizers shall be labeled with the name of the manufacturer or supplier.

5-4.6.6 Cylinders and containers shall be labeled in accordance with ANSI Z48.1, *Standard Method of Marking Portable Compressed Gas Containers to Identify the Material Contained*. Color coding shall not be utilized as a primary method of determining cylinder or container content.

5-4.6.7 All labeling shall be durable and withstand cleansing or disinfection.

5-5 Administration and Maintenance.

5-5.1 Elimination of Sources of Ignition.

5-5.1.1 Smoking materials (matches, cigarettes, lighters, lighter fluid, tobacco in any form) shall be removed from patients receiving respiratory therapy and from the area of administration.

5-5.1.2 No sources of open flame, including candles, shall be permitted in the area of administration.

5-5.1.3 Patients and hospital personnel in the area of administration shall be advised of respiratory therapy hazards and regulations.

5-5.1.3.1 Visitors shall be cautioned of these hazards through the prominent postings of signs (*see 5-5.1.4*).

5-5.1.3.2 Prudent practice dictates that in pediatric hospitals, or in pediatric wards of general hospitals, parents and other visitors to the nursing units be placed on actual notice of the hazards created by potential sources of ignition such as sparking toys.

5-5.1.3.3 It may be desirable to preclude the introduction of all such toys into any pediatrics nursing unit in which oxygen tents or oxygen hoods are used.

5-5.1.4 Precautionary signs, readable from a distance of 5 ft (1.4 m), shall be conspicuously displayed at the site of administration and in aisles and walkways leading to the area. They shall be attached to adjacent doorways, to building walls, or supported by other appropriate means. Precautionary signs should be approximately 8 in. by 11 in. (21 cm by 28 cm) in size.

NOTE: Special signs and additional precautionary measures should be employed whenever foreign languages present a communication problem.

5-5.1.4.1 A suggested minimum text for precautionary signs is:

**CAUTION
OXYGEN IN USE
NO SMOKING
NO OPEN FLAMES**

Any material that can burn in air will burn more rapidly in the presence of oxygen. No electrical equipment is allowed within an oxygen enclosure or within 5 ft (1.5 m) of it.

NOTE: This sign is intended to caution those not familiar with this chapter.

5-5.1.4.2 A suggested text for precautionary signs for oxygen tent canopies and oxygen hoods (*see 5-5.1.4.1*) used in pediatric nursing units is:

**CAUTION
OXYGEN IN USE
ONLY TOYS APPROVED BY
NURSES MAY BE GIVEN
TO CHILD**

5-5.1.5 Electrical equipment used within a site of administration or within oxygen delivery equipment shall comply with 5-4.4.2.

5-5.1.6 Defective electrical apparatus shall be tagged and repaired or discarded.

5-5.2 Misuse of Flammable Substances.

5-5.2.1 Flammable or combustible aerosols or vapors, such as alcohol, shall not be administered in oxygen-enriched atmospheres as outlined in 5-3.2.3.1.

5-5.2.2 Oil, grease or other flammable contaminants shall not be used with oxygen equipment.

5-5.2.3 Highly flammable materials made of nitrocellulose, such as eyeglass frames, combs, toys and toothbrushes, shall not be permitted at the site of administration.

5-5.2.4 Flammable and combustible liquids, such as rubbing compounds, oils and lotions, and flammable gases shall not be permitted at the site of administration. When flammable anesthetics such as ether and cyclopropane are being administered, the room shall be considered an anesthetizing location and the appropriate requirements in Chapter 3, *Use of Inhalation Anesthetics*, shall be observed. Lubricants for beds and motors shall be nonflammable.

5-5.2.5 High-pressure oxygen equipment shall not be sterilized with a flammable sterilizing agent such as ethylene oxide or alcohol. Sterilizing agents shall be oil-free and shall not damage materials.

5-5.2.5.1 High-pressure oxygen equipment shall not be sterilized in polyethylene bags.

NOTE: Sloughed particles of polyethylene produced by abrasion and flexure of such bags are pure hydrocarbons and therefore constitute a severe flammability hazard in high-pressure oxygen atmospheres. Nylon films produce practically no sloughing.

5-5.2.5.2 Equipment operated at oxygen pressures under 60 psig (.414 kPa) may be sterilized with nonflammable mixtures containing ethylene oxide and carbon dioxide or ethylene oxide and fluorocarbon diluents.

5-5.2.5.3 Cylinders and containers shall not be sterilized.

5-5.3 Prevention of Chemical Breakdown.

5-5.3.1 Equipment capable of producing surface temperatures sufficient to cause chemical breakdown of the atmosphere within a patient enclosure shall not be permitted therein.

5-5.3.1.1 Where diethyl ether vapor is involved, surface temperatures shall not exceed 248°F (120°C).

NOTE 1: Such a potentially hazardous atmosphere can be created by the placement in an incubator of a recently anesthetized infant or one whose mother received an inhalation anesthetic during delivery.

NOTE 2: Diethyl ether vapor can produce formaldehyde upon contact with a heating element.

5-5.4 Handling, Storage and Transport of Cylinders and Containers.

5-5.4.1 Personnel concerned with use and transport of equipment shall be trained in proper handling of cylinders, containers, hand trucks, supports, and valve protection caps.

5-5.4.2 When cylinder valve protection caps are supplied, they shall be secured tightly in place unless the cylinder is connected for use.

5-5.4.3 Cylinders and containers shall be stored in accordance with Chapter 3, *Use of Inhalation Anesthetics*, NFPA 56F, *Standard for Nonflammable Medical Gas Systems*, or NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites*, and as recommended in *Compressed Gas Association Pamphlet P-2, Characteristics and Safe Handling of Medical Gases*.

5-5.4.3.1 Containers shall not be stored in a tightly closed space such as a closet (see 5-3.2.3.1).

5-5.4.4 Large cylinders, exceeding size E and containers larger than 100 lb (45.4 kg) weight, shall be transported on a proper hand truck or cart complying with 5-4.5.

5-5.4.4.1 When small size (A, B, D, or E) cylinders are in use, they shall be attached to a cylinder stand or to therapy apparatus of sufficient size to render the entire assembly stable.

5-5.4.5 Cylinders and containers shall not be dropped, dragged or rolled.

5-5.4.6 Freestanding cylinders shall be properly chained or supported in a proper cylinder stand or cart.

5-5.4.6.1 Cylinders shall not be chained to portable or movable apparatus such as beds and oxygen tents.

5-5.4.6.2 Cylinders shall not be supported by, and neither cylinders nor containers shall be placed in proximity of, radiators, steam pipes or heat ducts.

NOTE: Cylinder and container temperatures greater than 125°F (52°C) may result in excessive pressure increase. Pressure relief devices are sensitive to temperature and pressure. When relief devices actuate, contents are discharged.

5-5.4.7 Very cold cylinders or containers shall be handled with care to avoid injury.

5-5.4.8 Cylinders and containers shall not be handled with hands, gloves or other materials contaminated with oil or grease.

5-5.4.9 Contents of cylinders and containers shall be identified by reading the labels prior to use. Labels shall not be defaced, altered or removed.

5-5.5 Making Cylinder and Container Connections.

5-5.5.1 Wrenches used to connect respiratory therapy equipment shall be manufactured of steel or other suitable material of adequate strength.

NOTE: Use of so-called "nonsparking" wrenches and tools is not necessary.

5-5.5.2 Cylinder valves shall be opened and connected in accordance with the following procedure:

(a) Make certain that apparatus and cylinder valve connections and cylinder wrenches are free of foreign materials.

(b) Turn the cylinder valve outlet away from personnel. Stand to the side — not in front and not in back. Before connecting the apparatus to cylinder valve, momentarily open cylinder valve to eliminate dust.

(c) Make connection of apparatus to cylinder valve. Tighten connection nut securely with an appropriate wrench (see 5-5.5.1).

(d) Release the low-pressure adjustment screw of the regulator completely.

(e) *Slowly* open cylinder valve to full open position.

(f) Slowly turn in the low-pressure adjustment screw on the regulator until the proper working pressure is obtained.

(g) Open the valve to the utilization apparatus.

5-5.5.3 Connections for containers shall be made in accordance with the container manufacturer's operating instructions.

5-5.5.4 Humidifiers and nebulizers shall be incapable of tipping or shall be mounted so that any tipping or alteration from the vertical shall not interfere with function or accuracy.

5-5.6 Transfilling Cylinders.

5-5.6.1 Transferring gaseous oxygen from one cylinder to another, if permitted by the responsible authority of the facility, shall be accomplished in a location remote from patient-care areas, utilizing equipment designed to comply with the performance requirements and procedures of CGA Pamphlet P-2.5, *Transfilling of High-Pressure Gaseous Oxygen to Be Used for Respiration*, and adhering to those procedures.

5-5.6.2 Mixing of compressed gases in cylinders shall be prohibited.

5-5.7 Transferring of Liquid Oxygen.

5-5.7.1 Transferring of liquid oxygen from one container to another, if permitted by the responsible authority of the facility, shall be accomplished in a location remote from patient care areas, utilizing equipment designed to comply with the performance requirements and procedures of CGA Pamphlet P-2.6, *Transfilling of Low-Pressure Liquid Oxygen to Be Used for Respiration*, and adhering to those procedures.

5-5.8 Care of Safety Mechanisms.

5-5.8.1 Personnel using cylinders and containers and other equipment covered in this chapter shall be familiar with the Pin-Index Safety System (*see 5-4.3.1*) and the Diameter-Index Safety System (*see 5-4.3.2*), both designed to prevent utilization of the wrong gas.

5-5.8.2 Safety relief mechanisms, noninterchangeable connectors and other safety features shall not be removed, altered, or replaced.

5-5.9 Transportation, Storage and Use of Equipment.

5-5.9.1 Flow control valves on administering equipment shall be closed prior to connection and when not in use.

5-5.9.2 Apparatus shall not be stored or transported with liquid agents in reservoirs.

5-5.9.3 Care shall be observed in attaching connections from gas services to equipment and equipment to patients.

5-5.9.4 Fixed or adjustable orifice mechanisms, metering valves, regulators and gauges shall not be connected directly to high-pressure cylinders unless specifically listed for such use and provided with appropriate safety devices.

5-5.9.5 Nasal respiratory therapy catheters shall be color coded green. Verification of proper connection to oxygen therapy equipment is necessary to prevent accidental attachment to gastric or intestinal catheters.

5-5.9.6 Equipment for respiratory therapy need not be electrically conductive unless intended for use in a hazardous location.

5-5.9.7 A periodic testing procedure for nonflammable medical gas and related alarm systems shall be implemented.

5-5.10 Servicing and Maintenance of Equipment.

5-5.10.1 Defective equipment shall be immediately removed from service.

5-5.10.2 Defective electrical apparatus shall not be used.

5-5.10.3 Equipment shall be serviced by qualified personnel only.

5-5.10.4 Areas designated for the servicing of oxygen equipment shall be clean, free of oil and grease, and not used for the repair of other equipment.

5-5.10.5 Only repair parts recommended by the manufacturer shall be employed.

5-5.10.6 Service manuals, instructions and procedures provided by the manufacturer shall be used in the maintenance of equipment.

5-5.10.7 A scheduled preventative maintenance program shall be followed.

5-5.11 Elimination of Shock Hazards.

5-5.11.1 Personnel are cautioned to be aware of the hazards presented by defective or improperly employed electrical equipment (*see 5-3.5*) and shall avoid the use of defective electrical equipment (*see 5-5.1.7*).

5-5.11.2 All electrical equipment shall be grounded according to applicable provisions of 9-5.1.3 of Chapter 9, Safe Use of Electricity in Patient Care Areas of Hospitals.

Chapter 6 Medical-Surgical Vacuum Systems in Hospitals

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A-6.

Information on referenced publications can be found in Chapter 12 and Appendix B.

6-1 Introduction.

6-1.1 Purpose. The purpose of this chapter is to provide information for the design and sizing, and safe and reliable use of medical-surgical vacuum systems.

There are potential fire and explosion hazards associated with medical gas central piping systems, including medical-surgical vacuum systems. The various components are usually not independent isolated components, but are parts of a larger system dedicated to total patient care and safety.

Many of these components are covered by existing standards to minimize the fire, explosive and patient safety hazard. With the increased use of vacuum systems, the potential for mistaken interconnection with oxidizing gases, for ingestion of flammable anesthetic gases, and for undercapacity requiring extended overheated operation all present potential hazards or compound other hazardous condition which should be properly addressed. While the potential for these problems exists, the Technical Committee is unaware of the actual occurrence of any significant fire-related hazards with vacuum systems.

There are also potential hazards to patients in the unplanned shutdown or failure of the systems secondary to a fire and/or the inability of the system to provide adequate levels of performance under normal or emergency situations. There is also the potential for mistaken interconnection with pressurized nonflammable medical gas systems described in NFPA 56F, *Standard for Non-flammable Medical Gas Systems*.

6-1.2 Scope. This chapter applies only to permanently installed, fixed medical-surgical vacuum systems in hospitals where such systems are intended for patient drainage, aspiration and suction and, under the conditions set forth in 6-3.2.8, for medical laboratory use. This chapter does not apply to water aspirator systems which dispose of drainage directly into sanitary sewers. This chapter does not cover suction apparatus or appliances attached to the vacuum system terminals (inlets).

6-1.3 Intended Use. This chapter is intended for use by those persons involved in the design, construction, inspection, and operation of hospitals.

6-1.4 Application of this Chapter. This chapter shall be applied to a new vacuum system. An existing medical-surgical vacuum system that is not in strict compliance with this chapter shall be permitted to be continued in use when such use does not constitute a distinct hazard to life. In any case the maintenance and testing requirements of this chapter shall be followed.

6-1.5 Interpretations. The National Fire Protection Association does not approve, inspect, or certify any

installation, procedure, equipment, or material; in determining the acceptability of installations, procedures, equipment or material the authority having jurisdiction may base acceptance on compliance with this chapter. To promote uniformity of interpretation and application of its documents, NFPA has established interpretations procedures. These procedures are outlined on the inside cover of this standard. Refer to the NFPA "Regulations Governing Committee Projects" for complete details.

6-1.6 Metric Units. While it is common practice for medical appliances to use metric units on their dials, gauges, and controls, the components of medical-surgical vacuum systems within the scope of this chapter, which are manufactured and used in the United States, employ non-metric dimensions. Since these dimensions (such as nominal pipe sizes) are not established by the National Fire Protection Association, the Technical Committee on Medical-Surgical Vacuum Systems cannot independently change them. Accordingly, this chapter uses dimensions that are presently in common use by the building trades in the United States. Conversion factors to metric units are included in Appendix C-6-3.

6-2 Terminal Performance Criteria.

6-2.1 General. The locations and number of vacuum system terminals (inlets) in a system shall be determined by consultation with medical and hospital staff having knowledge of the requirements for, and the utilization of, vacuum in each space or patient location.

6-2.2* Number of Terminals (Inlets). Table 6-2.2 sets forth the minimum number of system terminals (inlets) for

Table 6-2.2 Minimum Number of Vacuum Terminals (Without Waste Anesthetic Gas Disposal)

NOTE: If it is intended to use the vacuum system for waste anesthetic gas disposal, provision for an additional terminal (inlet) should be made.

<i>Anesthetizing Locations</i>	
Operating Room	3/room
Cystoscopy	3/room
Delivery	3/room
Special Procedures	3/room
Other Anesthetizing Locations	3/room
<i>Acute Care Locations (Non-Anesthetizing Location)</i>	
Recovery Room	3/bed
Intensive Care Units (Except Cardiac)	3/bed
Special Procedure	2/room
Emergency Rooms	1/bed
Emergency Rooms - Major Trauma	3/bed
Cardiac Intensive Care Units	2/bed
Catheterization Lab	2/bed
Surgical Excision Rooms	1/room
Dialysis Unit	1/2/bed
<i>Subacute Patient Care Areas (Non-Anesthetizing Location)</i>	
Nurseries	1/bed
Patient Rooms	1/bed
Exam & Treatment Rooms	1/bed
Respiratory Care	Convenience
<i>Other</i>	
Autopsy	1/Table
Central Supply	Convenience
Equipment Repair, Calibration and Teaching	Convenience

patient suction therapy, but does not include terminals (inlets) for disposing of waste anesthetic gases.

6-2.3 Minimum Flow and Pressure Requirements at Vacuum Terminals (Inlets). Piping shall be sized such that 3 SCFM can be evacuated through one terminal without reducing vacuum pressure below 12 in. of Hg at an adjacent terminal.

NOTE: This is not criterion for pump sizing purposes. See Appendix A-6 for pump sizing recommendations.

6-2.4 Overall System Pressure Drop Criteria. Pipe sizes shall be in conformity with good engineering practice for delivery of maximum design volumes.

NOTE: It is recommended that vacuum pressure loss, from source to farthest terminal when the calculated demand is drawn on the system, be limited to 3 in. Hg.

6-3 System Components.

6-3.1* Source of Vacuum.

6-3.1.1 Multiple Pumps. The central vacuum source shall consist of two or more vacuum pumps which alternately or simultaneously on demand serve the vacuum system. Each vacuum system shall be served by two or more vacuum pumps which alternately or simultaneously on demand supply the vacuum system. In the event one vacuum pump fails, the remaining pump(s) shall be sized to maintain required vacuum at 100 percent of total system demand. Each pump shall have a shutoff valve to isolate it from the system and other pump(s) for maintenance or repair, without loss of vacuum in the system.

NOTE 1: Depending on anticipated system demand and utilization, as determined by consultation with the medical hospital staff, two or more systems may be considered.

NOTE 2: Where several adjacent buildings are each equipped with vacuum sets, installation of a valved, normally closed, cross-connection line should be considered to provide emergency backup and operating economy under low load conditions. The pipe should be adequately sized. Consideration should also be given to the fact that, when the valve is open, continuous duty operation of the single vacuum source may pose special design considerations.

6-3.1.2 Minimum Vacuum and Operating Range. The vacuum pumps and collection piping shall be capable of maintaining a vacuum of 12 in. of mercury (Hg) at the terminal (inlet) farthest away from the central vacuum source when the calculated demand for the hospital is drawn in the system. The capacity of vacuum pumps shall be based on ACFM calculated at the lead vacuum switch setting. If the pump selected is not capable of continuous duty, the capacity of the pump shall be based on ACFM calculated at the pump's stop setting, or the pump shall be selected so that a stop setting can be reached on intermittent operation. (See Appendix C-6-1 for examples.)

NOTE: An operating range of 15 in. to 19 in. Hg is suggested at the receiver.

6-3.1.3 Pump Alternation. If automatic alternation of pumps in normal service is not provided, a manual alternation shall be achieved through an appropriate schedule determined by the hospital.

6-3.1.4 Backup Operation. A device shall be provided to automatically activate the additional pump unit(s) should the pump in operation be incapable of maintaining minimum required vacuum.

6-3.1.5 Electrical Power. Electrical equipment and wiring shall conform to the requirements of NFPA 70, *National Electric Code*. Emergency electrical service for the vacuum pumps shall conform to the requirements of Chapter 8 of this standard, *Essential Electrical Systems for Health Care Facilities*.

6-3.1.6 Pump Motors and Controls. Each vacuum pump motor shall be provided with a separate motor starting device and overload protection. A suitable disconnecting device shall be installed in the electrical circuit ahead of each motor starting device. Electrical control circuits shall be so arranged that shutting off or failure of one vacuum pump will not affect the operation of other pump(s).

6-3.1.7 Receivers (Tanks). Receiver(s) shall be installed where the size of the system would cause excessive cycling of the pump(s). A suitable method shall be provided for drainage so that substances which might accumulate may be drained from the receiver(s) (tank). The method, if included, shall be provided so that the receiver may be drained or serviced without interrupting the system.

NOTE: Considerations for proper receiver sizing are characteristics of the vacuum pump and volume of the piping system.

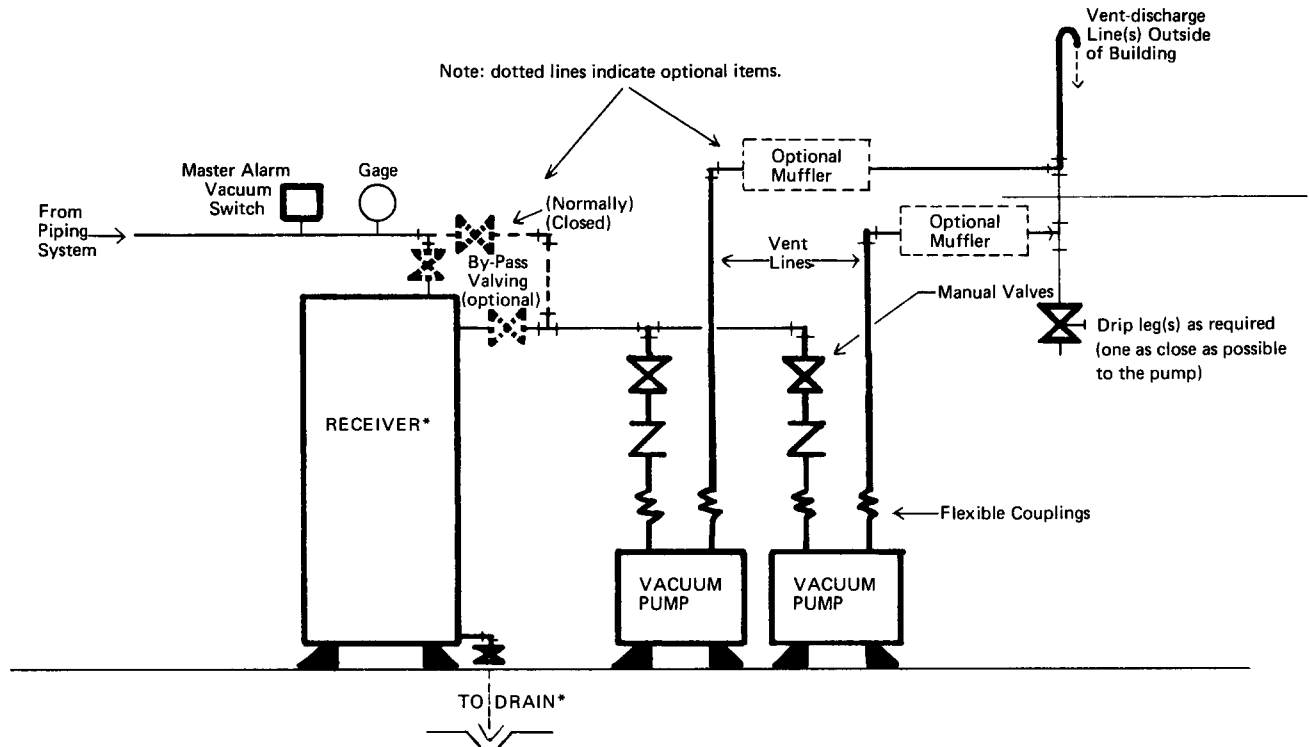
6-3.1.8* Noise and Vibration. Provision shall be made to minimize the transmission of noise and vibration created by the central vacuum source beyond the space in which the equipment is located.

6-3.1.9 Exhausts. The exhaust from the vacuum pumps shall be discharged outdoors in a manner which will minimize the hazards of noise and contamination to the hospital and its environment. The exhaust shall be located remote from any door, window, air intake, or other openings in buildings with particular attention given to separate levels for intake and discharge. Care shall also be exercised to avoid discharge locations contraindicated by prevailing winds, adjacent buildings, topography, and other influences. Outdoor exhausts shall be protected against the entry of insects, vermin, debris, and precipitation. Exhaust lines shall be sized to minimize back pressure.

6-3.1.10 Typical Vacuum Source. A schematic of a typical medical-surgical vacuum source is shown in Figure 6-3.1.10.

6-3.2 Vacuum Piping Network.

6-3.2.1 Pipe Materials. All pipelines shall be constructed of seamless Type K, L, or M copper tubing or other corrosion-resistant metallic tubing such as stainless steel, galvanized steel, etc. If vacuum piping is installed simultaneously with other medical gas piping, it shall either be labeled or otherwise identified prior to installation, to preclude inadvertent inclusion into a medical gas system, or it shall be cleaned and degreased in accordance with NFPA 56F, *Standard for Nonflammable Medical Gas Systems*. Copper pipelines shall be hard temper for exposed locations and soft temper for underground or concealed locations.



*See 6-3.1.7.

NOTE: Other arrangements that differ from this schematic in such items as the number of pumps, receivers, piping layout, etc., or other arrangements which meet specific recommendations of the vacuum source equipment manufacturer are permissible.

Figure 6-3.1.10 Typical Medical-Surgical Vacuum Source.

NOTE: The purpose of this requirement is that oxygen, nitrous oxide and compressed air lines are often installed in hospitals at the same time as vacuum systems, and carelessness and errors in installing the vacuum lines might result in fire, explosion, damage to or contamination of other medical pipelines, or inadvertent switching of pipes. (Also see NFPA 56F, *Standard for Nonflammable Medical Gas Systems*.)

6-3.2.2* Minimum Pipe Sizing. In both branch and main lines the minimum pipe size shall be not less than $\frac{1}{2}$ in. nominal, except that smaller pipe diameters shall be permitted for drops to individual terminals (inlets) and static lines to gauges and alarm actuators (vacuum switches). Pipe size for drops to individual terminals (inlets) shall not be less than $\frac{1}{4}$ in. I.D.

6-3.2.3 Pipe Supports. Piping shall not be supported by other piping, but shall be supported by pipe hooks, metal pipe straps, bands, or hangers suitable for the size of the pipe and of proper strength and quality at proper intervals so that the supports are on the joints. (See Table 6-3.2.3.) Pipeline supports shall be insulated from the pipe or be of a compatible material so as to prevent deterioration due to bimetallic electrolyte action.

Table 6-3.2.3 Intervals of Pipe Support

$\frac{1}{2}$ in. pipe or tubing	6 ft
$\frac{3}{4}$ in. or 1 in. pipe or tubing	8 ft
$1\frac{1}{4}$ in. or larger (horizontal)	10 ft
$1\frac{1}{4}$ in. or larger (vertical)	every floor level

6-3.2.4 Permanent Fittings. All fittings used for connecting copper tubing shall be wrought copper, brass, or bronze made especially for brazed or soldered joining, except as provided in 6-3.2.5.

6-3.2.5 Nonpermanent Fittings. Any nonpermanent-type fitting, such as unions, flare connections, etc., when used on vacuum system distribution lines, shall be installed so as to be readily accessible.

6-3.2.6 Mechanical and Environmental Protection. All installations, including buried piping, shall be adequately protected against frost, freezing, corrosion and physical damage. Ducts or casings shall be used wherever buried piping passes under a roadway, driveway, parking lot, or other area of subject to surface loads. Exposed piping shall be suitably protected against physical damage from the movement of portable equipment such as carts, stretchers, and trucks.

6-3.2.7 Pipe Identification. Vacuum piping shall be readily identified by appropriate labeling such as MEDICAL-SURGICAL VACUUM. Such labeling shall be by means of metal tags, stenciling, stamping, or adhesive markers, in a manner that is not readily removable. Labeling shall appear on the pipe at intervals of not more than 20 ft (6.1 m) and at least once in or above each room and each story traversed by the pipeline. Arrows (when used) shall point from the terminals (inlets) and toward the receiver or pump.

6-3.2.8 Analysis, Research and Teaching Laboratories. Where only one set of vacuum pumps is available for a combined medical-surgical system and an analysis, research, or teaching laboratory system, each connection from such a laboratory branch shall be piped through a fluid trap or scrubber with shutoff valves and drain valves, and shall be connected directly to the receiver (tank) and not into the network of piping serving patients.

NOTE: Any laboratory (such as for analysis, research, or teaching) in a hospital that is used for purposes other than direct support of patient therapy should preferably have its own self-supporting vacuum system, independent of the medical-surgical vacuum system. A small (satellite) medical laboratory used in direct support to patient therapy should not be required to be connected directly to the receiver or have fluid traps, scrubbers, etc., separate from the rest of the medical-surgical vacuum system.

6-3.3 Shutoff Valves.

6-3.3.1 General. Shutoff valves shall be provided to isolate appropriate sections or portions of the system for maintenance, repair, planned future expansion and to facilitate periodic testing.

6-3.3.2 Valve Types. Shutoff valves shall be of a type that will create no greater flow restriction than the piping to which they are connected.

6-3.3.3 Riser Valves. Shutoff valves shall be provided at the base of vertical risers servicing more than one floor.

6-3.3.4 Section Valves. A shutoff valve shall be provided on each floor between the riser and the first terminal (inlet) to allow for maintenance and periodic testing without serious disruption of service. In single-story facilities, a shutoff valve shall be installed between the main line and the first terminal of each branch line.

6-3.3.5 Valve Boxes. All shutoff valves in public and anesthetizing areas shall be installed in valve boxes with frangible or removable windows large enough to permit manual operation of the valve. The valve box shall be permanently labeled in substance as follows:

CAUTION — MEDICAL-SURGICAL VACUUM
VALVE
DO NOT CLOSE EXCEPT IN EMERGENCY
THIS VALVE CONTROLS VACUUM TO....

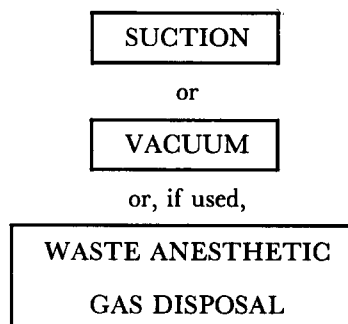
6-3.3.6 Valves not in Boxes. All shutoff valves which are not in labeled boxes, such as in the main line, risers, above suspended ceilings, etc., shall be identified by means of durable tags, nameplates, or labels in substance as follows:

CAUTION — MEDICAL-SURGICAL VACUUM
VALVE
DO NOT CLOSE EXCEPT IN EMERGENCY
THIS VALVE CONTROLS VACUUM TO....

6-3.4 Terminals (Inlets).

6-3.4.1 General. Each terminal (inlet) for vacuum shall be equipped with a valve mechanism of a type not

interchangeable with other systems (such as oxygen, compressed air, etc.), either threaded connection or quick coupler, and shall be legibly labeled in substance as follows:



6-3.4.2 Threaded Connections. Valves with threaded connections shall conform to the Diameter-Index Safety System as described in the Compressed Gas Association Pamphlet, CGA V-5.

6-3.4.3 Secondary Check Valves. Vacuum terminals (inlets) shall not incorporate a secondary check valve.

6-3.4.4 Physical Protection. Terminals (inlets) shall be located so as to avoid physical damage to the valve or attached equipment.

6-3.4.5 Physical Spacing. Careful consideration shall be given to provide adequate spacing between the terminals (inlets) and adjacent medical gas outlets.

6-3.4.6 Removable Assemblies. Terminal (inlet) assemblies, as furnished by manufacturers, shall be legibly marked VACUUM or SUCTION so that, in their state of disassembly for hookup to the vacuum system, proper identification is not lost.

6-4 Warning Systems.

6-4.1 Master Alarm System.

6-4.1.1 General. The vacuum system master alarm shall provide cancelable audible and noncancelable visual signals at a continuously monitored location so as to indicate when the vacuum in the main line drops below the level required to maintain 12 in. Hg (vacuum) at the terminal (inlet) farthest from the source. When one continuously monitored location is not available, a secondary master alarm shall be installed at some location, such as the telephone switchboard or the security office, where it is most likely to be seen or heard.

6-4.1.2 Actuator Switch. The actuator (vacuum switch) for the master alarm shall be connected to the main line immediately upstream (on the terminal or inlet side) of the main line valve [i.e., the main line valve is between the receiver (tank) and the master alarm vacuum switch].

6-4.1.3 Alarm Panels. The master alarm signal panel required in 6-4.1.1 (each with visual and audible signal) shall be actuated by the vacuum switch described in 6-4.1.2.

6-4.1.4 Panel Labels. The master alarm signal panel(s) shall be appropriately labeled.

6-4.1.5 Combined Alarm Signals. The vacuum alarm signal shall serve only the medical-surgical vacuum system. (See NFPA 56F, *Standard for Nonflammable Medical Gas Systems and Chapter 8 of this standard, Essential Electrical Systems for Health Care Facilities.*)

NOTE: The master alarm signal panel for the vacuum system may be combined with other alarm signals for other facility systems, such as oxygen, emergency electrical power, fire alarms, etc., provided the function of this alarm signal is clearly distinguished from the others by labeling as described in 6-4.1.4.

6-4.1.6 Alarm System Power. The master alarm signal system shall be energized by the essential electrical system described in 6-3.1.5. (See *Chapter 8 of this standard, Essential Electrical Systems for Health Care Facilities.*)

6-4.2 Area Alarm Systems.

6-4.2.1 General. Vacuum area alarm systems shall be provided in anesthetizing location areas and other life support and critical care areas, such as post-anesthesia recovery, intensive care units, coronary care units, etc.

NOTE 1: Two or more adjacent alarm areas may be served by a single signal panel at a location near the points of use which will provide responsible surveillance.

NOTE 2: For additional information concerning alarms for central medical gas piping systems, refer to NFPA 56F, *Standard for Nonflammable Medical Gas Systems.*

6-4.2.2 Visual and Audible Signals. The vacuum area alarm system shall incorporate both cancelable audible and noncancelable visual signals which are activated by actuators (vacuum switches) connected to the vacuum line serving each specific area.

6-4.2.3 Alarm Panels. The visual and audible signal panels shall be installed at nurses' stations or other suitable locations in the areas described in 6-4.2.1 and be appropriately labeled.

6-4.2.4 Actuator Switches. The actuator (vacuum switch) for each area described in 6-4.2.1 shall connect to the vacuum line for that area and upstream (on the terminal or inlet side) of any shutoff valves, with no shutoff valves intervening between the area alarm actuator (vacuum switch) and the terminals (inlets) in the area.

6-4.2.5 Actuator Switch Settings. Actuators (vacuum switches) for the area alarm signals shall be set to activate their respective warning signals (visual and audible) when the vacuum drops below 12 in. Hg (vacuum).

6-4.2.6 Electrical Power. The area alarm signal system shall be energized by the essential electrical system described in 6-3.1.5. (See *Chapter 8 of this standard, Essential Electrical Systems for Health Care Facilities.*)

6-4.3 Vacuum Gauges.

6-4.3.1 Main Line Gauge. A vacuum gauge shall be provided in the main vacuum line adjacent to the actuator (vacuum switch) for the master alarm, with this gauge located immediately upstream (on the terminal or inlet side) of the main line valve.

6-4.3.2 Area Gauge. Vacuum gauges shall be located at each area vacuum alarm signal location, with this gauge connected upstream (on the terminal or inlet side) of any valve controlling that area.

6-4.3.3 Gauge Identification. All permanently installed vacuum gauges and manometers for the vacuum system shall be those manufactured expressly for vacuum and labeled: VACUUM.

NOTE 1: Vacuum gauges should have an indicated range of 0 in. to 30 in. Hg (vacuum).

NOTE 2: Vacuum gauges may be part of shutoff valves in boxes, or incorporated in a unit with gauges for the other central medical gas piping systems described in NFPA 56F, *Standard for Nonflammable Medical Gas Systems.*

6-5 Installation of Piping System.

6-5.1 Piped Connections.

6-5.1.1 Joints. All joints in copper or stainless steel piping, except those at valves or at equipment requiring pipe thread connections, shall be made with solder or brazing materials having a melting point not less than 450°F (182°C). Joints in galvanized steel piping shall be threaded, flanged or gasketed couplings, compatible with the pipe material used.

NOTE: It is recognized that vacuum lines are installed and soldered at the same time as nonflammable medical gas systems. Therefore, silver brazing [at minimum 1000°F (691.4°C) melting point] should be considered to avoid inadvertent soft soldering of nonflammable medical gas piping.

6-5.1.2 Flux. Particular care shall be exercised in applying the flux to avoid leaving any excess inside the completed joints.

6-5.1.3 Cleaning. The outside of the tube and fittings shall be cleaned by washing with hot water after assembly.

6-5.2 Threaded Connections. Pipe thread joints shall be installed by tinning the male thread with soft solder, litharge and glycerin, polytetrafluoroethylene (such as Teflon®) tape, or a suitable luting compound.

6-5.3 Acceptance Testing.

6-5.3.1 The following tests are intended to be performed to certify acceptance of a system after initial installation. Routine tests for maintenance of the system are addressed in Section 6-6. The tests shall be conducted on the upstream portion of the medical-surgical vacuum system whenever it is breached and whenever modifications are made.

6-5.3.2 Inspection. A visual inspection of each joint shall be made to assure that the alloy has flowed completely in and around the joint and that hardened flux has not formed a temporary seal which holds test pressure. All excess flux shall be removed for clear visual inspection of connections.

6-5.3.3 Purging. After installation of the piping, but before attachment of the vacuum line to the vacuum pumps and receiver(s) (tank), and before installation of the vacuum alarm switches, station terminals (inlets), and gauges, the line shall be blown clear by means of oil-free dry nitrogen or air.

6-5.3.4 Leakage Tests. Before attaching the vacuum lines to the vacuum pumps, receivers(s) (tank), and alarm signaling system(s) switches and gauges, each section of the piping system shall be subjected to a test pressure not less than 150 psig by means of oil-free dry nitrogen or air. This test pressure shall be maintained until each joint has been examined for leakage by use of soapy water or other suitable means. All leaks shall be repaired and the section retested. (*See Compressed Gas Association Pamphlet G-10.1, Commodity Specification for Nitrogen.*)

6-5.3.5 Standing Pressure Test. After installation of a vacuum system, including terminals (inlets), but before attaching the vacuum lines to the vacuum pumps, receiver(s) (tank), and alarm system(s) switches and gauges, the entire system or sections of the system shall be subjected to a test pressure of not less than 60 psig by means of oil-free dry nitrogen or air. After allowance for temperature variation, the pressure at the end of 24 hours shall be within 5 psig of the initial pressure. Corrective action shall be taken if this performance is not verified. After completion of the test, corrections, and reverification if necessary, the system shall be connected to the vacuum pumps, receiver(s), alarm actuators (vacuum switches), and gauges.

NOTE: For information on how to correct pressure for temperature changes see NFPA 56F, *Standard for Nonflammable Medical Gas Systems*.

6-5.3.6 Cross Connection Test. Cross connection testing shall be performed as described in NFPA 56F, *Standard on Nonflammable Medical Gas Systems*.

6-5.3.7 Final Installation Leakage Test. The hospital shall perform a final installation leakage test for detecting leaks in the system.

NOTE: An acceptable method of testing is by means of shutting down portions of the system using the shutoff valves described in 6-3.3 to determine the capability of the section to maintain a vacuum. An acceptable condition is a vacuum level loss of less than 1.5 in. Hg in one hour with the system piping initially at a vacuum in excess of 12 in. Hg.

6-5.3.8 Schedule of Testing. When the piping is intended to be concealed inside of walls or partitions, the tests described in 6-5.3.3 and 6-5.3.5 shall be completed before the walls or partitions are closed in. Tests described in 6-5.3.4 shall be conducted after walls or partitions are closed in.

6-5.3.9 Records. Upon completion of the tests described in 6-5.3.1 through 6-5.3.5, a written record of the performance of these tests shall be maintained in the permanent records of the facility.

6-6 Maintenance and System Protection.

6-6.1 Maintenance.

6-6.1.1 General. The hospital shall establish routine preventive maintenance programs applicable to both the vacuum piping system and to the secondary equipment attached to vacuum terminals (inlets) to assure the continued good performance of the entire system.

NOTE: Clogging of regulators, for example, with lint, debris, or dried body fluids reduces system performance.

6-6.1.2 Leakage Tests. The hospital shall perform periodic tests for detecting leaks in the system in accordance with 6-5.3.8.

6-6.1.3 Terminal Performance Tests. Inlet terminal performance, as required in 6-2.3, shall be tested on a regular preventative maintenance schedule as determined by the hospital maintenance staff. The test shall be based on flow of free air (SCFM) into an inlet terminal while simultaneously checking the vacuum level.

NOTE 1: The test can be conducted using (1) a rotometer or other flow measuring device, and (2) a vacuum gauge, both devices fitted with appropriate inlet terminal connector.

NOTE 2: The test procedure will be to measure the flow with the terminal wide open while simultaneously measuring the vacuum level at an adjacent wall inlet terminal or other inlet terminal which is on the same branch line.

NOTE 3: It is recognized that this criterion may not be met by some existing systems. It is the responsibility of hospital personnel, based on past experience and use, to determine the acceptable alternate performance criterion for their system(s).

6-6.2 System Protection.

6-6.2.1 Instruction of Staff. The hospital shall instruct its personnel in the proper uses of the vacuum system in order to eliminate practices which reduce the system's effectiveness, such as leaving suction tips and catheters open when not actually aspirating, and using equipment arrangements which are improperly trapped, or which are untrapped.

NOTE: Suction collection bottles that are used as part of patient treatment equipment should be equipped with an overflow shutoff device to prevent carry-over of fluids into equipment of the piping system. It is recommended that a separate vacuum trap with shutoff be used between the suction collection bottle and the vacuum system terminal inlet.

6-6.2.2 Contamination. Liquid or debris shall not be introduced into the medical-surgical vacuum system for disposal.

6-6.2.3 Waste Anesthetic Gas Disposal.

NOTE: Nonflammable waste anesthetic gases may be disposed of by the medical-surgical vacuum system provided that its inclusion does not affect the performance of other parts of the system as outlined in 6-6.2.2 and in 6-6.2.3.1.

6-6.2.3.1 Explosion Hazard. Flammable anesthetic or other flammable vapors shall be diluted significantly below the lower flammable limit prior to disposal into the medical-surgical vacuum system.

NOTE 1: For further information, see Appendix A-3-2.1.1 on ANSI Z79.11, and Appendix C-3-1.3.1 on flammable anesthetic agents.

NOTE 2: Flammable and nonflammable gases are known to be incompatible with the seals and piping used in medical-surgical vacuum systems. If waste anesthetic gas disposal is to be included as part of the medical-surgical vacuum system, it should be recognized that this activity will cause certain deterioration of the system. The terminal performance tests outlined in 6-6.1.3 are extremely important in maintaining the integrity of the medical-surgical vacuum system, and they should be made at more frequent intervals if waste anesthetic gas disposal is included in the system.

6-6.2.4 Nonmedical Use. The medical-surgical system shall not be used for vacuum steam condensate return or other nonmedical or nonsurgical applications.

Chapter 7 Laboratories in Health-Related Institutions

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A-7.

Information on referenced publications can be found in Chapter 12 and Appendix B.

7-1 Introduction and Scope.

7-1.1 Hazards and Responsibilities. Laboratory facilities present fire hazards of a nature not encountered elsewhere in health-related institutions.

7-1.1.2 The governing boards of hospitals and health care-related facilities shall have the responsibility to protect the facilities for patient care and clinical investigation and the personnel employed therein.

7-1.2 Application of Chapter. This chapter shall be applied to all laboratories, except that construction and equipment requirements shall be applied only to new construction and new equipment. An existing laboratory that is not in strict compliance with this chapter shall be permitted to be continued in use when such use does not constitute a distinct hazard to life. Although compliance with this chapter is desirable, variations in existing facilities should be considered acceptable in instances where laboratory arrangements are in accordance with previous editions of this chapter or afford an equivalent degree of safety.

7-1.3 Scope.

7-1.3.1* This chapter shall apply to all laboratories located in health care occupancies or located in buildings occupied at any time by four (4) or more patients who are anesthetized, immobilized, or otherwise incapable of self-preservation in case of fire.

7-1.3.2 This chapter is not intended to cover hazards resulting from the misuse of chemicals, radioactive materials, or biological materials which will not result in fires or explosions. Although it deals primarily with hazards related to fires and explosions, many of the requirements to protect against fire or explosion, such as those for hood exhaust systems, also serve to protect persons from exposure to nonfire health hazards of these materials.

7-1.4 Interface with Existing Codes and Standards.

7-1.4.1 Where interface with existing NFPA or other consensus codes and standards occurs, reference is made to the appropriate source in the text.

7-1.4.2 Where necessary, due to the special nature of laboratories, codes and standards are supplemented in this text, so as to apply more specifically to buildings or portions of buildings devoted to laboratory usage.

7-2 Nature of Hazards.

7-2.1* General. Laboratory work may involve the use of flammable, combustible and explosive materials that can be safely handled only if they are treated with a respect for and a knowledge of their hazardous properties.

7-2.2 Fire Loss Prevention.

7-2.2.1 Hazard Assessment.

7-2.2.1.1 An evaluation shall be made for hazards that may be encountered during laboratory operations, before such operations are begun. The evaluation shall include hazards associated with the properties of the chemicals used, hazards associated with the operation of the equipment, and the hazards associated with the nature of the proposed reactions (e.g., evolution of acid vapors or flammable gases).

7-2.2.1.2 Periodic reviews of laboratory operations and procedures shall be conducted with special attention given to any change in materials, operations or personnel.

7-2.2.1.3 Unattended operations and automatic laboratory equipment shall be provided with periodic surveillance for abnormal operation or with automatic monitoring devices to detect and report abnormal operation.

7-2.2.1.4 When chemicals and reagents are ordered, steps shall be taken to determine the hazards and to transmit that information to those who will receive, store, use or dispose of the chemicals.

7-2.2.2 Fire Prevention Procedures. Fire prevention procedures shall be established. (See Section 7-6.)

7-2.2.3 Emergency Procedures.

7-2.2.3.1 Procedures for laboratory emergencies shall be developed. Such procedures shall include alarm actuation, evacuation and equipment shutdown procedures, and provisions for control of emergencies which may occur in the laboratory, including specific detailed plans for control operations by an emergency control group within the organization or a public fire department.

7-2.2.3.2 Emergency procedures shall be established for controlling chemical spills.

7-2.2.3.3* Emergency procedures shall be established for extinguishing clothing fires.

7-2.2.4 Orientation and Training.

7-2.2.4.1 New laboratory personnel shall be taught general safe practices for the laboratory and specific safety practices for the equipment and procedures they will use.

7-2.2.4.2 Continuing safety education and supervision shall be provided, incidents shall be reviewed monthly, and procedures shall be reviewed annually.

7-3 Structure, Equipment, and Fire Protection.

7-3.1* Construction and Arrangement.

7-3.1.1 Health care laboratories shall be separated from surrounding health care areas and from exit corridors by fire-resistive construction with a minimum rating of one hour, and all openings protected by ¾-hour rated assemblies.

Exception No. 1: Laboratories that are protected by automatic extinguishing systems and that are not classified as a severe hazard are not required to be separated.

Exception No. 2: Any opening in a laboratory corridor barrier may be held open only by an automatic release device complying with the applicable requirements in NFPA 101, Life Safety Code.

7-3.1.2 Interior finish in laboratories and means of egress shall comply with the applicable section of NFPA 101, *Life Safety Code*.

7-3.2 Exit Details.

7-3.2.1* Any room arranged for laboratory work which has an area in excess of 1,000 sq ft (92.9 sq m) shall have at least two exit access doors remote from each other, one of which shall open directly onto a means of egress.

7-3.2.2 Travel distance between any point in a laboratory unit and an exit access door shall not exceed 75 ft (22.9 m).

7-3.2.3 Exit access doors from laboratories shall meet the requirements of NFPA 101, *Life Safety Code*.

7-3.2.4 Laboratory corridors constituting access to an exit shall be not less than 60 in. (152.4 cm) in clear and unobstructed width.

7-3.2.5 Laboratory corridors, used for the transporting of patients in beds or litters, and constituting access to an exit, shall be not less than 96 in. (243.8 cm) in clear and unobstructed width.

7-3.3 Equipment.

7-3.3.1 Equipment Employing Liquids.

7-3.3.1.1 Tissue processors and similar automatic equipment employing flammable or combustible reagents shall be operated at least 5 ft (1.52 m) from the storage of combustible materials, unless separated by one-hour fire-resistive construction.

7-3.3.1.2* Unattended laboratory operations employing flammable or combustible reagents shall be conducted in an area equipped with an automatic fire extinguishing system.

7-3.3.2 Electrical Equipment and Appliances.

7-3.3.2.1 Power outlets shall be installed in accordance with NCCLS Standard ASI-5, *Power Requirements for Clinical Laboratory Instruments and for Laboratory Power Sources*. Outlets with two to four receptacles, or an equivalent power strip, shall be installed every 1.6 to 3.3 ft (0.5 to 1.0 m) in instrument usage areas, and either is to be at least 3.15 in. (8 cm) above the countertop.

7-3.3.2.2* Electrical equipment for laboratory use shall be tested for electrical safety against standards acceptable to the authority having jurisdiction.

7-3.3.2.3* Electrical equipment intended for use in hazardous areas in laboratories shall be approved by the authority having jurisdiction. (*See definition of Hazardous Area in Laboratories in Section 2-2 of Chapter 2.*)

7-3.3.2.4 Portable equipment intended for laboratory use shall be grounded or otherwise arranged with an approved

method to protect personnel against shock, in accordance with NFPA 70, *National Electrical Code*.

7-3.3.2.5 All electrical heating equipment to be used for laboratory procedures shall be equipped with over-temperature limit controls so arranged that thermostatic failure will not result in hazardous temperatures. When such equipment is intended for use with flammable or combustible liquids, its electrical components shall be explosion-proof, intrinsically safe, or ventilated in a manner that will prevent accumulation of flammable atmospheres under normal conditions of operations.

7-3.3.2.6 Heating equipment equipped with fans shall be arranged with an interlock arranged to disconnect the heating elements when the fan is inoperative, unless the fan is not essential to safe operation.

7-3.3.3 Gas Equipment.

7-3.3.3.1 Gas appliances shall be of an approved design and installed in accordance with NFPA 54, *National Fuel Gas Code*. Shutoff valves shall be legibly marked to identify the material they control.

7-3.3.4 Ventilation.

7-3.3.4.1* Laboratories provided with mechanical ventilation throughout or employing fume hoods as a fixed part of the exhaust system shall have the air supply and exhaust balanced to provide a negative pressure with respect to surrounding hospital occupancies.

Exception: Laboratories for procedures requiring maximum protection against contamination and not involving infectious or noxious materials may be arranged for slight positive pressure when the safety of the arrangement is affirmed by a responsible laboratory official.

7-3.3.4.2 Air exhausted from laboratory areas shall not be recirculated to other parts of the hospital.

7-3.3.4.3 Exit corridors shall not be used as plenums to supply or exhaust air from laboratory areas.

7-3.3.4.4 Exhaust systems for laboratory ventilation shall be arranged with motors and fans located at the discharge end of the systems, and with the exhaust air discharged above the roof in such a manner that it will not be drawn into any air intake, or blown into windows.

7-3.3.4.5 Air exhausted from areas in which highly infectious or radioactive materials are processed or used shall pass through high-efficiency (99.7 percent) filters before discharging to the atmosphere.

7-3.3.5* Fume Hoods.

7-3.3.5.1 Fume hoods shall be located in areas of minimum air turbulence and away from doors and windows, and in a manner that will not impede access to egress.

7-3.3.5.2 Glazing at the face of the hood shall be of a material which will provide protection to the operator or environment against the hazards normally associated with the use of the hood.

7-3.3.5.3 Fume hoods intended for use with perchloric acid and their associated equipment in the airstream, such as smoke detectors, shall be constructed of stainless steel or other material consistent with special exposures, and be provided with a water wash and drain system to permit periodic flushing of the duct and hood. Electrical equipment intended for installation within such ducts shall be designed and constructed to resist penetration by water. Lubricants and seals shall not contain organic materials.

Warning signs describing the nature of any hazardous effluent content shall be posted at fume hoods discharge points.

7-3.3.5.4 Fume hoods intended for use with radioactive isotopes shall be constructed of stainless steel or other material suitable for the particular exposure and shall comply with NFPA 801, *Facilities for Handling Radioactive Materials*.

7-3.3.5.5 Fume hood ventilating controls shall be so arranged that shutting off the ventilation of one fume hood will not reduce the exhaust capacity or create an imbalance between exhaust and supply for any other hood connected to the same system.

7-3.3.5.6* Fume hoods shall be so designed that the face velocity ventilation is adequate to prevent the backflow of contaminants into the room, especially in the presence of cross drafts or the rapid movements of an operator working at the face of the hood.

7-3.3.5.7 Shutoff valves for services, including gas, air, vacuum and electricity, shall be outside of the hood enclosure in a location where they will be readily accessible in the event of fire in the hood. The location of such shutoffs shall be legibly lettered in a related location on the exterior of the hood.

7-3.4* Fire Protection.

7-3.4.1* Automatic fire extinguishing protection shall be provided in all laboratories, including associated storage rooms, when:

(a) laboratories are not separated from surrounding areas by at least one-hour fire-resistive construction with door openings protected by Class C self-closing fire doors, and employ quantities of flammable, combustible or hazardous materials less than that which would be considered severe.

(b) laboratories are not separated from surrounding areas by at least two-hour fire-resistive construction with door openings protected by Class B self-closing doors, and employ quantities of flammable, combustible or hazardous materials considered severe.

NOTE: Where there is a critical need to protect data in process, reduce equipment damage, and facilitate return to service, considerations should be given to the use of Halon 1301 total flooding systems in sprinklered or unsprinklered computer rooms. Chapter 5 of NFPA 75, *Standard on Electronic Computer Systems*, provides general information on the protection of computer room equipment.

7-3.4.2 Automatic fire extinguishment and fire detection systems when required shall be connected to the facility fire alarm system and shall be arranged to immediately sound an alarm.

7-3.4.3 Fire extinguishers suitable for the particular hazards shall be located so that they will be readily available to personnel in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

7-3.5* Emergency Shower. Where the eyes or body of any person may be exposed to injurious corrosive materials, suitable fixed facilities for quick drenching or flushing of the eyes and body shall be provided within the work area for immediate emergency use. Fixed eye baths shall be designed and installed to avoid injurious water pressure.

If shutoff valves or stops are installed in the branch line leading to safety drenching equipment, the valves shall be OS and Y (outside stem and yoke), labeled for identification, and sealed in the open position. The installation of wall-mounted portable eye wash stations shall not preclude the adherence to the provisions of this section.

7-4 Flammable and Combustible Liquids.

7-4.1 General.

7-4.1.1 Flammable and combustible liquids shall be handled and used with care and with knowledge of their hazardous properties, both individually and in combination with other materials with which they can come in contact. (See *Appendix B*.)

7-4.2* Storage and Use.

7-4.2.1* Flammable or combustible liquids shall be used from and stored in approved containers, in accordance with NFPA 30, *Flammable and Combustible Liquids Code*.

7-4.2.2* Established laboratory practices shall limit working supplies of flammable or combustible liquids. The total capacity of flammable or combustible liquids outside of approved storage cabinets shall not exceed 10 gal (37.85 L) per 5,000 sq ft (464.4 sq m). The total capacity of all approved storage cabinets in a laboratory shall not exceed 60 gal (227.1 L) per 5,000 sq ft (464.4 sq m). No flammable or combustible liquids shall be stored or transferred from one vessel to another in any exit corridor or passageway leading to an exit. At least one approved flammable or combustible liquid storage room shall be available within any health care facility regularly maintaining a reserve storage capacity in excess of 300 gal (1135.5 L). Quantities of flammable and combustible liquids for disposal shall be included in the total inventory.

7-4.2.3 Venting of storage cabinets shall be permitted. Storage cabinets with approved flame arresters shall be permitted to be exhausted through a fume hood exhaust system. Construction of the venting duct within the laboratory shall be equal to the rating of the cabinet.

7-4.2.4 Flammable or combustible liquids shall not be positioned near Bunsen burners, ovens, hot pipes and valves or other sources of heat, in corridors, or within exhaust canopies.

7-4.2.5* Class I flammable or combustible liquids shall not be stored in refrigerators. Storage of other combustible liquids in well-sealed containers is permissible in listed flammable materials storage refrigerators or in refrigerators listed for Class I, Division 1, Group C and D. The

outside of doors to refrigerators shall be labeled to denote whether or not they are acceptable for storage of flammable or combustible liquids. If the refrigerator is not listed for the purpose, the warning shall be worded to prohibit all storage of flammable or combustible liquids.

7-4.3 Transfer of Flammable or Combustible Liquids. Transfer from bulk stock containers to smaller containers shall be made in storage rooms as described in NFPA 30, *Flammable and Combustible Liquids Code* or within a fume hood having a face velocity of at least 100 ft (30.5 m) per minute.

7-4.4 Handling of Flammable and Combustible Liquids.

7-4.4.1 Flammable liquids and combustible liquids with flashpoints lower than 200°F (93.3°C) (Class I, II, and IIIA liquids) shall be heated in hoods or with special local exhaust ventilation if the quantities exceed 10 ml, or if the liquid is heated to within 30° of the flash point of the liquid.

7-4.4.2 Flammable or combustible liquids shall be heated with hot water, steam, or an electric mantle, depending upon their boiling points. Open flames shall not be employed.

7-4.5* Disposal of Hazardous Materials. Disposal of hazardous materials shall be accomplished off the premises by a disposal specialist, or at a safe location away from the health care facility by competent personnel using procedures established in concurrence with the authority having jurisdiction.

7-5 Gases.

7-5.1* Use of Gases. Gases shall be handled and used with care and with knowledge of their hazardous properties, both individually and in combination with other materials with which they can come in contact. See NFPA 49, *Hazardous Chemicals Data*, and NFPA 491M, *Manual of Hazardous Chemical Reactions*.

7-5.2 Storage of Gas Cylinders.

7-5.2.1 Storage shall be in containers designed, constructed, tested and maintained in accordance with the US Department of Transportation Specifications and Regulations.

7-5.2.2 The capacities of individual cylinders, in pounds or cubic feet free gas at 1 atmosphere, shall not exceed:

- (a) LP Gases — 5 lb (2.27 kg)
- (b) Acetylene — 350 cu ft (9.9 cu m)
- (c) Other flammable gases — 356 cu ft (10 cu m) or water volume of 0.6 cu ft (.017 cu m).

7-5.2.3 Flammable gas cylinder storage for a laboratory, if inside any health care facility, shall be (except as permitted in 7-5.3.1) in a separate room or enclosure reserved exclusively for that purpose, having a fire-resistance classification of at least two hours, and ventilated in accordance with Chapter 3, Use of Inhalation Anesthetics. Containers in storage shall be kept in racks or secured in position.

7-5.2.4 In a laboratory, gas cylinders being held for prompt use shall not exceed one cylinder of the sizes stated in 7-5.2.2 or two days working needs, except as permitted in 7-5.3. Cylinders shall be in racks or secured in position.

7-5.2.5 Rooms or enclosures for storage of cylinders shall be well ventilated. Electrical equipment in flammable gas storage areas shall comply with NFPA 70, *National Electrical Code*, for Class I, Division 2 locations.

7-5.2.6 Enclosures for storage of nonflammable gases shall have at least one-hour fire-resistive construction, in accordance with NFPA 56F, *Nonflammable Medical Gas Systems*.

7-5.3 Supply for Piped Systems.

7-5.3.1 When a laboratory is intended to be routinely and frequently operated with flammable gases supplied from a manifold compressed system, the containers shall either:

(a) Be in a separate room having a fire-resistance classification of at least one hour and ventilated in accordance with Chapter 3, Use of Inhalation Anesthetics, or

(b) Be located outside of the building and connected to the laboratory equipment by a permanently installed piping system.

Exception: Wherever the volume and nature of the gas, in the judgment of the laboratory safety officer or other authority having jurisdiction, do not offer a hazard, the requirement for the remote locations of the cylinder may be waived.

7-5.3.2 When a laboratory is intended to be routinely and frequently operated with nonflammable gases supplied from a manifold compressed system:

(a) the manifold within the laboratory shall consist of not more than six cylinders;

(b) manifolds larger than six cylinders shall conform to 7-5.3.1;

(c) cylinders shall be secured in position.

7-5.3.3 A pressure-reducing valve shall be connected to each gas cylinder and adjusted to a setting to limit pressure in the piping system at the minimum required gas pressure.

7-5.3.4 Pressure regulators shall be compatible with the gas for which they are used.

7-5.4* Piping.

7-5.4.1 Piping systems for fuel gases, such as manufactured gas, natural gas and LP-Gas, shall comply with NFPA 54, *National Fuel Gas Code*, and NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*.

7-5.4.2 Piping systems for gaseous hydrogen shall comply with NFPA 50A, *Gaseous Hydrogen Systems at Consumer Sites*.

7-5.4.3 Piping systems for nonflammable medical gases shall comply with NFPA 56F, *Nonflammable Medical Gas Systems*.

7-5.4.4 Piping systems for acetylene shall comply with NFPA 51, *Standard for the Installation and Operation of Oxygen-Fuel Gas Systems for Welding and Cutting*.

7-5.4.5 Supply and discharge terminals of piping systems shall be legibly and permanently marked at both ends with the name of the gas to be piped, after testing, to establish their content and continuity.

7-5.4.6 Piping systems shall not be used for gases other than those for which they are designed and identified.

7-5.4.7 If a system is to be connected for use with a gas other than that for which it was originally installed, it shall be inspected for suitability for the proposed gas, purged with an inert gas (such as nitrogen), cleaned if necessary, and pressure tested in accordance with the appropriate piping standard. Each outlet of such a system shall be identified by chemical name and specifically converted for use with the successor gas.

7-5.5 Working Supplies. The aggregate accumulation of cylinders at any one working station shall not exceed one extra cylinder for each cylinder actually connected for use. All cylinders shall be secured in a rack or secured in an upright position.

7-5.6 Transfer of Gases. Transfer of compressed or liquefied gases from one gas container to another shall be prohibited.

7-6* Maintenance and Inspection.

7-6.1 Procedure.

7-6.1.1 For adequate laboratory safety in hospitals, careful maintenance and watchfulness are imperative.

7-6.1.2 A safety officer shall be appointed to supervise safe practices in the laboratory. Responsibilities shall include ensuring that the equipment and preparation for fire fighting are appropriate for the special fire hazards present. These responsibilities shall be in addition to surveillance of hazards attendant to caustics, corrosives, compressed gases, electrical installations, and other hazards indigenous to laboratories in health care facilities. This individual shall also supervise the periodic education of laboratory personnel, including new employee orientation, in the nature of combustible and flammable liquids and gases, first-aid fire fighting, and the use of protective equipment, and shall review unsafe conditions observed or reported.

NOTE: This individual may be the safety officer for the health care facility or may be a specifically designated laboratory safety officer.

7-6.1.3 Regular rounds of the health care facility laboratory shall be made by a member of the security force or another designated individual whenever the laboratory is unattended, but particularly and especially in the hours immediately following the departure of the laboratory staff for the night. The laboratory safety officer shall inform the security force of those areas and items of equipment of a hazardous nature requiring special surveillance.

7-6.1.4* Operations and equipment related to safe operations and practices, including such items as ventilating provisions; fire protection apparatus; periodical flushing of sinks; emergency showers and eye wash units; shelf stocks and storage of flammable and combustible materials; and caustic and corrosive liquids shall be reviewed at appropriate, regular intervals. A system of prompt reporting of defective equipment and its prompt repair shall be instituted, and periodic inspections shall be made of all electrical and gas equipment. The laboratory safety officer shall prepare and supervise the proper completion of a safety checklist that can be preserved for record.

7-6.1.5 Periodic safety inspection shall include the testing of all emergency showers, eye baths and other emergency equipment.

7-6.1.6* A system for disposing of hazardous chemicals and combustible trash shall be established and regularly maintained. Disposal of chemical wastes shall be in accordance with good safety practices and environmental standards.

7-6.2 Identification of Hazards.

7-6.2.1 All doors leading to laboratories in health-related facilities shall be marked with the emblem described in NFPA 704, *Identification of Fire Hazards of Materials*, to indicate the fire hazards of materials intended to be used within this area.

7-6.2.2 It shall be the responsibility of the laboratory safety officer to assure periodically that the emblem properly indicates the nature of the materials being used within the identified space.

7-6.2.3 It shall be the duty of the senior person responsible for activities in respective laboratory areas to inform the laboratory safety officer of changes in protocol and procedures that involve variations in the fire hazards of materials used in individual spaces.

Chapter 8 Essential Electrical Systems for Health Care Facilities

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A-8.

Information on referenced publications can be found in Chapter 12 and Appendix B.

Foreword

Medical and nursing sciences are becoming progressively more dependent upon electrical apparatus for the preservation of life of hospitalized patients. For example, year by year, more cardiac operations are performed, in some of which the patient's life depends upon artificial circulation of the blood; in other operations, life is sustained by means of electrical impulses that stimulate and regulate heart action; in still others, suction developed by electrical means is routinely relied upon to remove body fluids and mucus that might otherwise cause suffocation. In another sense, lighting is needed in strategic areas in order that precise procedures may be carried out, and power is needed to safeguard such vital services as refrigerated stores held in tissue, bone, and blood banks.

Interruption of normal electrical service in health care facilities may be caused by catastrophes such as storms, floods, fires, earthquakes, or explosions; by failures of the systems supplying electrical power; or by incidents within the facility. For all such situations, electrical systems should be planned to limit internal disruption and to provide for continuity of vital services at all times. Outages may be corrected in seconds or may require hours for correction. This indicates that the system or protection must be designed to cope with the longest probable outage.

Selecting vital areas and functions considered to be essential, designing safeguards to assure continuity in these circuits, and maintaining the electrical and mechanical components of such essential services so that they will work when called on are complex problems that warrant standardized guidance for regulating agencies, governing boards and administrators of health care facilities, and architects and engineers concerned with their construction. Such guidance is offered in this chapter.

This chapter is predicated on the basic principle of achieving dependability. It is intended to recognize the different degrees of reliability that can result from varying approaches to electrical design. Therefore, its requirements have been developed to allow the designer the flexibility needed to achieve a reliable electrical system.

8-1 General.

8-1.1 Purpose. The purpose of this chapter is to describe the performance and maintenance requirements of those portions of health care facilities' electrical systems that would jeopardize the safety of patients and other facility occupants if interrupted.

8-1.2* Scope. This chapter covers Essential Electrical Systems for hospitals, nursing homes, residential custodial care facilities, and other health care facilities serving patients.

Specific requirements for wiring and installation of equipment are covered in NFPA 70, *National Electrical Code*.

Requirements for illumination and identification of means of egress in health care facilities are covered in NFPA 101, *Life Safety Code*. The alternate source of emergency power for illumination and identification of means of egress shall be the Essential Electrical System.

This chapter does not cover the requirements for fire protection signaling systems except that the alternate source of power shall be the Essential Electrical System.

This chapter does not cover the requirements for fire pumps except that the alternate source of power shall be permitted to be the Essential Electrical System.

Requirements for the installation of stationary engines and gas turbines are covered in NFPA 37, *Standard on the Installation and Use of Stationary Combustion Engines and Gas Turbines*.

8-1.3 Intended Use. This chapter is intended for use by those persons involved in the design, construction, inspection and operation of health care facilities.

8-1.4 Authority Having Jurisdiction. See Section 2-1 of Chapter 2.

8-1.5 Application of this Chapter. This chapter shall be applied to new construction. An existing Essential Electrical System that is not in strict compliance with this chapter shall be permitted to be continued in use when such use does not constitute a distinct hazard to life.¹ In any case the maintenance and testing requirements of this chapter shall be followed.

8-1.6 Effective Date. The effective date of application of any provision of this chapter is not determined by the National Fire Protection Association. All questions related to applicability shall be directed to the authority having jurisdiction.

8-1.7 Interpretations. The National Fire Protection Association does not approve, inspect, or certify any installation, procedure, equipment, or material. In determining the acceptability of installations, procedures, equipment, or material the authority having jurisdiction may base acceptance on compliance with this chapter. To promote uniformity of interpretation and application of its standards the NFPA has established interpretation procedures. These procedures are outlined on the inside front cover of this standard. Refer to Section 16 of the NFPA "Regulations Governing Committee Projects" for complete details.

8-2 General Systems Requirements.

8-2.1 Requirements for All Facilities.

¹Although complete compliance with this chapter is desirable, variations in existing health care facilities should be considered acceptable in instances where wiring arrangements are in accordance with prior editions of this chapter, or afford an equivalent degree of performance and reliability. Such variations may occur particularly with certain wiring in separate or common raceways, with certain functions connected to one or another system or branch, or with certain provisions for automatically or manually delayed restoration of power from the alternate (emergency) source of power.

8-2.1.1 Sources of Power.

8-2.1.1.1 Essential Electrical Systems shall have a minimum of two independent sources of power: a normal source generally supplying the entire electrical system, and one or more alternate sources for use when the normal source is interrupted.

8-2.1.1.2 The alternate source of power shall be a generator(s) driven by some form of prime mover(s), and located on the premises.

Exception No. 1: Where the normal source consists of generating units on the premises, the alternate source shall be either another generating set or an external utility service.

Exception No. 2: Nursing homes or residential custodial care facilities meeting the requirements of the Exception to 8-4.1 or other nonhospital health care facilities meeting the requirements of 8-5.1 shall be permitted to use a battery system or self-contained battery integral with the equipment.

8-2.1.2* Design Considerations.

Facilities whose normal source of power is supplied by two or more separate central station-fed services (dual sources of normal power) experience greater reliability than those with only a single feed, and shall be considered whenever practical (*see Appendix A-8*), but such dual source of normal power does not constitute an alternate power source as defined in this chapter (*see Appendix A-8-2.1.2*).

Distribution system arrangements shall be designed to minimize interruptions to the electrical systems due to internal failures by use of adequately rated equipment. Among the factors to be considered are:

- (a) Abnormal currents: current-sensing devices, phase and ground, shall be selected to minimize the extent of interruption to the electrical system due to abnormal current caused by overload and/or short circuits.
- (b) Abnormal voltages such as single phasing of three-phase utilization equipment, switching and/or lightning surges, voltage reductions, etc.
- (c) Capability of achieving the fastest possible restoration of any given circuit(s) after clearing a fault.
- (d) Effects of future changes, such as increased loading and/or supply capacity.
- (e) Stability and power capability of the prime mover during and after abnormal conditions.
- (f) Sequence reconnection of loads to avoid large current inrushes that could trip overcurrent devices or overload the generator(s).

NOTE: Careful consideration should be given to the location of the spaces housing the components of the Essential Electrical System to minimize interruptions caused by natural forces common to the area (e.g., storms, floods, or earthquakes, or hazards created by adjoining structures or activities). Consideration should also be given to the possible interruption of normal electrical services resulting from similar causes as well as possible disruption of normal electrical service due to internal wiring and equipment failures. Consideration should be given to the physical separation of the main feeders of the Essential Electrical System from the normal wiring of the facility to prevent possible simultaneous destruction as a result of a local catastrophe.

In selecting electrical distribution arrangements and components for the Essential Electrical System, high priority should be given to

achieving maximum continuity of the electrical supply to the load. Higher consideration should be given to achieving maximum reliability of the alternate power source and its feeders rather than protection of such equipment, provided the protection is not required to prevent a greater threat to human life such as fire, explosion, electrocution, etc., than would be caused by the lack of essential electrical supply.

8-2.2 Automatic and Nonautomatic Transfer Switches.

8-2.2.1 General. Electrical characteristics of the transfer switches shall be suitable for the operation of all functions and equipment which they are intended to supply.

8-2.2.2 Switch Rating. The rating of the transfer switches shall be adequate for switching all classes of loads to be served, and withstand the effects of available fault currents without contact welding.

8-2.2.3 Automatic Transfer Switch Classification. Each automatic transfer switch shall be approved for emergency electrical service (*see NFPA 70, National Electrical Code, Section 700-3*) as a complete assembly.

8-2.2.4 Automatic Transfer Switch Features.

8-2.2.4.1 General. Automatic transfer switches shall be electrically operated, mechanically held. The transfer switch shall transfer and retransfer the load automatically.

Exception: In some installations, it may be desirable to program the transfer switch for a manually initiated retransfer to the normal source so as to provide for a planned momentary interruption of the load. If used, this arrangement shall be provided with a bypass feature to permit automatic retransfer in the event that the alternate source shall fail and the normal source is available.

8-2.2.4.2 Interlocking. Reliable mechanical interlocking, or an approved alternate method, shall be inherent in the design of transfer switches to prevent the unintended interconnection of the normal and alternate sources of power, or any two separate sources of power.

8-2.2.4.3* Voltage Sensing. Voltage sensing devices shall be provided to monitor all ungrounded lines of the normal source of power (*see Appendix A-8-2.2.4.3*).

8-2.2.4.4 Time Delay on Starting of Alternate Power Source. A time delay device may be provided to delay starting of the alternate source generator. The timer is intended to prevent nuisance starting of the alternate source generator with subsequent load transfer in the event of harmless momentary power dips and interruptions of the normal source. The time range must be short enough so that the generator can start and be on the line within 10 seconds of the onset of failure.

8-2.2.4.5 Time Delay on Transfer to Alternate Power. An adjustable time delay device shall be provided for those transfer switches requiring "delayed automatic" operation. The time delay shall commence when proper alternate source voltage and frequency are achieved. The delay device shall prevent transfer to the alternate power source until after expiration of the preset delay.

8-2.2.4.6* Time Delay on Retransfer to Normal Power. An adjustable timer with a bypass shall be provided to delay retransfer from the alternate source of

power to the normal. This timer will permit the normal source to stabilize before retransfer to the load and help to avoid unnecessary power interruptions. The bypass shall operate similarly to the bypass in 8-2.2.4.1.

8-2.2.4.7 Test Switch. A test switch shall be provided on each automatic transfer switch that will simulate a normal power source failure to the switch.

8-2.2.4.8 Indication of Switch Position. Two pilot lights, properly identified, shall be provided to indicate the transfer switch position.

8-2.2.4.9 Manual Control of Switch. A means for the safe manual operation of the automatic transfer switch shall be provided.

8-2.2.5 Nonautomatic Transfer Device Classification. Nonautomatic transfer devices shall be approved for emergency electrical service (*see NFPA 70, National Electrical Code, Section 700-3*).

8-2.2.6 Nonautomatic Transfer Device Features.

8-2.2.6.1 General. Switching devices shall be mechanically held. Operation shall be by direct manual or electrical remote manual control. Electrically operated switches shall derive their control power from the source to which the load is being transferred. A means for safe manual operation shall be provided.

8-2.2.6.2 Interlocking. Reliable mechanical interlocking, or an approved alternate method, shall be inherent in the design to prevent the unintended interconnection of the normal and alternate sources of power, or any two separate sources of power.

8-2.2.6.3 Indication of Switch Position. Pilot lights, properly identified, shall be provided to indicate the switch position.

8-2.3 Generator Sets.

8-2.3.1 General. Generator sets installed as an alternate source of power for essential electrical systems shall be designed to meet the requirements of such service.

8-2.3.2 Exclusive Use for Essential Electrical Systems. The generating equipment used shall be either reserved exclusively for such service or normally used for other purposes. If normally used for other purposes, two or more sets shall be installed, such that the demand and all other performance requirements of the Essential Electrical System shall be met with the largest single generator set out of service.

Exception: A single generator set shall be permitted to operate the Essential Electrical System for (1) peak demand control, (2) internal voltage control, or (3) load relief for the external utility, provided any such use will not decrease the mean period between service overhauls to less than three years.

8-2.3.3 Work Space or Room. Adequate space shall be provided for housing and servicing the generator set and associated equipment used for its starting and control. Service transformers shall not be installed in this area.

8-2.3.4 Requirements for Generator Sets.

8-2.3.4.1 Capacity and Rating. The generator set(s) shall have sufficient capacity and proper rating to meet the maximum expected demand of the Essential Electrical System at any one time.

8-2.3.4.2 Load Pickup. The generator set(s) shall have sufficient capacity to pick up the load and meet the minimum frequency and voltage stability requirements of the Emergency System within 10 seconds after loss of normal power.

8-2.3.4.3 Maintenance of Temperature. Provisions shall be made to maintain the generator room at not less than 50°F (10°C) or the engine water jacket temperature at not less than 70°F (21.1°C).

8-2.3.4.4 Ventilating Air. Provision shall be made to provide adequate air for cooling and to replenish engine combustion air.

8-2.3.4.5* Cranking Batteries. Internal combustion engine starting batteries shall have sufficient capacity to provide 60 seconds of continuous cranking.

8-2.3.4.6 Compressed Air Starting Devices. Internal combustion engine air starting devices shall have sufficient capacity to supply five 10-second cranking attempts, with not more than a 10-second rest between attempts, with the compressor not operating.

8-2.3.4.7 Fuel Supply. The fuel supply for the generator set shall be liquid with on-site fuel storage capacity. The amount of on-site storage shall take into account past outage records and delivery problems due to weather, shortages and other geographic conditions.

Exception: The use of other than on-site liquid fuels shall be permitted when there is a low probability of a simultaneous failure of both the off-site fuel delivery system and power from the outside electrical utility company.

8-2.3.5 Requirements for Safety Devices.

8-2.3.5.1 Internal Combustion Engines. Internal combustion engines serving generator sets shall be equipped with:

(a) A sensor device plus visual warning device to indicate a water jacket temperature below those required in 8-2.3.4.3.

(b) Sensor devices plus visual prealarm warning device to indicate:

1. High engine temperature (above manufacturer's recommended safe operating temperature range).

2. Low lubricating oil pressure (below manufacturer's recommended safe operating range).

(c) An automatic engine shutdown device plus visual device to indicate that a shutdown took place for:

1. Overcrank (failed to start).

2. Overspeed.

3. Low lubricating oil pressure.

4. Excessive engine temperature.

(d) A common audible alarm device to warn that any one or more of the prealarm or alarm conditions exist.

NOTE: One method to accomplish both (b) and (c) is to use two sensors for each alarm condition set at different operating points.

8-2.3.5.2 Other Types of Prime Movers. Prime movers, other than internal combustion engines, serving generator sets shall have appropriate safety devices plus visual and audible alarms to warn of alarm or approaching alarm conditions.

8-2.3.5.3 Liquid Fuel Supplies. Liquid fuel supplies for emergency or auxiliary power sources shall be equipped with a sensor device to warn that the main fuel tank contains less than a three-hour operating supply.

8-2.3.6 Alarm Annunciator. A remote annunciator, storage battery powered, shall be provided to operate outside of the generating room in a location readily observed by operating personnel at a regular work station (see *NFPA 70, National Electrical Code, Section 700-12*).

The annunciator shall indicate alarm conditions of the emergency or auxiliary power source as follows:

(a) Individual visual signals shall indicate:

1. When the emergency or auxiliary power source is operating to supply power to load.
2. When the battery charger is malfunctioning.

(b) Individual visual signals plus a common audible signal to warn of an engine-generator alarm condition shall indicate:

1. Low lubricating oil pressure.
2. Low water temperature (below those required in 8-2.3.4.3).
3. Excessive water temperature.
4. Low fuel — when the main fuel storage tank contains less than a three-hour operating supply.
5. Overcrank (failed to start).
6. Overspeed.

Where a regular work station may be unattended periodically, an audible and visual derangement signal, appropriately labeled, shall be established at a continuously monitored location. This derangement signal shall activate when any of the conditions in 8-2.3.6(a) and (b) occur, but need not display these conditions individually.

8-2.4 Maintenance of Essential Electrical Systems.

8-2.4.1 Maintenance Requirements.

8-2.4.1.1 Alternate Power Source. The generator set or other alternate power source and associated equipment, including all appurtenant parts, shall be so maintained as to be capable of supplying service within the shortest time practicable and within the 10-second interval specified in 8-2.3.4.2, 8-3.2.1, 8-4.3.1 and 8-5.6.1.

8-2.4.1.2 Circuit Breakers. Main and feeder circuit breakers shall be exercised annually.¹

8-2.4.1.3 Insulation Resistance. The resistance readings of main feeder insulation shall be taken prior to acceptance and whenever damage is suspected.

¹Main and feeder circuit breakers should be periodically tested under simulated overload trip conditions to ensure reliability (see *Appendix C-8-2*).

8-2.4.2 Inspection and Test.

8-2.4.2.1* Test Interval and Load. Generator sets serving Emergency and Equipment Systems shall be inspected weekly, and shall be exercised under load and operating temperature conditions for at least 30 minutes at intervals of not more than 30 days. The 30-minute exercise period is an absolute minimum, or the individual engine manufacturer's recommendations shall be followed.

NOTE: Records of changes to the Essential Electrical System should be maintained so that the actual connected load will be within the available capacity.

8-2.4.2.2 Test Conditions. The scheduled test under load conditions shall include a complete simulated cold start and appropriate automatic and manual transfer of all Essential Electrical Systems loads.

8-2.4.2.3 Test Personnel. The scheduled tests shall be conducted by competent personnel. The tests are needed to keep the machines ready to function and, in addition, serve to detect causes of malfunction and to train personnel in operating procedures.

8-2.4.3 Maintenance Record. A written record of inspection, performance, exercising period, and repairs shall be regularly maintained and available for inspection by the authority having jurisdiction. (See *Appendix C-8-2 for general maintenance guide*.)

8-2.4.4 Battery Maintenance. Storage batteries used in connection with Essential Electrical Systems shall be inspected at intervals of not more than seven days and shall be maintained in full compliance with manufacturer's specifications. Defective batteries shall be repaired or replaced immediately upon discovery of defects (see *NFPA 70, National Electrical Code, Section 700-4*).

8-3 Essential Electrical Systems for Hospitals.

8-3.1* General. Essential Electrical Systems for hospitals are comprised of two separate systems capable of supplying a limited amount of lighting and power service which is considered essential for life safety and effective hospital operation during the time the normal electrical service is interrupted for any reason. These two systems are the Emergency System and the Equipment System (see *Appendix C-8-1*).

The Emergency System shall be limited to circuits essential to life safety and critical patient care. These are designated the Life Safety Branch and the Critical Branch.

The Equipment System shall supply major electrical equipment necessary for patient care and basic hospital operation.

Both systems shall be arranged for connection, within time limits specified in this chapter, to an alternate source of power following a loss of the normal source.

The number of transfer switches to be used shall be based upon reliability, design, and load considerations. Each branch of the Essential Electrical System shall be permitted to be served by one or more transfer switches. One transfer switch shall be permitted to serve one or more branches or systems in a small facility.²

²In new construction careful consideration should be given to the benefits of multiple transfer switches. However, selection of the number and configuration of transfer switches, and associated switchgear, is to be made with consideration given to the trade-offs among reliability, transfer switch and generator load characteristics, maintainability, and cost.

8-3.2 Emergency System.

8-3.2.1 General. Those functions of patient care depending on lighting or appliances that are permitted to be connected to the Emergency System are divided into two mandatory branches, described in 8-3.2.2 and 8-3.2.3.

The branches of the Emergency System shall be installed and connected to the alternate power source specified in 8-2.1.1 so that all functions specified herein for the Emergency System shall be automatically restored to operation within 10 seconds after interruption of the normal source.

8-3.2.2 Life Safety Branch. The Life Safety Branch of the Emergency System shall supply power for the following lighting, receptacles, and equipment:

(a) Illumination of means of egress as required in NFPA 101, *Life Safety Code*.

(b) Exit signs and exit direction signs required in NFPA 101, *Life Safety Code*.

(c) Alarm and alerting systems including:

1. Fire alarms.

2. Alarms required for systems used for the piping of nonflammable medical gases as specified in NFPA 56F, *Standard on Nonflammable Medical Gas Systems*.

(d)* Hospital communication systems, where used for issuing instruction during emergency conditions.

(e) Task illumination and selected receptacles at the generator set location.

(f) Elevator cab lighting, control and signal systems.

No function other than those listed above in items (a) through (f) shall be connected to the Life Safety Branch.

8-3.2.3* Critical Branch. The Critical Branch of the Emergency System shall supply power for task illumination, fixed equipment, selected receptacles and special power circuits serving the following areas and functions related to patient care:

(a) Anesthetizing locations — task illumination, all receptacles and fixed equipment.

(b) The isolated power systems in special environments.

(c) Patient care areas — task illumination and selected receptacles in:

1. Infant nurseries,

2. Medication preparation areas,

3. Pharmacy dispensing areas,

4. Selected acute nursing areas,

5. Psychiatric bed areas (omit receptacles),

6. Ward treatment rooms, and

7. Nurses' stations (unless adequately lighted by corridor luminaries).

(d) Additional specialized patient care task illumination and receptacles, where needed.

(e) Nurse call systems.

(f) Blood, bone and tissue banks.

(g)* Telephone equipment room and closets.

(h) Task illumination, receptacles, and special power circuits for:

1. Acute care beds (selected),

2. Angiographic labs,

3. Cardiac catheterization labs,

4. Coronary care units,

5. Hemodialysis rooms or areas,

6. Emergency room treatment areas (selected),

7. Human physiology labs,

8. Intensive care units, and

9. Post-operative recovery rooms (selected).

(i) Additional task illumination, receptacles and special power circuits needed for effective hospital operation. Single-phase fractional horsepower exhaust fan motors which are interlocked with three-phase motors on the Equipment System shall be permitted to be connected to the critical branch.

NOTE: Care should be taken to analyze the consequences of supplying an area with only critical care branch power when failure occurs between the area and the transfer switch. Some proportion of normal and critical power, or critical power from separate transfer switches, may be appropriate.

8-3.2.3.1 Subdivision of the Critical Branch. It shall be permitted to subdivide the Critical Branch into two or more branches.

8-3.3 Equipment System.

8-3.3.1 General. The Equipment System shall be connected to equipment described in 8-3.3.3 and 8-3.3.4. It shall be permitted to be connected to equipment listed in Appendix A-8-4.4.3.

8-3.3.2 Connection to Alternate Power Source. The Equipment System shall be installed and connected to the alternate power source, such that equipment described in 8-3.3.3 is automatically restored to operation at appropriate time lag intervals following the energizing of the Emergency System. Its arrangement shall also provide for the subsequent connection of equipment described in 8-3.3.4 by either delayed automatic, or manual operation.

8-3.3.3 Equipment for Delayed Automatic Connection. The following equipment shall be arranged for delayed automatic connection to the alternate power source:¹

(a) Central suction systems serving medical and surgical functions, including controls. It shall be permitted to place such suction systems on the Critical Branch.

(b) Sump pumps and other equipment required to operate for the safety of major apparatus, including associated control systems and alarms.

(c) Compressed air systems serving medical and surgical functions, including controls.

8-3.3.4 Equipment for Delayed Automatic or Manual Connection. The following equipment shall be arranged for either delayed automatic or manual connection to the alternate power source (*see Appendix A-8-4.4.3*).

¹The equipment in 8-3.3.3(a) through (c) may be arranged for sequential delayed automatic action to the alternate power source to prevent overloading the generator where engineering studies indicate it is necessary.

(a) Heating equipment to provide heating for operating, delivery, labor, recovery, intensive care, coronary care, nurseries and general patient rooms.

Exception: Heating of general patient rooms during disruption of the normal source shall not be required under any of the following conditions:

1. The outside design temperature is higher than $+20^{\circ}\text{F}$ (-6.7°C), or

2. The outside design temperature is lower than $+20^{\circ}\text{F}$ (-6.7°C) and where a selected room(s) is provided for the needs of all confined patients, then only such room(s) need be heated, or

3. The facility is served by a dual source of normal power as described in 8-2.1.2.

NOTE: The outside design temperature is based on the 97½ percent design value as shown in Chapter 4 of the ASHRAE *Handbook of Fundamentals* (1981).

(b) Elevator(s) selected to provide service to patient, surgical, obstetrical and ground floors during interruption of normal power. [For elevator cab lighting, control and signal system requirements, see 8-3.2.2(f)].

In instances where interruption of normal power would result in other elevators stopping between floors, throw-over facilities shall be provided to allow the temporary operation of any elevator for the release of patients or other persons who may be confined between floors.

(c) Supply and exhaust ventilating systems for surgical and obstetrical delivery suites, special and intensive care units, isolation rooms constructed specifically for infection control, emergency treatment spaces, and laboratory fume hoods.

(d) Hyperbaric facilities.

(e) Hypobaric facilities.

(f) Automatically operated doors.

(g) Minimal electrically heated autoclaving equipment shall be permitted to be arranged for either automatic or manual connection to the alternate source.

(h) Other selected equipment shall be permitted to be served by the Equipment System.^{1,2}

8-3.4 System Operation Requirements.

8-3.4.1 General. The Emergency System and the Equipment System shall be so arranged that, in the event of failure of the normal power source, an alternate power source shall be automatically connected within 10 seconds to the Emergency System loads and to the switching devices (time delay or nonautomatic) supplying the Equipment System loads.

8-3.4.2 Description of Transfer Switch Operation.

8-3.4.2.1 The Essential Electrical System shall be served by the normal power source except when the normal power source is interrupted or drops below a predetermined voltage level. Settings of the sensors shall be determined by careful study of the voltage requirements of the load.

¹Consideration should be given to selected equipment in kitchens, laundries, and radiology rooms, and to selected central refrigeration.

²It is desirable that, where heavy interruption currents can be anticipated, the transfer load may be reduced by the use of multiple transfer devices. Elevator feeders, for instance, may be less hazardous to electrical continuity if they are fed through an individual transfer device.

8-3.4.2.2 Failure of the normal source shall automatically start the alternate source generator, either instantaneously or after a short delay (see 8-2.2.4.4). When the alternate power source has attained a voltage and frequency that satisfies minimum operating requirements of the Essential Electrical System, the load shall be connected automatically to the alternate power source.

8-3.4.2.3 Upon connection of the alternate power source, the loads comprising the Emergency System shall be automatically reenergized. The load comprising the Equipment System shall be connected either automatically after a time delay (see 8-2.2.4.5) or nonautomatically and in such a sequential manner as not to overload the generator.

8-3.4.2.4 When the normal power source is restored, and after time delay (see 8-2.2.4.6), the automatic transfer switches shall disconnect the alternate source of power and connect the loads to the normal power source.

8-3.4.2.5 If the emergency power source should fail and the normal power source has been restored, retransfer to the normal source of power shall be immediate, bypassing the retransfer delay timer.

8-3.4.2.6 If the emergency power source fails during a test, provisions shall be made to immediately retransfer to the normal source.

8-3.4.2.7 Nonautomatic transfer switching devices shall be restored to the normal power source as soon as possible after the return of the normal source or at the discretion of the operator.

8-3.5 Wiring Requirements.

8-3.5.1 Separation from Other Circuits. The Life Safety Branch and Critical Branch of the Emergency System shall be kept entirely independent of all other wiring and equipment. See NFPA 70, *National Electrical Code*, for installation requirements.

8-3.5.2 Receptacles.

8-3.5.2.1 The number of receptacles on a single branch circuit for areas described in 8-3.2.3(h) shall be minimized to limit the effects of a branch circuit outage. Branch circuit overcurrent devices shall be readily accessible to nursing and other authorized personnel.

8-3.5.2.2 The cover plates for the electrical receptacles or the electrical receptacles themselves supplied from the Emergency System shall have a distinctive color or marking so as to be readily identifiable.³

8-3.5.3 Switches. Switches installed in the lighting circuits connected to the Essential Electrical System shall comply with Article 700, Section D, of NFPA 70, *National Electrical Code*.

8-3.5.4 Mechanical Protection of the Emergency System. The wiring of the Emergency System of a hospital shall be mechanically protected by raceways, as defined in NFPA 70, *National Electrical Code*.

³If color is used to identify these receptacles the same color should be used throughout the facility.

Exception No. 1: Flexible power cords of appliances, or other utilization equipment, connected to the Emergency System shall not be required to be enclosed in raceways.

Exception No. 2: Secondary circuits of transformer-powered communication or signaling systems shall not be required to be enclosed in raceways unless otherwise specified by Chapter 7 or 8 of NFPA 70, National Electrical Code.

8-4 Essential Electrical Systems for Nursing Homes and Residential Custodial Care Facilities.

8-4.1 Applicability. The requirements of this section will apply to nursing homes and residential custodial care facilities.

Exception: Any freestanding building used for health care other than those described in Sections 8-3 and 8-5 shall be exempted from the requirements of this chapter and the remainder of this section provided:

(a) *It maintains admitting and discharge policies that preclude the provision of care for any patient or resident who may need to be sustained by electrical life support equipment, and*

(b) *Offers no surgical treatment requiring general anesthesia, and*

(c) *Provides an automatic battery-powered system or unit equipment that will be effective for at least 1½ hours and is otherwise in accordance with NFPA 101, Life Safety Code, and NFPA 70, National Electrical Code, and that will be capable of supplying lighting of at least one footcandle to exit lights, exit corridors, stairways, nursing stations, medication preparation areas, boiler rooms, and communication areas. This system must also supply battery power to operate all alarm systems.*

8-4.2 General. Essential Electrical Systems for nursing homes and residential custodial care facilities are comprised of two separate systems capable of supplying a limited amount of lighting and power service which is considered essential for the protection of life and safety and effective operation of the institution during the time normal electrical service is interrupted for any reason. These two separate systems are the Emergency System and the Critical System.

The number of transfer switches to be used shall be based upon reliability, design, and load considerations. Each branch of the Essential Electrical System shall be permitted to be served by one or more transfer switches. One transfer switch shall be permitted to serve one or more branches or systems in a small facility.¹ (Also see Appendix A-8-3.1.)

8-4.3 Emergency System.

8-4.3.1 General. The Emergency System shall be so installed and connected to the alternate source of power specified in 8-2.1.1 that all functions specified herein for the Emergency System will be automatically restored to operation within 10 seconds after interruption of the normal source.

¹In new construction careful consideration should be given to the benefits of multiple transfer switches. However, selection of the number and configuration of transfer switches, and associated switchgear, is to be made with consideration given to the trade-offs among reliability, transfer switch and generator load characteristics, maintainability, and cost.

8-4.3.2 Automatic Connection to Emergency System. The Emergency System shall supply power for the following lighting, receptacles, and equipment:

(a) Illumination of means of egress as required in NFPA 101, Life Safety Code.

(b) Exit signs and exit directional signs required in NFPA 101, Life Safety Code.

(c) Alarm and alerting system, including:

1. Fire alarms.

2. Alarms required for systems used for the piping of nonflammable medical gases as specified in NFPA 56F, *Standard on Nonflammable Medical Gas Systems*.

(d)* Communication systems, where used for issuing instructions during emergency conditions.

(e) Sufficient lighting in dining and recreation areas to provide illumination to exit ways of 5 footcandles minimum.

(f) Task illumination and selected receptacles at the generator set location.

(g) Elevator cab lighting, control and communication systems.

No function other than those listed above in items (a) through (g) shall be connected to the Emergency System.

8-4.4 Critical System.

8-4.4.1 General. The Critical System shall be so installed and connected to the alternate power source that equipment listed in 8-4.4.2 shall be automatically restored to operation at appropriate time lag intervals following the restoration of the Emergency System to operation. Its arrangement shall also provide for the additional connection of equipment listed in 8-4.4.3 by either delayed automatic or manual operation.

8-4.4.2 Delayed Automatic Connections to Critical System. The following equipment shall be connected to the Critical System and be arranged for delayed automatic connection to the alternate power source:

(a) Patient care areas — task illumination and selected receptacles in:

1. Medication preparation areas.

2. Pharmacy dispensing areas.

3. Nurses' stations (unless adequately lighted by corridor luminaries).

(b) Sump pumps and other equipment required to operate for the safety of major apparatus and associated control systems and alarms.

8-4.4.3* Delayed Automatic or Manual Connections to Critical System. The following equipment shall be connected to the Critical System and be arranged for either delayed automatic or manual connection to the alternate power source:

(a) *Heating Equipment to Provide Heating for General Patient Rooms.* Heating of general patient rooms during disruption of the normal source shall not be required under any of the following conditions:

1. The outside design temperature is higher than +20°F (-6.7°C), or

2. The outside design temperature is lower than

+20°F (-6°C) and where a selected room(s) is provided for the needs of all confined patients, then only such room(s) need be heated, or

3. The facility is served by a dual source of normal power as described in 8-2.1.2.

NOTE: The outside design temperature is based on the 97½ percent design value as shown in Chapter 4 of the ASHRAE *Handbook of Fundamentals* (1981).

(b) *Elevator Service.* In instances where interruptions of power would result in elevators stopping between floors, throw-over facilities shall be provided to allow the temporary operation of any elevator for the release of passengers. [For elevator cab lighting, control and signal system requirements, see 8-4.3.2(g)].

8-4.4.4 Optional Connections to the Critical System. Additional illumination, receptacles and equipment shall be permitted to be connected only to the Critical System.

8-4.5 System Operation Requirements.

8-4.5.1 General. The Emergency System and the Critical System shall be so arranged that, in the event of failure of the normal power, an alternate power source shall be automatically connected within 10 seconds to the Emergency System loads and to the time delay and/or nonautomatic switching devices supplying the Critical System.

8-4.5.2 Description of Transfer Switch Operation.

8-4.5.2.1 The Essential Electrical System shall be served by the normal power source except when the normal power source is interrupted or drops below a predetermined voltage level. Settings of the sensors shall be determined by careful study of the voltage requirements of the load.

8-4.5.2.2 Failure of the normal source shall automatically start the alternate source generator, either instantaneously or after a short delay (see 8-2.2.4.4). When the alternate power source has attained a voltage and frequency that satisfies minimum operating requirements of the Essential Electrical System, the load shall be connected automatically to the alternate power source.

8-4.5.2.3 Upon connection of the alternate power source, the loads comprising the Emergency System shall be automatically reenergized. The loads comprising the Critical System shall be connected either automatically after a time delay (see 8-2.2.4.5) or nonautomatically and in such a sequential manner as not to overload the generator.

8-4.5.2.4 When the normal power source is restored, and after time delay (see 8-2.2.4.6), the automatic transfer switches shall disconnect the alternate source of power and connect the loads to the normal power source.

8-4.5.2.5 If the emergency power source should fail and the normal power source has been restored, retransfer to the normal source of power shall be immediate, bypassing the retransfer delay timer.

8-4.5.2.6 Nonautomatic transfer switching devices shall be restored to the normal power source as soon as possible after the return of the normal source or at the discretion of the operator.

8-4.6 Wiring Requirements.

8-4.6.1 Separation from Other Circuits. The Emergency System shall be kept entirely independent of all other wiring and equipment.

NOTE: See NFPA 70, *National Electrical Code*, for installation requirements.

8-4.6.2 Receptacles. The cover plates for the electrical receptacles or the electrical receptacles themselves supplied from the Emergency System shall have a distinctive color or marking so as to be readily identifiable.¹

8-5 Essential Electrical Systems for Other Health Care Facilities.

8-5.1 Applicability. The requirements of this section shall apply to any health care facility not covered in Sections 8-3 or 8-4, and in which:

- (a) Inhalation anesthetics are administered in any concentration to patients, or
- (b) Patients require electrical life support equipment.

8-5.2 General. The Essential Electrical System for these facilities comprises a system capable of supplying a limited amount of lighting and power service which is considered essential for life safety and orderly cessation of procedure during the time normal electrical service is interrupted for any reason.²

8-5.3 Connection to the Essential Electrical System. The system shall supply power for task illumination which is related to the safety of life and which is necessary for the safe cessation of procedures in progress. The system shall also supply power as follows:

- (a) That required for all anesthesia and resuscitative equipment used in areas where inhalation anesthetics are administered to patients including alarm and alerting devices as required in Chapters 3 and 6 of NFPA 56F, *Standard on Nonflammable Medical Gas Systems*.
- (b) That required for all electrical life support equipment.

8-5.4 Connections to Alternate Source of Power.

8-5.4.1 The emergency system shall have an alternate source of power separate and independent from the normal

¹If color is used to identify these receptacles the same color should be used throughout the facility.

²It must be emphasized that the type of system selected and its area and type of coverage should be appropriate to the medical procedures being performed in the facility. For example, a battery-operated emergency light which switches "on" when normal power is interrupted and an alternate source of power for suction equipment, along with the immediate availability of some portable hand-held lighting would be advisable where oral and maxillofacial surgery (e.g., extraction of impacted teeth) is performed. On the other hand, in dental offices where simple extraction, restorative, prosthetic, or hygienic procedures are performed, only remote corridor lighting for purposes of egress would be sufficient. Emergency power for equipment would not be necessary. Similar to oral surgery locations, a surgical clinic requiring use of life support or emergency devices such as suction machines, ventilators, cautery or defibrillators would again require both emergency light and power.

source that will be effective for a minimum of 1½ hours after loss of the normal source.¹

8-5.4.2 The alternate source of power for the system shall be specifically designed for this purpose and shall be either a generator, battery system, or self-contained battery integral with the equipment.

8-5.5 System Operation Requirements.

8-5.5.1 General. The system shall be so arranged that, in the event of failure of normal power source, the alternate source of power shall be automatically connected to the load within 10 seconds.

8-5.5.2 Description of Transfer Switch Operation with Engine Generator Sets.

8-5.5.2.1 The operation of the equipment shall be so arranged that the load will be served by the normal source except when the normal source is interrupted, or on a voltage drop below the setting of the voltage sensing device. The settings of the voltage sensing relays shall be determined by careful study of the voltage requirements of the load.

8-5.5.2.2 When the normal source is restored, and after time delay (*see 8-2.2.4.6*), the automatic transfer switch

shall disconnect the alternate source of power and connect the loads to the normal power source.

8-5.5.2.3 If the alternate power source fails and the normal power source has been restored, retransfer to the normal source of power shall be immediate.

8-5.5.3 Description of Transfer Switch Operation with Battery Systems.

8-5.5.3.1 Failure of the normal source shall automatically transfer the load to the battery system.

8-5.5.3.2 Battery systems shall meet all requirements of Article 700 of NFPA 70, *National Electrical Code*.

8-5.5.3.3 Retransfer to the normal source shall be automatic upon restoration of the normal source.

8-5.6 Wiring Requirements.

8-5.6.1 General. The design, arrangement and installation of the system shall be in accordance with NFPA 70, *National Electrical Code*.

8-5.6.2 Receptacles. The cover plates for the electrical receptacles or the electrical receptacles themselves supplied from the Emergency System shall have a distinctive color or marking so as to be readily identifiable.²

¹Consideration should be given to medical procedures which may necessitate a longer time that emergency power be supplied.

²If color is used to identify these receptacles the same color should be used throughout the facility.

Chapter 9 Safe Use of Electricity in Patient Care Areas of Hospitals

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A-9.

Information on referenced publications can be found in Chapter 12 and Appendix B.

Preface

This chapter has arisen from a concern about electrical safety in the Hospital. The scope of the Technical Committee responsible for this chapter is: "this Committee shall have primary responsibility to develop criteria for safeguarding patients and patient care staff in health care facilities from hazards of electricity and electrical equipment including electrical supply systems, under the conditions unique to patient care."

The chapter states the basic electrical safety performance criteria for patient care areas to be followed by hospital personnel, and provides performance criteria for manufacturers of appliances and for the installation implementation requirements contained in Article 517, NFPA 70, *National Electrical Code*.

Consistent with this directive, this chapter has an appendix accompanying it. Appendix A-9 interprets some of the basic criteria by presenting different methodologies and alternative procedures to achieve the level of safety defined by the criteria.

9-1 Introduction.

9-1.1 Purpose. The purpose of this chapter is the practical safeguarding of hospital patients and staff from the hazards arising from the use of electricity in medical diagnosis and therapy.

9-1.2 Scope. This chapter is concerned primarily with the electric shock hazard. Although an appliance which yields erroneous data or functions poorly may be dangerous, quality and assurance of full appliance performance is not covered except as it may relate to direct electrical or fire injury to patients or personnel. The chapter covers patient care areas of hospitals and those areas of outpatient facilities classified as Class H (see 9-1.5, *Patient Care Areas*).

This chapter does not cover other health care facilities outside a hospital.

This chapter does not cover areas of hospitals such as laboratories, offices, darkrooms, storage areas and plant equipment areas from which a patient is normally excluded.

This chapter does not require formal approval or listing of experimental or research apparatus built to order, or under development, provided such apparatus is used under qualified supervision and provided the apparatus is demonstrated to have a degree of safety equivalent to that described herein or whose degree of safety has been deemed acceptable by the hospital.

This chapter does not require formal approval or listing of any appliance.

9-1.3 Intended Use. This chapter is intended for use by those persons involved in the manufacture, design, construction, testing, inspection or operation of a hospital or any of its appliances or equipment used in patient care areas of the hospital.

Criteria for manufacturers and designers are specified separately from those testing requirements for hospitals.

9-1.4 Responsibility of the Hospital. It shall be the responsibility of the hospital to provide an environment that is reasonably safe from the shock and burn hazards attendant with the use of electricity in patient care areas (see Section 9-4, *Administration and Maintenance for further information*).

Also, as used in this chapter, the term hospital (except where it obviously refers to the physical structure) shall mean the entity and that portion of its internal governing structure which has the responsibility for the elements of hospital operation covered by this chapter, including building design, purchasing specifications, inspection procedures, maintenance schedules, and training programs affecting such use.

It is understood that the individuals who are responsible will vary from one hospital to another, although in most cases the hospital's administration exercises the concomitant authority. It is further recognized that fulfillment of this responsibility frequently occurs by means of delegating appropriate authority to staff, consultants, architects, engineers, and others.

9-1.5 Patient Care Areas. Areas of a health care facility in which patient care is administered are classified as general care areas, critical care areas, and wet locations. The governing body of the facility shall designate these areas in accordance with the type of patient care anticipated, and with the following definitions of the three types of areas.

(a) General care areas are patient bedrooms, examining rooms, treatment rooms, clinics and similar areas in which it is intended that the patient shall come in contact with ordinary appliances such as a nurse call system, electric beds, examining lamps, telephones and entertainment devices. In such areas, it may also be intended that patients be connected to electromedical devices (such as heating pads, electro-cardiographs, drainage pumps, monitors, otoscopes, ophthalmoscopes, intravenous lines, etc.). (Class G)

(b) Critical care areas are those special care units, intensive care units, coronary care units, angiography laboratories, cardiac catheterization laboratories, delivery rooms, operating rooms, and similar areas in which patients are intended to be subjected to invasive procedures and connected to line-operated, electromedical devices. (Class H)

NOTE: Inhalation Anesthetizing Locations. Inhalation anesthetizing locations shall be classified in accordance with Chapter 3, *Safe Use of Inhalation Anesthetics*.

(c) Wet locations are those patient care areas that are normally subject to wet conditions, including standing water on the floor, or routine dousing or drenching of the work area. Routine housekeeping procedures and incidental spillage of liquids do not define a wet location. (Class W)

9-1.6 Application of this Chapter. This chapter shall be applied to new construction and new equipment. This chapter shall not require the alteration or replacement of existing construction or equipment.

Existing appliances and construction may deviate from this chapter. Guidance on determining the acceptability of such appliances and construction is offered in Appendix A-9, and in other sections of the chapter.

9-1.7 Interpretations. The National Fire Protection Association, Inc., does not approve, inspect, or certify any installation, procedure, equipment, or material. In determining the acceptability of installations, procedures, or material the authority having jurisdiction may base acceptance on compliance with this standard. To promote uniformity of interpretation and application of its standards, NFPA has established interpretation procedures. These procedures are outlined on the inside front cover of this standard. Refer to NFPA "Regulations Governing Committee Projects" for complete details.

9-1.8* Nature of Hazards. The hazards attendant to the use of electricity include electrical shock, thermal injury and interruption of power. (For further information see Appendix A-9.)

9-1.8.1 Availability of Electrical Power. Interruption of the supply of electric power in a hospital may be a hazard. Implementation of the requirements of Section 9-3 of this chapter serves to maintain the required level of continuity and quality of electrical power for patient care electrical appliances.

9-1.8.2* Control of Shock Hazard. Control of electric shock hazard requires the limitation of electric current that might flow in an electric circuit involving the patient's body, and is accomplished through a variety of alternative approaches covered in Appendix A-9.

9-1.8.3 Electrical Fires. Electrical systems may be subject to the occurrence of electrical fires. Grounding systems, overcurrent protective devices, and other subjects discussed in this chapter may be intended for fire prevention, as well as other purposes. This aspect of electrical systems is the primary focus of other NFPA standards, and will not be emphasized herein.

9-2 Electrical Power Systems for Patient Care Areas.

9-2.1 General.

9-2.1.1 Scope of this Section. This section describes criteria for the safe performance of electric distribution and grounding systems under the conditions of use unique to patient care. The performance criteria shall apply to all types of electrical distribution systems in patient care areas.

9-2.1.2 Classification. Patient care areas shall be classified in accordance with 9-1.5.

9-2.2 Availability of Electrical Power. Each appliance of a hospital requiring electrical line power for operation shall be supported by power sources and distribution systems that provide power adequate for each service.

9-2.2.1 Essential electrical systems shall be installed in accordance with Chapter 8, Essential Electrical Systems for Health Care Facilities.

9-2.2.2 Circuit breakers, fuses, Ground Fault Circuit Interrupters (GFCIs) and Ground Fault Interrupters (GFIs) shall be coordinated so that power interruption in that part of the circuit which precedes the interrupting device closest to a fault shall not occur.

9-2.3 Construction—Installation Requirements. These requirements apply to new construction. Existing installations need not be modified, provided that they meet the operational safety requirements in 9-2.4, Operational Safety Requirements.

9-2.3.1* Electrical Power Distribution System.

9-2.3.1.1* Branch Circuits in a Patient Vicinity. Branch circuits serving a given patient vicinity shall be fed from not more than one normal branch circuit distribution panel and/or one emergency branch circuit distribution panel.

Exception: Branch circuits serving only special purpose outlets or receptacles (e.g., portable X-ray receptacles) need not conform to the requirements of this section.

9-2.3.1.2 Power Receptacles.

9-2.3.1.2.1* Types of Receptacles. Each power receptacle shall provide at least one separate, highly dependable grounding pole capable of maintaining low contact resistance with its mating plug despite electrical and mechanical abuse. Special receptacles (such as four-pole units providing an extra pole for redundant grounding or ground continuity monitoring; or locking type receptacles; or, where required for reduction of electrical noise on the grounding circuit, receptacles in which the grounding terminals are purposely insulated from the receptacle yoke) shall be permitted.

9-2.3.1.3 Minimum Number of Receptacles. The number of receptacles shall be determined by the intended use of the patient care area. There shall be sufficient receptacles located so as to avoid the need for extension cords or multiple outlet adapters. In any case, there shall be provision for the attachment of at least four separate appliances with a total connected load of at least 20 amperes for each patient vicinity.

Exception No 1: Receptacles shall not be required in bathrooms or toilet rooms.

Exception No. 2: Receptacles shall not be required in areas where medical requirements mandate otherwise, e.g., certain psychiatric, pediatric or hydrotherapy areas.

9-2.3.1.4 Polarity of Receptacles. Each receptacle shall be wired in accordance with NFPA 70, *National Electrical Code*, to ensure correct polarity.

9-2.3.1.5 Low Voltage Systems. Fixed systems of 30 volts (dc or ac rms) or less shall be ungrounded and the insulation between each ungrounded conductor and the primary circuit which is supplied from a conventionally grounded distribution system shall provide the same protection as required for the primary voltage.

Exception: A grounded low voltage system shall be permitted provided that load currents are not carried in the grounding conductors.

9-2.3.1.6 Isolated Power Systems. An isolated power system is not required to be installed in any patient care area except as specified in Chapter 3, Use of Inhalation Anesthetics. The system shall be permitted to be installed, however, and when installed, shall conform to the performance requirements specified in Chapter 3, Use of Inhalation Anesthetics.

9-2.3.1.7 Ground Fault Circuit Interrupters (GFCIs). If used, the GFCIs shall be approved for the purpose.

NOTE: Listed Class A ground fault circuit interrupters are required to trip when a fault current to ground is 6 milliamperes or more.

9-2.3.2 Grounding Systems.

9-2.3.2.1 Grounding Circuitry Integrity. Grounding circuits and conductors in patient care areas shall be installed in such a way that the continuity of other parts of those circuits cannot be interrupted nor the resistance raised above an acceptable level by the installation, removal or replacement of any installed equipment, including power receptacles.

9-2.3.2.2* Reliability of Grounding. In all patient care areas the reliability of an installed grounding circuit to a power receptacle shall be at least equivalent to that provided by an electrically continuous copper conductor of appropriate ampacity run from the receptacle to a grounding bus in the distribution panel. The grounding conductor shall conform to NFPA 70, *National Electrical Code*.

Exception: Existing construction which does not use a separate grounding conductor shall be permitted to continue in use provided it meets the performance requirements in 9-2.4, Operational Safety Requirements.

Where metal receptacle boxes are used, the performance of the connection between the receptacle grounding terminal and the metal box shall be equivalent to the performance provided by copper wire no smaller than No. 12 AWG.

9-2.3.2.3* Grounding Interconnection with Essential Electrical System. In patient care areas supplied by the normal distribution system and any branch of the Essential Electrical System, the grounding system of the normal distribution system and the Essential Electrical System shall be interconnected.

9-2.3.2.4 Use of Quiet Grounds. A quiet ground, if used, shall not defeat the purposes of the safety features of the grounding systems detailed herein.

NOTE: Care should be taken in specifying such a quiet grounding system since the grounding impedance is controlled only by the grounding wires and does not benefit from any conduit or building structure in parallel with it.

9-2.3.2.5 Patient Equipment Grounding Point. A patient equipment grounding point comprising one or more grounding terminals or jacks shall be permitted in an accessible location in the patient vicinity.

9-2.3.2.6 Special Grounding in Patient Care Areas. In addition to the grounding required to meet the performance requirements of 9-2.4, Operational Safety Requirements, additional grounding shall be permitted where special circumstances so dictate. (*See A-9-1.8, Nature of Hazards.*)

NOTE: Special grounding methods may be required in patient vicinities immediately adjacent to rooms containing high power or high-frequency equipment that causes electrical interference with monitors or other electromedical devices. In extreme cases, electromagnetic induction may cause the voltage limits of 9-2.4, Operational Safety Requirements, to be exceeded.

Electromagnetic interference problems may be due to a variety of causes, some simple, others complex. Such problems are best solved one at a time. In some locations, grounding of stretchers, examining tables or bed frames will be helpful. Where necessary, a patient equipment grounding point should be installed. This can usually be accomplished even after completion of construction by installing a receptacle faceplate fitted with grounding posts. Special grounding wires should not be used unless they are found to be essential for a particular location because they may interfere with patient care procedures or present trip hazards.

9-2.3.3 Use of Additional Safeguards Against Electric Shock.

9-2.3.3.1 Wet Location Patient Care Areas. (Class W)

9-2.3.3.1.1 General. Wet Location (Class W) patient care areas shall be provided with special protection against electric shock because the contact resistance of the body may be reduced by moisture, and electrical insulation is more subject to failure. This special protection shall be provided by a power distribution system which inherently limits the possible ground fault current due to a first fault to a low value, without interrupting the power supply; or by a power distribution system in which the power supply is interrupted if the ground fault current does, in fact, exceed a value of 6 milliamperes.

Exception No. 1: Patient beds, toilets, bidets, and wash basins shall not be required to be considered wet locations.

*Exception No. 2: In existing construction, the requirements of 9-2.3.3.1.1 may be waived provided that a written inspection procedure, acceptable to the authority having jurisdiction, is continuously enforced by a designated individual at the hospital, to indicate that equipment-grounding conductors for 120-volt, single-phase, 15- and 20-ampere receptacles, equipment connected by cord and plug, and fixed electrical equipment are installed and maintained in accordance with NFPA 70, *National Electrical Code*, and applicable performance requirements of this chapter. The procedure shall include electrical continuity tests of all required equipment, grounding conductors, and their connections. These tests shall be conducted as follows:*

Fixed receptacles, equipment connected by cord and plug, and fixed electrical equipment shall be tested:

- (a) *When first installed.*
- (b) *Where there is evidence of damage.*
- (c) *After any repairs.*
- (d) *At intervals not exceeding 6 months.*

9-2.3.3.1.2 The use of an isolated power system (IPS) shall be permitted as a protective means capable of limiting ground fault current without power interruption. When installed, such a power system shall conform to the requirements of Chapter 3, Use of Inhalation Anesthetics.

9-2.3.3.1.3 Where power interruption is tolerable, the use of a ground fault circuit interrupter (GFCI) shall be permitted as the protective means which monitors the actual ground fault current and interrupts the power when that current exceeds 6 milliamperes.

9-2.4* Operational Safety Requirements.

9-2.4.1 Safety Testing Procedures and Criteria for Acceptability.

9-2.4.1.1 Grounding System Testing. The effectiveness of the grounding system shall be determined by voltage measurements and impedance measurements.

(a) *New construction.* The effectiveness of the grounding system shall be evaluated before acceptance.

(b) *Existing construction.* The effectiveness of the grounding system of existing construction shall be evaluated and documented. Such evaluation shall be repeated when major sections are modified.

Exception No. 1: Small wall-mounted conductive surfaces, not likely to become energized, such as surface-mounted towel and soap dispensers, mirrors, and so forth, need not be intentionally grounded or tested.

Exception No. 2: Large metal conductive surfaces not likely to become energized, such as windows, door frames, and drains, need not be intentionally grounded nor periodically tested.

9-2.4.1.2 Reference Point. The voltage and impedance measurements shall be taken with respect to a reference point. The reference point shall be one of the following:

(a) A reference grounding point (*see Chapter 2, Definitions*).

(b) A grounding point in or near the room under test which is electrically remote from receptacles. Example: an all metal cold water pipe.

(c) The grounding contact of a receptacle that is powered from a different branch circuit from the receptacle under test.

9-2.4.1.3 Voltage Measurements. The voltage measurements shall be made under no fault conditions between a reference point and exposed conductive surfaces (including ground contacts of receptacles) in a patient vicinity. The voltage measurements shall be made with an accuracy of ± 20 percent.

NOTE: The reference point may be the reference grounding point or the grounding contact of a convenient receptacle.

9-2.4.1.4 Impedance Measurements. The impedance measurement shall be made with an accuracy of ± 20 percent.

9-2.4.1.4.1 New Construction. The impedance measurement shall be made between the reference point and the grounding contact of each receptacle in the patient vicinity. The impedance measurement shall be the ratio of the 60 Hz voltage developed between a point under test and a reference point to 60 Hz current applied to the point under test.

9-2.4.1.4.2 Existing Construction. The impedance (at 60 Hz or at dc) shall be measured between the reference

point and the grounding contact of each receptacle in the patient vicinity. The impedance measurement shall be the ratio of the voltage developed between a point under test and a reference point to a current applied to the point under test. If the test is performed when the system is in use on a patient, it must not endanger the patient even if the grounding circuit being tested is faulty.

9-2.4.1.5 Test Equipment. Electrical safety test instruments shall be tested periodically, but not less than annually, for acceptable performance.

(a) Voltage measurements specified in 9-2.4, Operational Safety Requirements, shall be made with an instrument having an input resistance of 1,000 ohms ± 10 percent at frequencies of 1,000 Hz or less.

(b) The voltage across the terminals (or between any terminal and ground) of resistance measuring instruments used in occupied patient care areas shall not exceed 500 mv rms or 1.4 dc or peak to peak.

9-2.4.1.6 Criteria for Acceptability.

9-2.4.1.6.1 New Construction.

(a) Voltage limit shall be 20 mv.

(b) Impedance limit shall be 0.1 ohm.

Exception: For quiet ground systems, limit shall be 0.2 ohm.

9-2.4.1.6.2 Existing Construction.

(a) The voltage limit shall be:

1. 500 mv for general care areas and wet areas.

NOTE: The 500 mv limit is based on physiological values. Since the actual voltages normally measured in modern construction are usually less than 10 mv with nominal construction, voltages exceeding 20 mv may indicate a deteriorating condition and should be investigated.

2. 40 mv for critical care areas.

NOTE: The 40 mv limit is based on physiological values. Since the actual voltages normally measured in modern construction are usually less than 10 mv with nominal construction, voltages exceeding 20 mv may indicate a deteriorating condition and should be investigated.

(b) The impedance limit shall be 0.2 ohm.

9-2.4.2 Receptacle Testing.

(a) The physical integrity of each receptacle shall be confirmed by visual inspection.

(b) The continuity of the grounding circuit in each electrical receptacle shall be verified.

(c) Correct polarity of the hot and neutral connections in each electrical receptacle shall be confirmed.

(d) The retention force of the grounding blade of each electrical receptacle (except locking-type receptacles) shall be not less than 115 grams (4 oz).

9-2.4.3 Isolated Power System Tests. If installed, the isolated power system shall be tested in accordance with Chapter 3, Use of Inhalation Anesthetics.

9-2.4.4 Testing of GFCI. If GFCIs are used, a device or component which causes 6 milliamperes to flow to ground shall be momentarily connected between the energized conductor of the power distribution circuit being protected,

and ground, to verify that the GFCI does indeed interrupt the power. If the test is performed when the system is in use on a patient, it must not endanger the patient even if the grounding circuit being tested is faulty.

9-2.5 Testing Intervals. Testing shall be performed no less frequently than as listed below.

9-2.5.1 For Receptacle Testing.

General Care Areas: 12 months

Critical Care Areas: 6 months

Wet Locations: 12 months

Exception: Where documented performance data are available to justify longer intervals than those shown, such longer intervals shall be permitted.

9-2.5.2 For GFCI Testing.

At least every 12 months.

9-2.5.3 Whenever the electrical system has been altered or replaced, that portion of the system shall be tested.

9-2.6* Documentation. A record shall be maintained of the tests required by this section and associated repairs or modification. At a minimum, this record shall contain the date, the rooms or areas tested, and an indication of which items have met or have failed to meet the performance requirements of this section.

9-3 Hospital Requirements for Electrical Appliances in Patient Care Areas.

9-3.1 Scope. This section provides operation and testing requirements intended to guide hospital and hospital inspection personnel in the safe use of all electrical appliances in patient care areas of the hospitals.

NOTE: See Chapter 2 for definition of patient care-related electrical appliance.

9-3.2 Policies and Procedures. The hospital shall establish policies and procedures related to the safe use of electric appliances (*see Section 9-4, Administration and Maintenance*).

9-3.3 Safe Appliance Policy and Criteria for Hospitals. The requirements of this section apply to all electrical appliances. This section's requirements and procedures are intended to be implemented by the hospital to evaluate existing equipment or to evaluate new equipment as part of routine incoming inspection procedures.

9-3.3.1 All cord-connected electrically powered appliances used in the patient vicinity shall be provided with a three-wire power cord and a three-pin grounding-type plug.

Exception: Double-insulated appliances shall be permitted to have two conductor cords.

Household or office appliances not commonly equipped with grounding conductors in their power cords shall be permitted provided they are not located within the patient vicinity. For example, electric typewriters, pencil sharpeners and clocks at nurses' stations, or electric clocks or TVs which are normally outside the patient vicinity but may be in a patient's room, shall not be required to have grounding conductors in their power cords.

9-3.3.2 Protection of Patients with Direct Electrical Pathways to the Heart. Only equipment which is specifically designed for the purpose, i.e., provided with suitable isolated patient leads or connections (*see 9-5.2, Direct Electrical Pathways to the Heart*), shall be connected directly to electrically conductive pathways to a patient's heart. Such electrically conductive pathways include intracardiac electrodes such as implanted pacemaker leads and guide wires. The hospital shall have a policy which prohibits the use of external cardiac pacemakers and pacing leads with external terminals which are not properly protected from potentially hazardous contact with conductive surfaces.

9-3.3.3 Electrical appliance controls (such as bed controls, pillow speakers, television controls and nurse-call controls) which do not meet the minimum requirements of 9-5.1, General Requirements for Manufacturers, shall be mounted so that they can not be taken into the bed.

Exception: Existing low-voltage controls may be used in general patient care areas.

9-3.3.4 Adapters. With the exception of three-to-two-prong adapters, adapters shall be permitted to be used to permit appliances fitted with distinctive plugs (such as those which may still be in use in anesthetizing locations) to be used with conventional power receptacles. The wiring of the adapter shall be tested for physical integrity, polarity, and continuity of grounding at the time of assembly, and periodically thereafter. Construction of adapters and cords shall be adequate for the application to avoid overload (i.e., AWG 16 or greater) and shall meet the requirements of 9-5.1.2.1, Attachment Plugs, and 9-5.1.2.2, Power Cords.

9-3.3.5 Appliances Intended to Deliver Electrical Energy. Electrical energy delivering appliances shall conform to the leakage, grounding, and other requirements of this chapter when powered, but not delivering energy.

NOTE 1: When delivering energy, such appliances may deviate from these requirements only to the extent essential for their intended clinical function.

NOTE 2: Appliances that intentionally or which may inadvertently apply electrical energy to the patient, or to components in contact with the patient, require special safety considerations.

NOTE 3: Since there is a wide range of power levels, output frequencies, and purposes of appliances that apply electricity directly to patients or to patient-connected devices, it is not feasible to cite them in detail.

9-3.4 Tests Conducted by Hospitals.

9-3.4.1 The physical integrity of the power cord, the attachment plug and cord strain relief shall be confirmed by visual inspection or other appropriate tests.

9-3.4.2* The resistance between the appliance chassis, or any exposed conductive surface of the appliance, and the ground pin of the attachment plug shall be measured. The resistance shall be less than 0.50 ohm. The cord shall be flexed at its connection to the attachment plug or connector, and at its connection to the strain relief on the chassis during the resistance measurement. This measurement shall only apply to appliances that are used in the patient vicinity. (*See Appendix A-9-3.4.2 for suggested test methods.*)

Exception: The requirement does not apply to escutcheon or nameplates, small screws, etc., that are unlikely to become energized.

9-3.4.3* Leakage Current Tests. The following requirements shall apply to all tests.

(a) The resistance tests of 9-3.4.2 shall be conducted before undertaking any leakage current measurements.

(b) *Techniques of Measurement.* Each test shall be performed with the appropriate connection to a properly grounded ac power system.

(c) *Frequency of Leakage Current.* The leakage current limits stated in 9-3.4.3 shall be rms values for dc and sinusoidal waveforms up to 1 KHz. For frequencies above 1 KHz the leakage current limits shall be the values given in 9-3.4.4 multiplied by the frequency, in KHz, up to a maximum multiplier of 100.

NOTE 1: The limits for nonsinusoidal periodic, modulated, and transient waveforms remain to be determined.

NOTE 2: For complex leakage current waveforms, a single reading from an appropriate metering system can represent the physiologically effective value of the composite wave form, provided that the contribution of each component to the total reading is weighted in accordance with 9-3.4.3(c).

This weighting can be achieved by a frequency response shaping network which precedes a flat response meter, or by a meter whose own frequency response characteristic matches 9-3.4.3(c).

(d) *Leakage Current in Relation to Polarity.* Leakage current measurements shall be made with the polarity of the power line normal, the power switch of the appliance "on" and "off," and with all operating controls in the positions to cause maximum leakage current readings. The leakage current limits in 9-3.4.3 and 9-3.4.4 shall not be exceeded in any of these conditions.

9-3.4.3.1 Chassis Leakage Current, Permanently Wired Appliances. Permanently wired appliances in the patient vicinity shall be tested prior to installation while the equipment is temporarily insulated from ground. The leakage current from frame to ground of permanently wired appliances installed in general or critical patient care areas shall not exceed 5.0 milliamperes with all grounds lifted. After installation, such appliances shall be tested periodically in accordance with 9-2.4.1.3 (Voltage Measurements) and 9-2.4.1.6.2 (Existing Construction).

9-3.4.3.2 Chassis Leakage Current, Cord-Connected Patient Care-Related Appliances.

9-3.4.3.2.1 The leakage current for cord-connected appliances shall be measured. The limit shall be 100 microamperes. Figure 9-3.4.3.2.1 shows one method of performing this test.

If multiple appliances are mounted together by the hospital in a single cart or rack, and one power cord supplies power, the leakage current shall be measured as an assembly.

Exception No. 1: Existing appliances with leakage currents up to 250 microamps shall be permitted to be used provided an appropriate inspection and maintenance program is established for these items to ensure that the integrity of the grounding connection is reliably maintained.

Exception No. 2: Where existing or special equipment (such as mobile X-ray machines) exhibit chassis leakage current between 250 and 500 microamperes, this condition does not represent a hazard to the patient as long as the grounding connection is intact. Such equipment shall be permitted to be kept in service provided a documented maintenance schedule is established to assure the integrity of the grounding connection. A three-month interval is a nominal period. Depending on the intensity of the use of the appliance and prior test data, the hospital shall be permitted to establish a protocol with shortened or lengthened time intervals.

NOTE: Where existing equipment exceeds 500 microamps, such as some types of ultrasound therapy devices or portable hypothermia units, etc., methods to reduce leakage current such as the addition of a small isolation transformer to that device or methods to provide equivalent safety by adding redundant equipment ground are permissible.

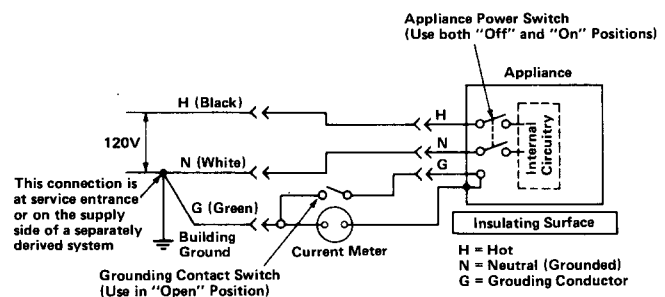


Figure 9-3.4.3.2.1 Test Circuit for Measuring Chassis Leakage Current.

9-3.4.3.2.2 Measurements shall be made with the appliance ground broken in two modes of appliance operation: power plug connected normally and with the appliance on and with the appliance off (if equipped with an on/off switch). When the appliance has fixed redundant grounding (e.g., permanently fastened to the grounding system), the chassis leakage current test shall be conducted with the redundant grounding intact.

9-3.4.3.3 Lead Leakage Current Tests and Limits. The tests specified in this section shall be required for incoming inspections, and following repairs and modifications which may have compromised the patient lead leakage current.

9-3.4.3.3.1 Lead to Ground (Nonisolated Input). The leakage current between all patient leads connected together and ground shall be measured with the power plug connected normally and the device on. Figure 9-3.4.3.3.1 is an example of an acceptable test configuration. The leakage current shall be less than 100 microamperes.

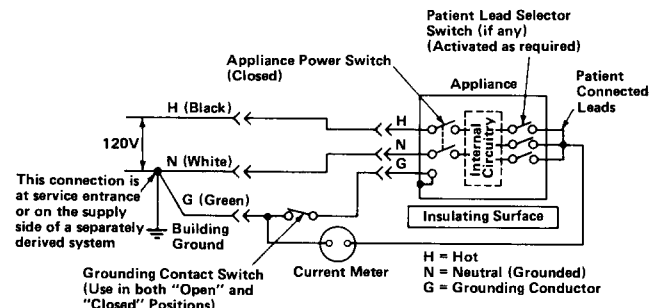


Figure 9-3.4.3.3.1 Test Circuit for Measuring Leakage Current Between Patient Leads and Ground (Nonisolated).

9-3.4.3.3.2 Lead to Ground (Isolated Input). The leakage current between each patient lead and ground for an appliance with isolated leads shall be measured with the power plug connected normally and the device on. Figure 9-3.4.3.3.2 is an example of an acceptable test configuration. The leakage current shall be less than 10 microamperes.

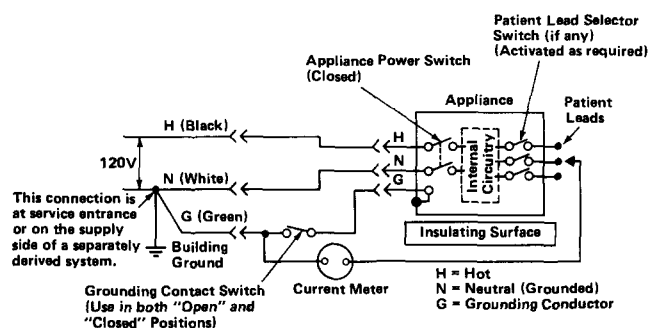


Figure 9-3.4.3.3.2 Test Circuit for Measuring Leakage Current Between Patient Leads and Ground (Isolated).

9-3.4.3.3.3 Isolation Test (Isolated Input). The current driven into the leads of an appliance which has isolated leads, when an external power source at line voltage and frequency is applied between each lead and ground, shall be measured in accordance with Figure 9-3.4.3.3.3. The leakage current shall be less than 20 microamperes in each case. The test is made with the appliances normal patient cables.

Suitable safety precautions (such as including a resistance in series to limit the current, insulation of the meter and a momentary switch) shall be taken to protect the operator. In appliances without a power cord or with ungrounded, exposed conductive surfaces, measurements shall be made with the exposed conductive surfaces temporarily grounded. If there is no exposed conductive surface, measurement shall be made with a simulated surface, as described in 9-5.3.4.2, Appliances with No Exposed Conductive Surfaces, which is also temporarily grounded.

Only isolated patient leads shall be connected to intracardiac catheters or electrodes.

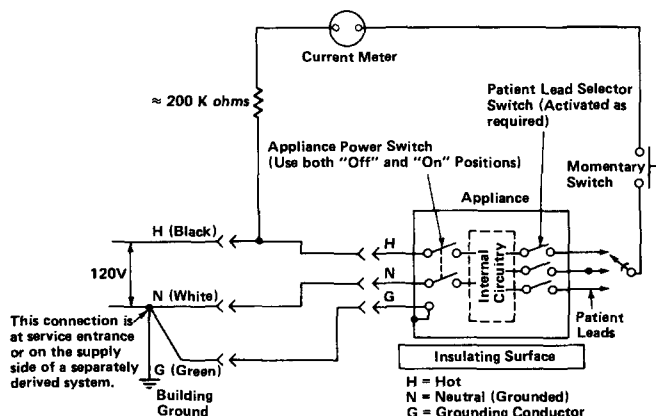


Figure 9-3.4.3.3.3 Test Circuit for Measuring the Electrical Isolation of Isolated Patient Leads.

9-3.4.3.3.4 Between Leads (Nonisolated Input). The leakage current between any one lead (not ground) and each other lead shall be measured. Figure 9-3.4.3.3.4/9-3.4.3.3.5 is an example of an acceptable test configuration. The leakage current shall be less than 50 microamperes for the ground wire open and closed.

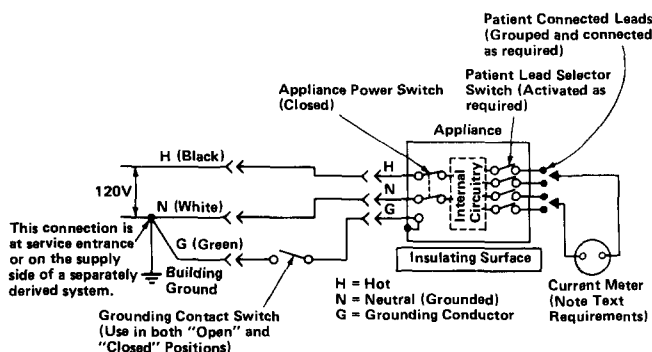


Figure 9-3.4.3.3.4/9-3.4.3.3.5 Test Circuit for Measuring Leakage Current Between Patient Leads (Nonisolated and Isolated).

9-3.4.3.3.5 Between Leads (Isolated Input). The leakage current between any one lead (not ground) and each other lead shall be measured. Figure 9-3.4.3.3.4/9-3.4.3.3.5 is an example of an acceptable test configuration. The leakage current shall be less than 10 microamperes for the ground wire open and closed.

9-3.4.4 Hospital-Owned Household Appliances. The leakage current for hospital-owned household appliances (e.g., housekeeping or maintenance appliances) that may be used in a patient vicinity and are likely to contact the patient shall be measured. The leakage current shall be less than 500 microamperes.

9-3.4.5 Testing Intervals.

9-3.4.5.1 The hospital shall establish policies and protocols for the type of test and intervals of testing for each appliance.

9-3.4.5.2 All appliances which may be used in patient care areas of hospitals shall be tested in accordance with 9-3.3, Safe Appliance Policy and Criteria for Hospitals and 9-3.4, Tests Conducted by Hospitals, before being put into service for the first time and after repair or modification. Patient care-related electrical appliances shall be retested at intervals determined by their normal location or area of normal use, but not exceeding the intervals listed below.

General Care Areas (Class G): 12 months

Critical Care Areas (Class H): 6 months

Wet Locations (Class W): 6 months

Exception No. 1: The testing intervals listed are intended to be nominal values and hospitals shall be permitted to adopt a protocol using either longer or shorter intervals provided that there is a documented justification based on previous safety testing records for the equipment in question, unusually light or heavy utilization, or similar considerations.

Exception No. 2: Hospital-owned household or other appliances which may be in the patient vicinity, but which are not intended to contact the patient shall be tested at

intervals deemed appropriate by the hospital. Some equipment in this category may require only an infrequent visual inspection. The hospital shall be permitted to structure a testing protocol and frequency for some equipment which may be more limited than that prescribed in 9-3.3 and 9-3.4.

Exception No. 3: The test specified in 9-3.4.3.3.3, Isolation Test shall be required for incoming inspections, and following repairs and modifications which may have compromised the patient lead isolation.

9-3.4.6* Documentation. A record shall be maintained of the tests required by this chapter and associated repairs or modifications. At a minimum, this record shall contain the date, unique identification of the equipment tested, and an indication of which items have met or have failed to meet the performance requirements of this section.

9-4 Administration and Maintenance.

9-4.1 General. This chapter is complementary to the performance requirements described in Sections 9-2, Electrical Power Systems and 9-3, Hospital Requirements for Electric Appliances. Each hospital shall be permitted to select a specific electrical safety program that is appropriate to its particular needs.

The physical protection afforded by the installation of an electrical distribution system which meets the requirements of this chapter and the purchase of properly constructed and tested appliances shall be augmented by having designated departments of the facility assume responsibility for the continued functioning of the electrical distribution system (Section 9-2) and the inspection, testing, and maintenance of electrical appliances (Section 9-3).

9-4.2 Responsibility. To achieve the performance criteria of Sections 9-2 and 9-3 of this chapter the governing body of the hospital shall be permitted to assign responsibility to appropriate hospital personnel, consultants, architects, engineers, or others.

The hospital shall adopt regulations and practices concerning the use of electric appliances, and shall establish programs for the training of physicians, nurses, and other personnel who may be involved in the procurement, application, use, inspection, testing, and maintenance of electrical appliances for the care of the patient.

The hospital shall ensure that policies are established and maintained that permit the attending physician to satisfy the emergency needs of any patient which may supersede the requirements of this chapter. Each such special use shall be clearly documented and reviewed to attempt to have future similar needs met within the requirements of this chapter.

9-4.3 Qualifications and Training of Personnel. Personnel concerned with the application and maintenance of electric appliances, including physicians, nurses, nurse aids, engineers, technicians, and orderlies, shall be cognizant of the risks associated with their use. To achieve this end the hospital shall provide appropriate programs of continuing education for its personnel.

9-4.4 Procurement of Electric Appliances.

9-4.4.1 General. Medical and surgical electrical instru-

mentation and monitoring devices, as well as all electric appliances used for the care and entertainment of the patient, purchased or otherwise acquired for use by the hospital (e.g., leased, donated, constructed on-site, loaned, etc.), shall meet the safety performance criteria of this chapter.

9-4.4.2 Specification of Conditions of Purchase. The procurement authority shall include in its purchasing documents any appropriate requirements or conditions specifically related to the hospital's use of the appliance, which may include, but are not restricted to, the following:

NOTE: The hospital may wish to reference compliance with this chapter on its purchasing document.

(a) The type of appliance listing or certification required, if any,

(b) The delivery of manufacturer's test data, where pertinent,

(c) Special conditions of use (such as in anesthetizing or other locations with special hazards),

(d) Unusual environmental conditions (such as high humidity, moisture, salt spray, etc.), and

(e) The type of electric power system (i.e., grounded or isolated) intended to energize the appliance, the nature of the overcurrent devices, the use of auxiliary emergency power, etc., when pertinent.

9-4.4.3* Manuals for Appliances. Purchase specifications shall require the vendor to supply suitable manuals for operators or users upon delivery of the appliance. The manuals shall include installation and operating instructions, inspection and testing procedures and maintenance details. [See 9-5.1.8.1(m).]

9-4.4.4 System Demonstration. Any system consisting of several electric appliances shall be demonstrated as a complete system, after installation, by the vendor designated to assume system responsibility, and prior to acceptance of the systems by the hospital. The vendor shall demonstrate the operation of the system and provide appropriate initial instruction to operators and maintenance personnel.

NOTE: This section is not intended to prevent the hospitals from assembling their own systems.

9-4.5 Testing.

9-4.5.1 General. The hospital shall perform the testing procedures at intervals as specified in Sections 9-2, Electrical Power Systems and 9-3, Hospital Requirements for Electric Appliances.

9-4.5.2 Test Logs. A log of test results and repairs shall be maintained and kept for an appropriate time.

9-4.6 Instruction Manuals. A permanent file of instruction and maintenance manuals as described in Section 9-3 shall be maintained and be accessible. It shall preferably be in the custody of the engineering group responsible for the maintenance of the appliance. Duplicate instruction manuals shall be available to the user. Any safety labels and condensed operating instructions on an appliance shall be maintained in readable condition.

9-4.7 Appliances Not Provided by the Hospital. Policies shall be established for the control of appliances not supplied by the hospital.

9-5 Requirements for Manufacturers of Patient Care-Related Electrical Appliances.

9-5.1 General.¹

NOTE: See Chapter 2, Definitions for definition of patient care-related electrical appliance.

9-5.1.1 Mechanical Construction.

9-5.1.1.1 Separation of Patient Circuits. Patient-connected circuits within an appliance shall be sufficiently separated or insulated from all other circuits within the appliance to prevent accidental contact with hazardous voltages or currents.

9-5.1.1.2 Mechanical Stability. The appliance shall be mechanically stable in the position of normal use. If the appliance is intended for use in an anesthetizing location, Chapter 3, Use of Inhalation Anesthetics, applies.

9-5.1.2 Electrical Requirements — Appliances Equipped with Power Cords.

9-5.1.2.1 Attachment Plugs.

(a) *General.* Attachment plugs listed for the purpose shall be used on all cord-connected appliances.

NOTE: Hospital grade listing is acceptable, but not required.

(b) *Construction and Use.* The plug (cap) shall be a two-pole, three-wire grounding type. (See ANSI C73.11, C73.12, C73.45, C73.46; and 410-56, 410-57, 410-58 of NFPA 70, National Electrical Code.)

Exception No. 1: Appliances used in special locations or purposes may be equipped with plugs approved for the location (e.g., Chapter 3, Use of Inhalation Anesthetics).

Exception No. 2: If the power cord of an appliance does not require and does not contain a grounding conductor it shall not be fitted with a grounding-type plug [see 9-5.1.2.2(e), Cords Without Grounding Conductors].

Exception No. 3: Appliances supplied by other than 120v single phase systems shall use the grounding-type plug (cap) appropriate for the particular power system (e.g., ANSI C73.16, C73.17, C73.18, C73.28, C73.83, C73.84, C73.86, C73.87, C73.88, C73.89, C73.90, C73.91, C73.92, C73.94, and C73.95).

The grounding prong shall be constructed so that it cannot be easily broken. The grounding prong of the plug shall be the first to be connected to and last to be disconnected from the receptacle. If screw terminals are used, the stranded conductor shall be twisted to prevent stray strands, but the bundle shall not be tinned after

twisting, or the conductor shall be attached by an approved terminal lug. The power cord conductors shall be arranged so that the conductors are not under tension in the plug. The grounding conductor shall be the last one to disconnect when a failure of the plug's strain relief allows the energized conductors to be disrupted.

(c) *Strain Relief.* Strain relief shall be provided. The strain relief shall not cause thinning of the conductor insulation. The strain relief of replaceable plugs shall be capable of being disassembled. Plugs may be integrally molded onto the cord jacket if the design is listed for the purpose.

(d) *Testing.* The wiring of each cord assembly shall be tested for continuity and polarity at the time of manufacture, when assembled into an appliance, and when repaired.

9-5.1.2.2 Power Cords.

(a) *Material and Gauge.* The flexible cord, including the grounding conductor, shall be of a type suitable for the particular application, listed for use at a voltage equal to or greater than the rated power line voltage of the appliance, and have an ampacity, as given in Table 400-5, NFPA 70, National Electrical Code, equal to or greater than the current rating of the device.

"Hard Service" (SO, ST, or STO) or "Junior Hard Service" (SJO, SJT, or SJTO) or equivalent listed flexible cord shall be used (see Table 400-4 of NFPA 70, National Electrical Code) except where an appliance with a cord of another designation has been listed for the purpose.

NOTE: "Hard Service" cord is preferable where it may be subject to mechanical abuse. A cord length of 10 ft (3.1 m) is recommended for general locations, and 18 ft (5.5 m) for operating rooms, but may be of a different length if designed for a specific location.

(b) *Grounding Conductor.* Each electric appliance shall be provided with a grounding conductor in its power cord. The grounding conductor shall be no smaller than No. 18 AWG. The grounding conductor of cords longer than 15 ft (4.6 m) shall be no smaller than No. 16 AWG. Grounding conductors shall meet the resistance requirements of 9-5.3.2, Grounding Circuit Continuity.

Exception: A grounding conductor in the power cord need not be provided for listed double-insulated appliances, but such a grounding conductor shall be permitted to be used to ground exposed conductive surfaces (see 9-5.1.3.2, Grounding of Exposed Conductive Surfaces).

(c) *Separable Cord Sets.* A separable power cord set shall be permitted to be used if it can be shown that an accidental disconnection is unlikely or not hazardous. Separable power cord sets shall be designed so that the grounding conductor is the first to be connected and the last to be disconnected. Cord-set plugs and receptacles at the appliance shall be polarized in accordance with ANSI C73.13 and C73.17.

Appliances with separable cord sets shall meet the grounding wire resistance requirements of 9-5.3.2, Grounding Circuit Continuity when the cord set is connected to the appliance. Both the cord set and the means of connection to the appliance shall be listed for the purpose.

(d) *Connection to Circuit and Color Codes.* Power cords, regardless of whether intended for use on grounded

¹It is the intent that Section 9-5 should not be used by authorities having jurisdiction over hospitals to limit hospital purchases to patient care-related electrical appliances meeting these requirements; rather it is the intent to encourage equipment manufacturers to conduct the specified tests in order to ensure state-of-the-art electrical safety in their patient care-related electrical appliances. Similarly, it is not the intent of the Technical Committee to require hospitals to conduct tests using these manufacturers requirements to verify that their patient care-related electrical appliances are in conformance to the requirements of this chapter. In this respect, it is the intent of the Committee that hospitals perform only those tests specified in Section 9-3, Hospital Requirements for Electrical Appliances in Patient Care Areas.

or isolated power systems, shall be connected in accordance with the conventions of a grounded system. (See 200-2 to 200-10 of NFPA 70, National Electrical Code.)

The circuit conductors in the cord shall be connected to the plug and the wiring in the appliance so that any of the following devices, when used in the primary circuit, are connected to the ungrounded conductor: the center contact of an Edison base lampholder; a solitary fuseholder; a single pole, overcurrent protective device; and any other single pole, current interrupting device. [See Exception No. 2, to 210-5(b) of NFPA 70, National Electrical Code.]

Exception: If a second fuseholder or other overcurrent protective device is provided in the appliance, it may be placed in the grounded side of the line.

(e) **Cords Without Grounding Conductors.** If the power cord of an appliance does not require and does not contain a grounding conductor, it shall not be fitted with a grounding-type plug.

(f) **Testing.** The wiring of each cord assembly shall be tested for continuity and polarity at the time of manufacture, when assembled into an appliance, and when repaired.

(g) **Cord Strain Relief.** Cord strain relief shall be provided at the attachment of the power cord to the appliance so that mechanical stress, either pull, twist, or bend, is not transmitted to internal connections. If the strain relief is molded onto the cord, it shall be bonded to the jacket, and shall be of compatible material.

9-5.1.3 Wiring Within Appliances Equipped with Power Cords.

9-5.1.3.1 Protection of Wiring in Appliances. Within the appliance, the power conductors of the cord and the associated primary wiring (other than the grounding conductor) shall be mounted and dressed to minimize the likelihood of accidental electrical contact with the frame or exposed conductive parts of the appliance.

9-5.1.3.2 Grounding of Exposed Conductive Surfaces. All exposed conductive surfaces of an electric appliance likely to become energized from internal sources shall be bonded together to provide electric continuity with the connection to the grounding conductor.

NOTE 1: Size and location are the main criteria used in determining what is not likely to become energized and thus may be exempted from the bonding and grounding requirements. Items such as screws, nameplates, hinges, metal trim, handles and other hardware are unlikely to become energized because of their size. If they are sufficiently isolated from internal sources they need not be grounded.

NOTE 2: Also, it is unnecessary for exposed conductive surfaces to be grounded separately with individual or looped grounding wires if, by reliable contact or connection with other grounded metal portions (frame), these surfaces can maintain ground.

9-5.1.3.3 Connection to Permit Replacement. The connection of the power cord to the appliance shall permit ready replacement of the cord except where the power cord is not intended to be replaced by the user.

9-5.1.3.4 Connection of the Grounding Conductor. The grounding conductor shall be connected to the exposed metal or frame of the appliance by a terminal or bolt so that a reliable electrical connection is always maintained. The connection shall be arranged so that it will not be

broken during electrical or mechanical repair of the appliance, except replacement of the power cord.

The power cord shall be arranged so that the grounding conductor is the last to disconnect when a failure of the strain relief at the appliance allows the cord to be pulled free. When a grounding conductor is not required and is not provided, the appliance shall be visibly labeled to indicate that fact.

9-5.1.3.5 Connections with Grounding Conductor.

Any component, such as a filter or test circuit, within an appliance that intentionally reduces the impedance between the energized conductors and the grounding conductor shall be in operation when the leakage current tests specified in 9-5.3.4, Leakage Current from Appliance to Ground, are performed.

9-5.1.3.6 Overcurrent Protection. An overcurrent protective device shall be permitted to be placed in the attachment plug, the power cord, or in the main body of the appliance.

NOTE: It is recommended that a listed overcurrent protective device be used in the power input circuit of all appliances.

The overcurrent protective device shall precede any other components within the appliance, including the primary power control switch.

Exception: Listed insulated terminal blocks or strips, listed connecting devices, and RFI filters for use on power systems shall be permitted to precede the overcurrent device (see 9-5.1.3.5).

This requirement shall not preclude the use of overcurrent protective devices within the appliance. The power control switch and overcurrent protective device shall be permitted to be combined into one component provided it is identified to indicate the combined function.

9-5.1.3.7 Primary Power Control Switch. When a primary power control switch is provided on an appliance it shall interrupt all primary power conductors, including the neutral conductor. The grounding conductor shall not be interrupted by the switch.

Exception: When the primary power wiring of an appliance is polarized so as to ensure the proper connection of its neutral conductor to the electric distribution system of the building, that neutral conductor need not be interrupted by a primary power control switch.

An in-line switch shall be permitted in a primary power cord only if the switch is listed with the appliance with which it is intended to be used.

9-5.1.3.8 Rack- or Cart-Mounted Equipment. Each appliance mounted in an equipment rack or cart, when rated by the manufacturer as a stand alone appliance, shall independently meet the requirements of 9-5.3.

When multiple appliances, as designated by the manufacturer, are mounted together in a cart or rack, and one power cord supplies power, the cart or rack shall meet the requirements of 9-5.3.

9-5.1.4 Connectors and Connections to Devices.

9-5.1.4.1 Indexing of Receptacles for Patient Leads. Receptacles on appliances shall be designed and constructed so that those contacts which deliver electric

current in a way and of a magnitude greater than 500 microamperes, when measured in accordance with 9-5.3.5.1, 9-5.3.5.2, 9-5.3.5.4 and 9-5.3.5.5, are female and indexed. Receptacles and plugs shall be polarized if improper orientation can create a hazard.

9-5.1.4.2 Distinctive Receptacles for Patient Leads. Where reversal or misconnection of patient leads to an appliance might constitute a hazard (for example: reversal of active and dispersive electrodes of electrosurgical machines), distinctive, noninterchangeable connections shall be employed.

NOTE: The purpose of these requirements is to prevent interchanging connectors in any manner which permits the inadvertent delivery of a hazardous current to a patient.

9-5.1.5 Line Voltage Variations and Transients.

9-5.1.5.1 General. All appliances shall be capable of operating within line voltage variations that conform with ANSI C84.1-1977 (and 1980 supplement), *Voltage Ratings for Electric Power Systems and Equipment*.

NOTE: The design of an appliance intended for life support should minimize the effects on performance of transient, line voltage variations or other electrical interference. The design of all appliances should minimize the production of line variations and transients.

9-5.1.6 General Design and Manufacturing Requirements.

9-5.1.6.1 Thermal Standards. Electric appliances not designed to supply heat to the patient, and operated within reach of a nonambulatory patient, shall not have exposed surface temperatures in excess of 122°F (50°C). Surfaces maintained in contact with the skin of patients and not intended to supply heat shall not be hotter than 104°F (40°C).

9-5.1.6.2 Toxic Materials. Surfaces that contact patients shall be free of materials which commonly cause toxic reactions. Coatings used on these surfaces shall conform to ANSI Z66.1-1964 (R1972), *Specifications for Paints and Coatings Accessible to Children to Minimize Dry Film Toxicity*.

9-5.1.6.3 Chemical Agents. Electric appliances containing hazardous chemicals shall be designed to facilitate the replenishment of these chemicals without spillage to protect the patient, the operating personnel, and the safety features of the appliance from such chemicals.

NOTE: Preference should be given to the use of replaceable sealed canisters of chemicals.

9-5.1.7 Fire and Explosion Hazards.

9-5.1.7.1 Materials and Supplies. Materials used in the construction of, and supplies for, electric appliances shall be noncombustible or flame retardant and impermeable to liquids and gases to the extent practicable; or the materials used in the construction of, and supplies for, electric appliances shall not ignite from internal heating or arcing resulting from any and all possible fault conditions. This includes spillage of liquids such as water and intravenous solutions onto the appliance.

Exception: Materials used in the construction and operation of electric appliances shall be permitted to be combustible when essential to their intended function.

9-5.1.7.2 Oxygen-Enriched Atmospheres. Electric appliances employing oxygen, or which are intended to be used in oxygen-enriched atmospheres, shall comply with the appropriate provisions of Chapter 5, Respiratory Therapy; Chapter 10, Hyperbaric Facilities; and Chapter 11, Hypobaric Facilities, in addition to all applicable provisions of this chapter.

NOTE: See also NFPA 53M, *Oxygen-Enriched Atmospheres*.

9-5.1.7.3 Inhalation Anesthetizing Locations. Electric appliances used in inhalation anesthetizing locations shall comply with the provisions of Chapter 3, Use of Inhalation Anesthetics in addition to all applicable provisions of this chapter.

9-5.1.8 Instruction Manuals and Labels.

9-5.1.8.1 Manuals. The manufacturer of the appliance shall furnish operator's, maintenance and repair manuals with all units. These manuals shall include operating instructions, maintenance details, and testing procedures.

The manuals shall include the following where applicable:

- (a) Illustrations which show location of controls.
- (b) Explanation of the function of each control.
- (c) Illustrations of proper connection to the patient and other equipment.
- (d) Step-by-step procedures for proper use of the appliance.
- (e) Safety considerations in application and in servicing.
- (f) Difficulties that might be encountered, and care to be taken if the appliance is used on a patient simultaneously with other electric appliances.
- (g) Schematics, wiring diagrams, mechanical layouts, parts lists and other pertinent data for the appliance as shipped.
- (h) Functional description of the circuit.
- (i) Electrical supply requirements (volts, frequency, amperes and watts), heat dissipation, weight, dimensions, output current, output voltage, and other pertinent data.
- (j) The limits of electrical supply variations shall be specified. Performance specifications of the appliance shall be given for the applicable limits of electrical supply variations.
- (k) Technical performance specifications including design levels of leakage current.
- (l) Instructions for unpacking (readily available upon opening), inspecting, installing, adjusting and aligning.
- (m) Comprehensive preventive and corrective maintenance and repair procedures.

Where appropriate, the information itemized shall be permitted to be supplied in the form of a separate operating manual and a separate maintenance manual, except that the separate maintenance manual shall also include essentially all the information included in the operating manual.

9-5.1.8.2 Operating Instructions on Appliances. Condensed operating instructions shall be visibly and permanently attached to, or displayed on, any appliance which is

intended to be used in emergency situations, and which could result in injury or death to the operator or patient if improperly used.

9-5.1.8.3 Labeling. The manufacturer shall furnish, for all appliances, labels which are readily visible and legible, and which remain so after being in service for the expected life of the appliance under hospital service and cleaning conditions. Controls and indicators shall be labeled to indicate their function. When appropriate, appliances shall be labeled with precautionary statements. All appliances shall be labeled with model numbers, date of manufacture, manufacturer's name, and the electrical ratings including voltage, frequency, current and/or wattage of the device. Date of manufacture shall be permitted to be a code, if its interpretation is provided to the user. Appliances shall be labeled to indicate if they (1) are listed for use as medical equipment, and (2) have isolated patient leads. Appliances intended for use in anesthetizing locations shall be labeled in an approved manner. (*See Chapter 3, Use of Inhalation Anesthetics.*)

9-5.1.9 Additional Requirements for Special Appliances.

9-5.1.9.1 Signal Transmission Between Appliances.

9-5.1.9.1.1* General. Signal transmission lines from an appliance in a patient location to remote appliances shall employ a signal transmission system designed to prevent hazardous current flowing in grounding interconnection of the appliances.

9-5.1.9.1.2 Outdoor Signal Transmission. Outdoor signal transmission lines from appliances attached to patient shall be equipped with surge protection appropriate to the type of transmission line used. Such appliances or signal transmission lines shall be designed to prevent a hazard to the patient from exposure of the lines to lightning, power contact, power induction, rise in ground potential, radio interference, etc.

9-5.1.9.2 Appliances Intended to Deliver Electrical Energy.

9-5.1.9.2.1 Conditions for Meeting Safety Requirements. Electrical energy delivering appliances shall conform to the leakage, grounding, and other requirements of this chapter when powered, but not delivering energy.

NOTE 1: When delivering energy, such appliances may deviate from these requirements only to the extent essential for their intended clinical function.

NOTE 2: Appliances that intentionally or which may inadvertently apply electrical energy to the patient or to components in contact with the patient, require special safety considerations.

NOTE 3: Since there is a wide range of power levels, output frequencies and purposes of appliances that apply electricity directly to patients or to patient-connected devices, it is not feasible to cite them in detail.

9-5.1.9.2.2 Specific Requirements by Type of Device.

(a) *Electrically Powered Transducers.* Exposed metal parts of these devices shall be considered electrodes and meet the applicable requirements of 9-5.3, Manufacturers' Tests. Connectors shall be designed to prevent inadvertent interchange of leads if interchange could constitute a hazard to the patient or operator.

NOTE: Electrically powered transducers include pressure transducers, flowmeters, endoscopes, etc. The electrical energy is not intended to be applied to the patient but to a device that contacts the patient.

(b) *Patient Impedance Measuring Devices.* For a particular application, the combination of frequency and current levels shall limit the applied current to the minimum necessary to achieve the medical purposes, but not to exceed the limits given in 9-5.3.5, Lead Leakage Current Tests and Limits, whichever is appropriate.

NOTE: Assessment of physiologic functions by electric impedance measurements usually requires direct contact with the patient and injection of electric current.

(c) *Electrotherapeutic Devices.* Appliances which require specific pulse forms or high power levels shall be designed to protect the operator and attendant personnel from accidental electric shock.

NOTE: Electrotherapeutic devices include devices for electro-sleep, electroanesthesia and electroschock.

(d)* *Electrosurgery.* Electrosurgical devices shall meet the requirements of 9-5.1.9.2.1, Conditions for Meeting Safety Requirements.

NOTE 1: See Appendix E, Safe Use of High-Frequency Electricity in Health Care Facilities, for information on electrosurgical devices.

NOTE 2: Electrosurgery uses high levels of continuous or pulsed radio frequency power. It presents some unique hazards. It generates sparks with the attendant ignition hazard. It generates radio frequency interference that may obstruct monitoring. It may cause burns at inadvertent ground return paths if its return circuit is inadequate. Demodulation products may contain components which cause fibrillation or stimulation. DC monitoring currents may cause chemical burns. Capacitive or inductive coupling may occur.

(e) *Cardiac Defibrillation.* Since the operator holds the high-voltage patient electrode paddles and defibrillation may be a hurried emergency procedure, the appliance shall be designed to protect the operator and attendant personnel from accidental electric shock.

NOTE: Cardiac defibrillation applies high-voltage, short-duration pulses to the patient.

9-5.1.10 Low-Voltage Appliances and Appliances Not Connected to the Electric Power Distribution System.

9-5.1.10.1 General. Appliances and instruments operating from batteries or their equivalent, an external source of low voltage, or which are not connected to the electric power distribution system shall conform to all applicable requirements of this section, Requirements for Manufacturers. This shall include communication, signaling, entertainment, remote control, and low-energy power systems.

Exception: Telephones.

9-5.1.10.2 Rechargeable Appliances. Battery-operated appliances that are rechargeable while in use shall meet all the requirements of 9-5.3.3, Leakage Current Tests, for line-operated appliances.

9-5.1.10.3 Low-Voltage Connectors. Attachment plugs used on low-voltage circuits shall have distinctive configurations which do not permit interchangeable connection with circuits of other voltages.

9-5.1.10.4 Isolation of Low-Voltage Circuits. Low-voltage circuits shall be electrically isolated from the electric power distribution system.

9-5.1.11 Cardiac Monitors and Electrocardiographs. Monitoring of cardiac activity is crucial to effective defibrillation. Design of electrocardiographs, cardiac monitors or blood pressure monitors intended for use on patients in Class H areas shall include protection against equipment damage during defibrillation of the patient.

9-5.2 Direct Electrical Pathways to the Heart. The requirements of this section shall apply only to manufacturers except where specifically noted.

NOTE: This section is concerned with the patient who may have either of two types of direct electrical connections to the heart. The obvious and most hazardous conductor comprises a wire in contact with the heart muscle. This may be a pacemaker electrode, a guide wire, transthoracic or implanted electrode. The second type of conductor is a liquid column contained within a nonconductive catheter with the internal end in the heart.

9-5.2.1 Cardiac Electrodes.

9-5.2.1.1 General. Appliances which have isolated patient leads shall be labeled as having isolated patient leads in accordance with 9-5.3.5, Lead Leakage Current Tests and Limits.

9-5.2.1.2 Insulation of Cardiac Leads. Pacemaker leads and other wires intended for insertion into the heart, together with their adapters and connections to appliances, shall be insulated except for their sensing or stimulation areas.

NOTE: The hospital is required to have a policy to protect pacing leads with external terminals from potentially hazardous contact with conductive surfaces (see 9-3.3.2, *Protection of Patients*).

Exception No. 1: Metal stylets or guidewires temporarily introduced into a vein or artery for purposes of positioning a catheter need not be insulated. When such guidewires are inside the heart the operator shall exercise extreme care to ensure safe use. When used in conjunction with electrical devices (e.g., positioning catheters by use of ECG recordings), the guidewire shall be insulated as required above.

Exception No. 2: Insulated wires designed to be introduced through a surgical needle, or other special wires where it is not practicable to maintain insulation, shall not be required to maintain insulation during introduction or manipulation. At such times the operator shall take appropriate safeguards.

9-5.2.1.3 Safety Requirements for Cardiac Electrodes. The electrode catheter, fitting, and associated appliance, when assembled, shall meet the applicable requirements of 9-5.3.5, Lead Leakage Current Tests and Limits, for isolated patient leads.

9-5.2.1.4 Insulation of Pacemaker Connections. Uninsulated or open-type connectors shall not be used for external cardiac pacemaker terminals.

9-5.2.2 Liquid-Filled Catheters.

9-5.2.2.1 Cardiac Catheter System. Any conductive element of a liquid catheter system which can come in contact with the liquid column shall be insulated from ground or electric energy sources.

NOTE: A liquid catheter system may consist of the catheter itself, pressure transducers, electronic appliances and associated accessories.

9-5.2.2.2 Nonconductive Cardiac Catheters. A nonconductive catheter containing a conductive liquid, when connected to its appropriate system, shall meet the applicable requirements of 9-5.3.5, Lead Leakage Current Tests and Limits, for isolated patient leads with the patient end of the liquid-filled catheter considered to be an electrode.

9-5.2.2.3 Conductive Cardiac Catheters. If the liquid column is contained in a catheter made of conductive material having an electrical conductivity approximating that of blood, the system shall not require connection to an isolated patient lead. Conductive catheters shall be appropriately identified.

9-5.2.3 Angiographic Catheters. Appliances used to inject contrast media into the heart or major vessels shall meet the same safety requirements as other liquid-filled catheter systems.

NOTE: Although contrast injectors are not intended to apply electrical energy to the patient, they may deliver current from the power source and also may generate transient voltages large enough to be hazardous.

9-5.3 Manufacturers' Tests for Safety on Patient Care-Related Electrical Appliances.

9-5.3.1 General. This section describes tests by manufacturers for the safe operation of an appliance. (Tests to be conducted by the hospital are found in 9-3.4, Tests Conducted by Hospitals.) The tests in this subsection are in addition to the design requirements of the entire Section 9-5, Requirements for Manufacturers. The appliance manufacturer shall perform the testing which is adequate to ensure that each finished appliance will meet the specified test limits of this section.

Exception: Potentially destructive-type tests need only be performed by the manufacturer to assure design compliance for new appliances.

9-5.3.2 Grounding Circuit Continuity.

9-5.3.2.1 Measurement of Resistance. The resistance between the appliance chassis, or any exposed conductive surface of the appliance, and the ground pin of the attachment plug shall be measured. The resistance shall be less than 0.15 ohm. The cord shall be flexed at its connection to the attachment plug or connector, and at its connection to the strain relief on the chassis during the resistance measurement.

9-5.3.3* Leakage Current Tests.

9-5.3.3.1* General.

(a) *Techniques of Measurement.* Each test shall be performed with the appropriate connection to a properly grounded ac power system.

(b) *Frequency of Leakage Current.* The leakage current limits stated in 9-5.3.4, Leakage Current From Appliance to Ground and 9-5.3.5, Lead Leakage Current Tests and Limits shall be rms values for dc and sinusoidal waveforms up to 1 KHz. For frequencies above 1 KHz the leakage current limits shall be the values given in 9-5.3.4 and 9-5.3.5 multiplied by the frequency, in KHz, up to a maximum multiplier of 100.

NOTE 1: The limits for nonsinusoidal periodic, modulated, and transient waveforms remain to be determined.

NOTE 2: For complex leakage current waveforms, a single reading from an appropriate metering system can represent the physiologically effective value of the composite wave form, provided that the contribution of each component to the total reading is weighted in accordance with 9-5.3.3.1(b).

This "weighting" can be achieved by a frequency response shaping network which precedes a flat response meter, or by a meter whose own frequency response characteristic matches 9-5.3.3.1(b).

(c) **Leakage Current in Relation to Polarity.** Leakage current measurements shall be made with the polarity of the power line normal and reversed, the power switch of the appliance "on" and "off," and with all operating controls in the positions to cause maximum leakage current readings. The leakage current limits in 9-5.3.4 and 9-5.3.5 shall not be exceeded in any of these conditions.

9-5.3.4 Leakage Current from Appliance to Ground.

9-5.3.4.1 Test Methods. The current shall be measured from the exposed conductive surfaces of the appliance to ground with all grounding conductors open at the end nearest the power receptacle. The appliance shall not be grounded by any other means. The current meter shall be inserted between the exposed conductive surfaces and ground. This test shall be made under the conditions of 9-5.3.3.1(a) and (b). This test is illustrated in Figure 9-5.3.4.1.

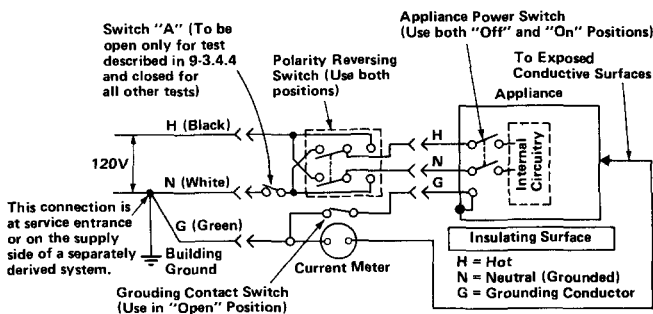


Figure 9-5.3.4.1 Test Circuit for Measuring Leakage Current from Exposed Conductive Surfaces.

Appliances required to meet the limits of 9-3.4.4, Hospital-Owned Household Appliances (i.e., appliances not intended to contact a patient) shall be tested with switch "A" open (open neutral). All other appliances meeting the limits of 9-5.3.4.3(a) and (b), Chassis Leakage Current Limits, shall be tested with switch "A" closed (connected neutral).

9-5.3.4.2 Appliances with No Exposed Conductive Surfaces. When the appliance has no exposed conductive surface, one shall be simulated by placing a 3.9 by 7.8 in. (10 by 20 cm) bare metal foil in intimate contact with the exposed surface. This shall be considered the "exposed metal surface" of the appliance and all appropriate tests shall be performed to the foil.

9-5.3.4.3* Chassis Leakage Current Limits.

(a) **Cord-Connected Appliances.** Cord-connected appliances which are intended for use in the patient vicinity shall not exceed 100 microamperes of chassis leakage current as measured in 9-5.3.4.1, Test Methods.

(b) **Permanently Wired Equipment.** Permanently wired equipment installed in the patient vicinity shall not have leakage current from the frame to ground in excess of 5.0 milliamperes. The leakage current shall be measured prior to installation by the installer and verified and accepted by the hospital. This measurement shall be made in accordance with 9-5.3.4.1 while the equipment is temporarily insulated from ground.

9-5.3.5 Lead Leakage Current Tests and Limits.

9-5.3.5.1 Lead to Ground (Nonisolated Input). The lead leakage current to ground shall be measured under the conditions of 9-5.3.3.1, Leakage Current Tests — General. The test shall be made between each patient lead and ground, and between the combined patient leads and ground. The test shall be made with the patient leads active (e.g., in the case of a multilead instrument, the lead selector switch shall be advanced through all operating positions). Each measurement shall be performed with the grounding conductors both opened and closed. For this purpose the grounding conductor shall be interrupted at the plug end of the appliance cord. Figure 9-5.3.5.1 is an example of an acceptable test configuration. The leakage current shall be less than 50 microamperes.

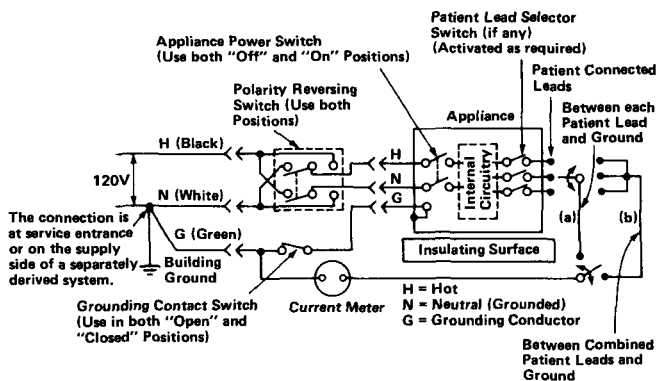


Figure 9-5.3.5.1 Test Circuit for Measuring Leakage Current Between Patient Leads and Ground (Nonisolated).

9-5.3.5.2 Lead to Ground (Isolated Input). The leakage current to ground between each patient lead and ground shall be measured under the conditions of 9-5.3.5.1, Leakage Current Tests — General. The test shall be made with the patient leads active (e.g., in the case of a multilead instrument, the lead selector switch shall be advanced through all operating positions). Each measurement shall be performed with the grounding conductors both opened and closed. For this purpose the grounding conductor shall be interrupted at the plug end of the appliance cord. Figure 9-5.3.5.2 is an example of an acceptable test configuration. The leakage current shall be less than 10 microamperes.

9-5.3.5.3 Isolation Test (Isolated Input). The isolation between each patient lead and ground for an appliance that has been labeled as having isolated patient leads shall be measured by observing the current produced by applying an external source of power-line frequency and voltage between the lead and ground while the leads are approximately 8 in. (20 cm) from a grounded conductive surface. Similarly, the isolation at the apparatus terminals to the

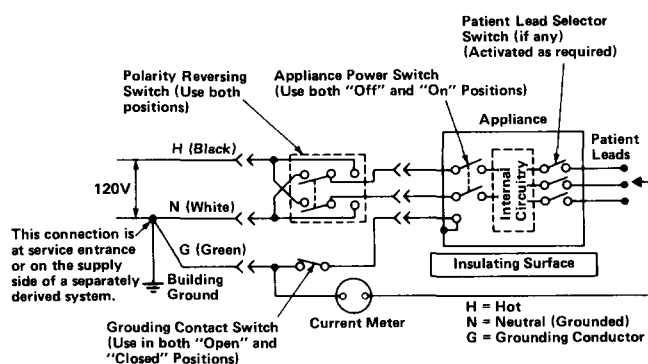


Figure 9-5.3.5.2 Test Circuit for Measuring Leakage Current Between Patient Leads and Ground (Isolated).

patient cables shall be measured. Figure 9-5.3.5.3 is an example of an acceptable test configuration. At the patient end of the leads the leakage current shall be less than 20 microamperes and at the apparatus terminals less than 10 microamperes. Only appliances meeting this requirement shall be permitted to be identified as having isolated patient leads.

Suitable safety precautions (such as including a resistance in series to limit the current, insulation of the meter and a momentary switch) shall be taken to protect the operator. In appliances without a power cord or with ungrounded, exposed conductive surfaces, measurements shall be made with the exposed conductive surfaces temporarily grounded. If there is no exposed conductive surface, measurement shall be made with a simulated surface, as described in 9-5.3.4.2, Appliances with No Exposed Conductive Surfaces, which is also temporarily grounded.

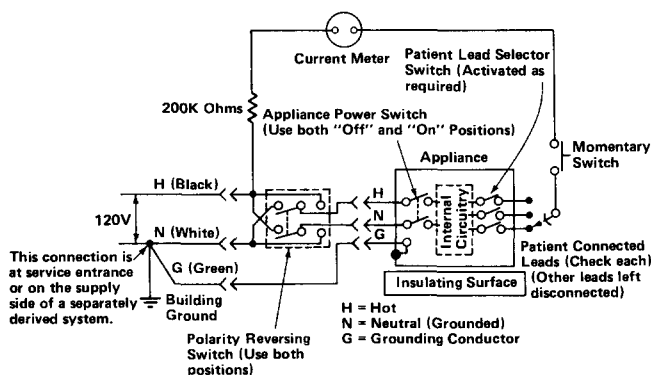


Figure 9-5.3.5.3 Test Circuit for Measuring the Electrical Isolation of Isolated Patient Leads.

9-5.3.5.4 Between Leads (NonIsolated Input). The current between any pair of leads or any single lead and all others shall be measured under the conditions of 9-5.3.3.1, Leakage Current Tests — General. Each measurement shall be performed with the grounding conductors both opened and closed. For this purpose the grounding conductor shall be interrupted at the plug end of the appliance cord. Figure 9-5.3.5.4/9-5.3.5.5 is an example of an acceptable test configuration. The leakage current shall be less than 50 microamperes.

Exception: Measuring leakage current between any single lead and all other leads need only be performed to assure the approval agency of design compliance.

9-5.3.5.5 Between Leads (Isolated Input). The current between any pair of leads or any single lead and all others shall be measured under the conditions of 9-5.3.3.1, Leakage Current Tests — General. Each measurement shall be performed with the grounding conductors both opened and closed. For this purpose the grounding conductor shall be interrupted at the plug end of the appliance cord. Figure 9-5.3.5.4/9-5.3.5.5 is an example of an acceptable test configuration. The leakage current shall be less than 10 microamperes.

Exception: Measuring leakage current between any single lead and all other leads need only be performed to assure the approval agency of design compliance.

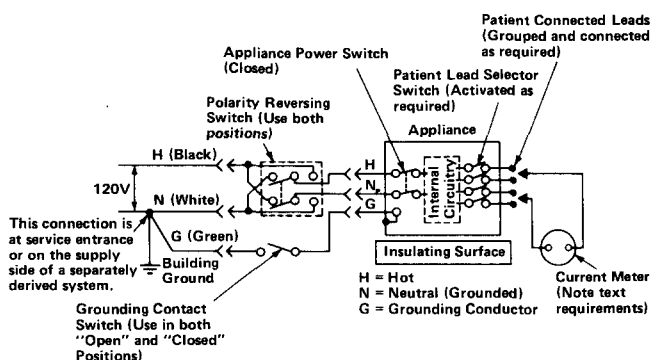


Figure 9-5.3.5.4/9-5.3.5.5 Test Circuit for Measuring Leakage Current Between Patient Leads (Nonisolated and Isolated).

9-5.4 Flammable Gases. Additional design and construction requirements for appliances used in flammable anesthetizing locations are contained in Chapter 3, Use of Inhalation Anesthetics.

Chapter 10 Hyperbaric Facilities

NOTICE: Information on referenced publications can be found in Chapter 12 and Appendix B.

10-1 Introduction and Scope.

10-1.1 General.

10-1.1.1 During the past 20 years there has been a widespread interest in the use of oxygen therapy at elevated environmental pressures to drench the tissues of the patient's body with oxygen, to treat certain medical conditions or to prepare the patient for surgical or radiographic therapy. These techniques are also employed widely for the treatment of decompression sickness (e.g., bends, caisson worker's disease) and carbon monoxide poisoning.

10-1.1.2 Such treatment involves placement of the patient, with or without attendants, in a hyperbaric chamber or pressure vessel, the pressure of which is raised above ambient pressure. In the course of the treatment the patient breathes up to 100 percent oxygen.

10-1.1.2.1 In addition to patient care, these chambers also are being employed for research purposes, using experimental animals, and in some instances man himself.

10-1.1.2.2 The partial pressure of oxygen present in the gaseous mixture is the determinant factor of the amount of available oxygen. This pressure will rise if the volume percentage of oxygen present increases or if the total pressure of a given gas mixture containing oxygen increases or if both factors increase. Since the sole purpose of the hyperbaric technique of treatment is to raise the total pressure within the treatment chamber, an increased partial pressure of oxygen always is available during treatment unless positive means are taken to limit the oxygen content. In addition, the patient is often given an oxygen-enriched atmosphere to breathe.

10-1.1.3 There is continual need for human diligence in the establishment, operation and maintenance of hyperbaric facilities.

10-1.1.3.1 It is the responsibility of the chief administrator of the facility possessing the hyperbaric chamber to adopt and enforce appropriate regulations for hyperbaric facilities. In formulating and administering the program, full use should be made of technical personnel highly qualified in hyperbaric chamber operations and safety.

10-1.1.3.2 It is essential that personnel having responsibility for the hyperbaric facility establish and enforce appropriate programs to fulfill the provisions of this chapter.

10-1.1.4 Potential hazards can be controlled only when continually recognized and understood by all pertinent personnel.

10-1.2 Purpose.

10-1.2.1 The purpose of this chapter is to set forth minimum safeguards for the protection of patients or other

subjects of, and personnel administering, hyperbaric therapy and experimental procedures. Its purpose is also to offer some guidance for rescue personnel who might not ordinarily be involved in hyperbaric chamber operation, but who might become so involved in an emergency.

NOTE: In view of the experimental nature of hyperbaric medicine, many of the hazards and attendant safeguards have not yet been investigated adequately. The Committee believes that, despite the lack of knowledge needed to prescribe fully for safe practices in hyperbaric medicine, the publication of this chapter is needed for general guidance. Comments based on continuing experience are solicited so that this chapter may be revised from time to time.

10-1.3 Scope.

10-1.3.1 This chapter applies to hyperbaric chambers and associated facilities which are used, or intended to be used, for medical applications and experimental procedures at pressures from 0 psig to 100 psig (14.7 psia to 114.7 psia).

NOTE: This chapter does not apply to respiratory therapy employing oxygen-enriched atmospheres at ambient pressures. See Chapter 5, Respiratory Therapy.

10-1.3.1.1 This chapter covers the recognition of, and protection against, hazards of an electrical, explosion or implosion nature, as well as fire hazards.

10-1.3.1.2 Medical complications of hyperbaric procedures are discussed primarily to acquaint rescue personnel with these problems.

10-1.3.2 This chapter applies to both single- and multiple-patient occupancy hyperbaric chambers, to animal chambers the size of which precludes human occupancy, and to those in which the chamber atmosphere contains an oxygen partial pressure greater than 0.21 atmosphere absolute (3.09 psia).

NOTE: Hazards differ significantly depending on the occupancy and chamber atmosphere. For this reason, chambers are classified (see 10-1.5) for the purpose of defining the hazards and setting forth the safeguards within the chapter.

10-1.4 Application of this Chapter. This chapter shall be applied only to new construction and new equipment. It shall not require the alteration or replacement of existing construction or equipment. Existing construction or equipment shall be permitted to be continued in use when such use does not constitute a distinct hazard to life.

10-1.5 Classification of Chambers.

10-1.5.1 General. Chambers shall be classified according to occupancy in order to establish appropriate minimum essentials in construction and operation.

10-1.5.2 Occupancy.

- (a) Class A — Human, multiple occupancy
- (b) Class B — Human, single occupancy
- (c) Class C — Animal, no human occupancy.

NOTE: Chambers designed for animal experimentation equipped for access of personnel to care for the animals are classified as Class A for the purpose of this chapter.

10-1.6 Nature of Hazards.

10-1.6.1 This chapter for the use of hyperbaric facilities is intended to provide protection against fire, explosion and

other hazards without unduly limiting the activities of professional personnel involved in patient (in the case of hospitals) or other care. This principle, without minimizing the hazards, recognizes that professional personnel shall be guided by all of the hazards to life that are inherent in and around hyperbaric treatment procedures.

10-1.6.2 Potential hazards involved in the design, construction, operation and maintenance of hyperbaric facilities are formidable. For a discussion of these hazards, see the information in Appendix C-10.

NOTE: The navies of the world have established an enviable safety record in their use of hyperbaric facilities for deep sea diving research, training and operations. A knowledge of this safety record must not lull hyperbaric personnel into a false sense of security, however. The potential hazards remain. Where civilian personnel — patients, experimental subjects and chamber attendants — are involved, an appreciation of these hazards and their mitigation becomes even more important.

10-2 Construction and Equipment.

10-2.1 Housing for Hyperbaric Facilities.

10-2.1.1 Class A chambers and all ancillary service equipment shall be housed in fire resistant construction of not less than two-hour classification which shall be a building either isolated from other buildings or separated from contiguous construction by two-hour noncombustible (under standard atmospheric conditions) wall construction.

10-2.1.1.1 If there are connecting doors through such common walls of contiguity, they shall be at least B label, 1½-hour fire doors. All construction and finish materials shall be noncombustible under standard atmospheric conditions.

NOTE: Characteristics of building construction housing hyperbaric chambers and ancillary facilities are no less important to safety from fire hazards than are the characteristics of the hyperbaric chambers themselves. It is conceivable that a fire emergency occurring immediately outside a chamber, given sufficient fuel, could seriously endanger the life or lives of those inside the chamber. Since the service facilities such as compressors, cooling equipment, reserve air supply, oxygen, etc., will in all probability be within the same building, these will also need protection while in themselves supplying life-maintaining service to those inside.

10-2.1.1.2 The room or rooms housing the Class A chambers and service equipment, such as described in 10-2.1.1, shall be for the exclusive use of the hyperbaric operation.

10-2.1.1.3 The supporting foundation for any chamber should be sufficiently strong to support the chamber. Consideration shall be given to any added floor stresses which will be created during any on-site hydrostatic testing.

10-2.1.2 During use, Class B chambers fabricated of nonmetallic pressure-containing component(s) shall be housed and sprinkler-protected as specified in 10-2.1.1, 10-2.1.1.1 and 10-2.1.1.2.

Exception: Class B chambers constructed according to ANSI/ASME PVHO-1, Safety Standard for Pressure Vessels for Human Occupancy, supplied by an oxygen

pipng system installed according to NFPA 56F, Nonflammable Medical Gas Systems and equipped to discharge the effluent gas from the chamber to the exterior of the building, need not be housed and sprinkler-protected as specified in 10-2.1.1, 10-2.1.1.1 and 10-2.1.1.2.

10-2.2 Fabrication of the Hyperbaric Chamber.

10-2.2.1 Class A, B and C chambers shall be designed and fabricated to meet ANSI/ASME PVHO-1, *Safety Standard for Pressure Vessels for Human Occupancy*, by personnel qualified to fabricate vessels under such codes.

10-2.2.2 Class A chambers shall be equipped with a floor which is structurally capable of supporting equipment and personnel necessary for the operation of the chamber according to its expected purpose.

10-2.2.2.1 The floor of Class A chambers shall be noncombustible.

10-2.2.2.2 If the procedures to be carried out in the Class A hyperbaric chamber require antistatic flooring, the flooring shall be installed in accordance with the provisions of Chapter 3, Use of Inhalation Anesthetics.

10-2.2.2.3 If a bilge is installed, access to the bilge shall be provided for cleaning purposes. The floor overlying the bilge shall be removable or, as an alternative, there shall be other suitable access for cleaning the bilge.

NOTE 1: Where feasible, it is recommended that Class A chambers be constructed without a bilge or other enclosures that will collect dirt, dust or liquids.

NOTE 2: It may not be feasible or practical to construct certain chambers without a bilge.

10-2.2.3 The interior of Class A chambers shall be unfinished or treated with a finish which is inorganic zinc based or high quality epoxy or equivalent, or which is flame resistant.

10-2.2.3.1 If sound-deadening materials are employed within a hyperbaric chamber, they shall be flame resistant as defined in Chapter 2, Definitions.

10-2.2.4 A sufficient number of viewing ports and access ports for piping and monitoring and related leads shall be installed during initial fabrication of the chamber. Prudent design considerations dictate that at least 150 percent excess pass-through capacity be provided, for future use.

10-2.2.4.1 Access ports in Class A chambers for monitoring and other electrical circuits shall be housed in enclosures which are weatherproof both inside and outside the chamber for protection in the event of sprinkler activation.

10-2.2.4.2 Viewports shall be designed and fabricated according to ANSI/ASME PVHO-1, *Safety Standard for Pressure Vessels for Human Occupancy*.

10-2.3 Illumination.

10-2.3.1 Wherever possible, all sources of illumination shall be mounted outside the pressure chamber and arranged to shine through chamber ports.

10-2.3.1.1 Lighting fixtures used in conjunction with viewports shall be designed as specified in ANSI/ASME PVHO-1.

10-2.3.1.2 Gasket material shall be of a type which permits the movement of thermal expansion and shall be suitable for the temperatures, pressures and composition of gases involved. Where practical, noncombustible gasket material shall be employed. Gaskets of "O" rings shall be confined to grooves or enclosures which will prevent their being blown out or squeezed from the enclosures or compression flanges.

10-2.3.2 Fluorescent lamps may be employed for general illumination within Class A chambers provided the ballasts are positioned outside the chamber and the fixtures are housed in self-contained, vented containers.

10-2.3.3 If it necessary to employ portable surgical spot illumination units in the chamber, these units shall be installed in a self-contained, vented, shatterproof fixture.

10-2.3.4 Permanent lighting fixtures installed within the hyperbaric chamber, and any portable lighting fixtures brought into the chamber, shall comply with the requirements of NFPA 70, *National Electrical Code*, Article 500, Class I, Division 1, and approved for use in Class I, Group C atmospheres at the maximum proposed pressure and oxygen concentration.

10-2.3.4.1 All lighting fixtures shall be type-tested and approved in an external pressure of $1\frac{1}{2}$ times maximum allowable working pressure. All lighting units to be placed inside a chamber (fluorescent or portable surgical spot lamps) shall be individually pressure tested to withstand the maximum proposed pressure of the chamber.

10-2.4 Ventilation of Class A Chambers.

10-2.4.1 Whenever the Class A chamber is used as an operating room, it shall be adequately ventilated and the air supply thereto conditioned according to the minimum requirements for temperature recommended for hospital operating rooms as specified in Chapter 3, Use of Inhalation Anesthetics.

Exception: Class A chambers which are not used in the capacity of an operating room should maintain a temperature which is comfortable for the occupants [usually $75^{\circ} \pm 5^{\circ}F$ ($22^{\circ} \pm 2^{\circ}C$)]. The thermal control system should be designed to maintain the temperature below $85^{\circ}F$ ($29^{\circ}C$) during pressurization if possible, and above $65^{\circ}F$ ($19^{\circ}C$) during depressurization if possible.

NOTE: Chapter 3, Use of Inhalation Anesthetics specifies a desirable temperature of $68^{\circ}F$ ($20^{\circ}C$). It is impractical to maintain such a temperature during pressurization, but efforts should be made in the design and operation of thermal control systems to maintain the temperature as close to $75^{\circ}F$ ($22^{\circ}C$) as possible. The air handling system of all Class A chambers should be capable of maintaining relative humidity in the range of 50 to 70 percent during stable depth operations.

10-2.4.1.1 The minimum ventilation of a Class A chamber shall be 3 cu ft (.085 cu m) (of pressurized air) per occupant per minute with no less than 3 cu ft per minute (.085 cu m per minute).

Exception: When a mask oxygen overboard dump system is used to exhaust exhaled gases, the ventilation schedule shall be based on the number of occupants who are not using the overboard dump system, except that the ventilation schedule shall be not less than 3 cu ft per minute (0.085 cu m per minute).

10-2.4.1.2 If volatile agents are being utilized (e.g., nitrous oxide, methoxyflurane, halothane) the minimum continuous ventilation for Class A chambers shall be eight compartment changes per hour.

NOTE: Experience and practice may dictate the need for a threshold sanitary ventilation in excess of the minimum rates specified.

10-2.4.1.3 Provision shall be made for ventilation during nonpressurization of Class A chambers as well as during pressurization.

10-2.4.1.4 Individual breathing apparatus shall be supplied for each occupant of a Class A chamber for use in case air in the chamber is fouled by combustion or otherwise. Each breathing apparatus shall be available for immediate use and breathing mixture shall be independent of chamber atmosphere. Air supply shall be sufficient for simultaneous use of all breathing apparatus. Such apparatus shall function at all pressures which may be encountered in the chamber.

10-2.4.1.5 Portable self-contained breathing apparatus shall be available outside a Class A chamber for use by personnel in the event that the air in the vicinity of the chamber is fouled by smoke or other combustion products of fire.

10-2.4.2 Sources of air for Class A chamber atmosphere shall be such that toxic or flammable gases are not introduced. Intakes shall be located so as to avoid air contaminated by exhaust from vehicles, stationary engines or building exhaust outlets.

10-2.4.2.1 Positive efforts shall be undertaken to assure that air for a Class A chamber atmosphere is not fouled by handling (i.e., by oil bath compressors and the like).

10-2.4.3 Warming or cooling of the atmosphere within a Class A chamber may be accomplished by circulating the ambient air within the chamber over or past coils through which a constant flow of warm or cool water is circulated. Dehumidification may be accomplished through the use of cold coils; humidification, by the use of an air-powered water nebulizer. Suitable noncombustible packing and nonflammable lubricant shall be employed on the fan shaft.

10-2.5 Fire Protection in Class A Chambers.

10-2.5.1 The system design shall be such that prior to activation of the water deluge system, whether operated in the automatic or manual mode, interior chamber power shall be automatically deactivated first and the emergency lighting and communication system shall be activated.

10-2.5.2 A fixed extinguishing system shall be installed within all Class A chambers. It shall be capable of manual

activation. When operated in the automatic mode, activation shall occur within one second of perception of sensible flame development. When operated in the manual mode, system activation shall occur within one second of the manual activation signal.

NOTE: Since inadvertent discharge of the extinguishing agent can disrupt operation of the facility, proper precautions to prevent such an occurrence should be observed. *See 10-3.2.1.2.*

10-2.5.2.1 Duration of application of extinguishers in Class A chambers shall be governed by the type of system. The quantity of agent discharged shall provide the necessary concentration or saturation throughout the chamber for complete extinguishment.

10-2.5.2.2 For water systems in Class A chambers, sufficient spray nozzles shall be installed to provide reasonably uniform spatial coverage with horizontal and vertical jets and an average density at floor level of 2 to 3 gpm per sq ft (27.8 L/min/m²).

NOTE: Experience has shown that when water is discharged through conventional sprinkler heads into a hyperbaric atmosphere, the spray angle is reduced because of the increased density of the atmosphere, even though the water pressure differential is maintained above atmospheric pressure. Therefore, it is necessary to compensate by increasing the number of sprinkler heads.

10-2.5.2.3 The limit on duration of application of water-based extinguishers in Class A chambers shall be governed by the capacity of the chamber and its drainage system. There shall be sufficient water available to maintain the flow specified in 10-2.5.2.2 for approximately one-minute duration. Extinguisher controls shall be located both inside and outside the chamber.

10-2.5.3 Automatically activated extinguishment systems for Class A chambers are optional. If installed, they shall meet the requirements of 10-2.5.3.1 through 10-2.5.3.7.

10-2.5.3.1 Surveillance fire detectors responsive to the radiation from flame shall be employed for automatic activation in Class A chambers. Type and arrangement of detectors shall be such as to activate within one second of fire origination.

10-2.5.3.2 The number of such detectors employed in Class A chambers and their location will be dependent upon the sensitivity of each detector and the configuration of the space or spaces to be protected.

NOTE: Additional detectors are required to avoid "blind" areas if the chamber contains compartmentation.

10-2.5.3.3 There shall be a manual activator located at the operator's console outside the Class A chamber, and at least two locations inside the chamber. As an alternative method of in-chamber activator, a chain running the length of the chamber adjacent to the ceiling may be provided.

10-2.5.3.4 The fire detection system in Class A chambers shall have automatic or "floating" battery standby. Extinguishing system shall have stored pressure to operate at least 15 seconds without electrical supply.

10-2.5.3.5 The power supply for booster pumps when used with deluge water sprinkler systems in Class A chambers, and for other emergency facilities, shall be

separate from that supplying all other electrical equipment. Activation control circuitry shall have emergency standby provisions. (*See 10-2.7.1.4.*)

10-2.5.3.6 A visual and aural indication of the activation of the extinguishing system in Class A chambers shall be provided at the chamber operator's control console and at the switchboard of the telephone operator or a suitable authority to activate the emergency fire/rescue network of the institution containing the hyperbaric facility.

NOTE: The requirements in 10-2.5.3.6 do not preclude the use of an alarm system affording direct fire department contact.

10-2.5.3.7 The alarm system for Class A chambers shall include continuous electrical supervision to indicate occurrence of a break or ground fault condition in the circuit. A distinctive trouble signal shall be provided which shall be activated by this occurrence.

10-2.5.4 A manual extinguishing system also shall be provided inside Class A chambers.

10-2.5.4.1 This system for Class A chambers shall consist of two ½-in. water handlines, located strategically within the chamber, preferably adjacent to opposite ends of the chamber. Fire blankets and portable carbon dioxide extinguishers shall not be installed or carried into the chamber.

NOTE: Experience has shown that fire blankets and portable carbon dioxide extinguishers are not effective in controlling fires in oxygen-enriched atmospheres. Valuable time can be lost in attempting to use such devices.

10-2.5.4.2 In the case of Class A chambers having personnel locks, at least one such line shall also be located in each lock.

10-2.5.4.3 Each handline in a Class A chamber shall be activated by a manual quick-opening quarterturn valve located within the chamber or the personnel lock.

10-2.5.4.4 The handlines in a Class A chamber shall be supplied from water mains, augmented where necessary with a "surge tank" which will assure 50 psi minimum water pressure above the maximum hyperbaric chamber pressure.

10-2.5.4.5 Power and control circuits for this booster pump for Class A chambers shall be supplied as noted in 10-2.5.3.5.

10-2.5.4.6 Both the handlines and (where applicable) the deluge sprinkler system of a Class A chamber shall be equipped with manual override valves located at the chamber operator's console and appropriately identified.

10-2.5.5 Activation of any of the fire extinguishing systems of a Class A chamber shall cause the electrical circuits within the chamber, except the sound-powered telephone circuits and intrinsically safe circuits provided with ground fault circuit interrupters where required by NFPA 70, *National Electrical Code*, to be inactivated automatically and rendered electrically dead.

10-2.5.6 Visibility within the chamber shall be maintained through the continued operation of externally mounted fixtures. (*See 10-2.3.1 through 10-2.3.1.2.*)

10-2.5.7 A hydraulically calculated automatic wet pipe sprinkler system shall be installed in the room housing the Class A chamber and in any ancillary equipment rooms. The room shall have automatic wet pipe sprinkler system heads equipped with fusible links installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

10-2.6 Fire Protection in Class B and C Chambers. Since type B and C chambers may be portable, sprinkler systems similar to those described above shall be installed in all areas in which such chambers will be used. (See 10-2.1.1.2 except as modified by 10-2.1.2.)

10-2.6.1 The provisions of NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall be referred to when applicable to any class of chamber.

10-2.7 Electrical Systems.

10-2.7.1 Source of Power to Hyperbaric Chambers.

10-2.7.1.1 All essential electric equipment and circuits associated with the hyperbaric chamber, whether within or outside of the chamber, shall have a minimum of two independent sources of electric power, one to be fed from a prime mover-driven generator set located on the premises of the facility.

10-2.7.1.2 The electrical circuits contained within the chamber and all permanent lighting, whether within or outside of the chamber, and all circuits used for communication and alarm systems shall be connected to the Emergency System. (See Chapter 8, *Essential Electrical Systems for Health Care Facilities*.)

10-2.7.1.3 Electric motor-driven compressors and auxiliary electrical equipment used for atmospheric control within the chamber and normally located outside the chamber shall be connected to the Equipment System. (See Chapter 8, *Essential Electrical Systems for Health Care Facilities*.)

Exception: When reserve air tanks of sufficient capacity to maintain pressure and air flow within the hyperbaric enclosure and to supply high pressure air for the rapid pressurization of the decompression chamber are provided, the compressor and auxiliary equipment need not have an alternate source of power. It is the intent of this paragraph that the chamber occupants be protected from rapid decompression due to failure of the normal source of power.

10-2.7.1.4 The circuits and equipment listed in 10-2.5.3.1, 10-2.5.3.4, 10-2.5.3.5, 10-2.7.1.2 and 10-2.7.1.3 shall be so installed and connected to an alternate source of power that they will be automatically restored to operation within 10 seconds after interruption of the normal source.

10-2.7.2 Electrical Wiring and Equipment.

10-2.7.2.1 No electrical equipment, with the exception of intrinsically safe equipment and equipment listed for use in 100 percent oxygen at 3 ATA pressure, shall be used in any chamber in which the percent by volume of oxygen exceeds 23.5 percent. Equipment which is used in chambers with concentrations of oxygen of 23.5 percent by

volume or less shall be continuously purged with nitrogen or shall be intrinsically safe for that atmosphere.

10-2.7.2.2 All electrical circuits serving equipment located adjacent to, or in the vicinity of, the Class A hyperbaric chamber shall be installed in rigid metal conduit so equipped as to prevent water from entering the conduit system, including boxes and fittings used therewith. Conduit shall be equipped with approved drains. All switches, connectors, terminals and junction boxes shall be completely waterproof.

NOTE: It is necessary that these circuits be protected from exposure to water from the sprinkler system protecting the chamber housing in the event of a fire in the vicinity of the chamber while it is in operation.

10-2.7.2.3 All electrical circuits contained within the chamber shall be supplied from an ungrounded electrical system, fed from isolating transformers located outside the chamber, and equipped with a Line Isolation Monitor with appropriate signal lamps as specified in Chapter 3, *Use of Inhalation Anesthetics*. It is desirable that this indicator be capable of sensing single or balanced capacitive-resistive faults, as well as leakage of current to ground.

10-2.7.2.4 All electrical wiring installed in the hyperbaric chamber shall comply with the requirements of NFPA 70, *National Electrical Code*, Article 500, Class I, Division 1. Equipment installed therein shall be approved for use in Class I, Group C atmospheres at the maximum proposed pressure and oxygen concentration. Either threaded rigid metal conduit or Type MI cable with termination fittings approved for the location shall be the wiring method employed. All boxes, fittings and joints shall be explosionproof. (See Article 501, NFPA 70, *National Electrical Code*.)

10-2.7.2.5 Fixed electrical equipment within the hyperbaric enclosure shall comply with the requirements of NFPA 70, *National Electrical Code*, Article 500, Class I, Division 1. Equipment installed therein shall be approved for use in Class I, Group C atmospheres at the maximum proposed pressure and oxygen concentration.

NOTE: It is the intention of this chapter that no electrical equipment be installed or used within the chamber that is not intrinsically safe or designed and tested for use under hyperbaric conditions. Any electrical component within the chamber may constitute an intolerable hazard, and should not be permitted without exhaustive study. Control devices, wherever possible, should be installed outside of the hyperbaric chamber and actuated by some suitable mechanical, hydraulic, or other nonelectrical control device which may be operated from any desired location within the chamber.

10-2.7.2.6 Overcurrent protective devices shall comply with the requirements of NFPA 70, *National Electrical Code*, Article 240, and shall be installed outside of, and adjacent to, the hyperbaric enclosure. Equipment used inside the hyperbaric enclosure may have its own individual overcurrent devices incorporated within the equipment, provided this device is approved for Class I, Division 1, Group C atmospheres at the maximum proposed pressure and oxygen concentration. Each circuit shall have its own individual overcurrent protection in accordance with Article 240-11 of NFPA 70, *National Electrical Code*.

10-2.7.2.7 Each ungrounded circuit within or partially within the hyperbaric enclosure shall be controlled by a switch outside the enclosure having a disconnecting pole for each conductor. These poles shall be ganged.

10-2.7.2.8 Switches, receptacles, and attachment plugs designed for electrical systems used in ordinary locations are prohibited from use in hyperbaric chambers because of the frequent sparks or arcs that result from their normal use. All receptacles and attachment plugs shall conform to Section 3-3, Chapter 3, Use of Inhalation Anesthetics.

10-2.7.3 Hyperbaric Chamber Service Equipment. All hyperbaric chamber service equipment, switchboards or panelboards shall be installed outside of, and adjacent to, the hyperbaric enclosure, and so arranged as to readily permit manual supervisory control by operators in visual contact with the chamber interior.

10-2.8 Intercommunications and Monitoring Equipment.

10-2.8.1 Intercommunications equipment is mandatory to the safe operation of a hyperbaric facility.

10-2.8.1.1 All intercommunications equipment shall be approved as intrinsically safe. (*See Chapter 2, Definitions.*) All fixed conductors inside the chamber shall be insulated with insulation that is flame resistant in accordance with the definitions given in Chapter 2, for example "MI" cable or Teflon® insulated cable.

10-2.8.1.2 Microphones, loudspeakers, and hand phones located in the chamber and personnel locks shall be approved as intrinsically safe at the maximum proposed pressure and oxygen concentration and shall operate on less than five volts. All other components of the intercommunications equipment, including the audio output transformers, shall be located outside of the hyperbaric facility.

Exception: Oxygen mask microphones with external relays designed to operate on equal to or less than 28 volts and not to exceed a current of 0.25 amps may be used provided they qualify as intrinsically safe at the maximum proposed pressure and oxygen concentration. If push-to-talk switches are used, they shall be of the hermetically sealed pressure tested type and arc-suppressed circuits shall be incorporated in the switch.

10-2.8.1.3 Voice sensors when part of an oxygen mask shall be approved as intrinsically safe for 95 ± 5 percent oxygen at the maximum proposed pressure.

10-2.8.1.4 All electrical conductors inside the chamber and personnel locks shall be insulated with insulation that is flame resistant in accordance with the definitions given in Chapter 2.

Exception: Grounds through the piping system need not be insulated.

10-2.8.1.5 The intercommunications system also shall connect all personnel locks with both the main chamber and the chamber operator's control panel.

NOTE: It is recommended that each Class A chamber be equipped with a system with dual channels, and a sound-powered telephone or surveillance microphone system be furnished in addition.

10-2.8.2 All patient monitoring equipment shall be located on the outside of the chamber and the monitoring leads conveyed through appropriate pass-throughs. Information about the status of an anesthetized patient should be transmitted to members of the operating team via the intercommunications equipment. As an alternative, the oscilloscopic screen or other monitoring device indicator may be placed adjacent to one of the viewing ports. As another alternative monitors continuously purged with inert gas and designed so as not to exceed maximum safe operating temperature and pressure changes may be employed.

10-2.8.2.1 The conductors or patient leads extending into the hyperbaric chamber shall be intrinsically safe, up to seven atmospheres pressure, as defined in NFPA 70, *National Electrical Code*, and shall be listed for use in Class I, Group C, Division 1 hazardous locations under pressures up to 100 psig — 114.7 psia pressure.

NOTE: The minimum electrical energy required to ignite explosive atmospheres decreases as the pressure of the explosive atmosphere increases. Therefore, intrinsically safe circuits which have been tested and found suitable for explosive atmospheres at ambient pressures (atmospheric) may not be intrinsically safe when used in the presence of flammable anesthetic gas (or vapor) air mixtures above atmospheric pressure.

10-2.8.3 Any other electrically operated equipment brought into the hyperbaric chamber, or installed in the chamber, including monitoring and intercommunications equipment, shall be explosionproof or be intrinsically safe as defined by NFPA 70, *National Electrical Code*, in 95 ± 5 percent oxygen and up to 100 psig — 114.7 psia pressure.

10-2.8.4 Automatic fire detection equipment is covered in 10-2.5.3 through 10-2.5.3.7.

10-2.8.5 Sensors shall be installed to detect levels of carbon dioxide (above 0.2 percent), carbon monoxide (above 15 ppm) and volatilized hydrocarbons (above 500 ppm). As an alternative, periodic sampling of chamber air in Class A chambers without oxygen-enriched environments shall be accomplished at least once each month of operation. (*See ventilation requirements in 10-2.4.1 and 10-2.4.1.2.*)

Exception: Sensors are not required in the case of the Class B chamber continuously purged with 95 ± 5 percent oxygen.

10-2.8.6 All detectors or sensors mounted inside the hyperbaric chamber shall be intrinsically safe and *implosion*proof at the maximum proposed operating pressure and oxygen concentration. Control equipment shall be installed outside the chamber.

10-2.9 Other Equipment and Fixtures.

10-2.9.1 All furniture used in the hyperbaric facility shall be grounded as recommended for installation and use in hazardous locations in Chapter 3, Use of Inhalation Anesthetics.

10-2.9.2 Exhaust from all classes of chambers shall be piped outside of the building, the point of exit being clear of all neighboring hazards and clear of possible re-entry of exhaust gases into the building, and protected by a grille or

fence of at least 2 ft (.6 m) radius from the exhaust port. A protective grille or fence is not required when the exhaust is above the building height.

10-2.9.3 Requirements cited in this section are minimum ones. Discretion on the part of chamber operators and others may dictate the establishment of more stringent regulations.

10-3 Administration and Maintenance.

10-3.1 General.

10-3.1.1 Purpose. Section 10-3 contains requirements for administration and maintenance which shall be followed as an adjunct to physical precautions specified in Section 10-2.

10-3.1.2 Recognition of Hazards. The hazards involved in the use of hyperbaric facilities can be mitigated successfully only when all of the areas of hazard are fully recognized by all personnel and when the physical protection provided is complete and is augmented by attention to detail by all personnel of administration and maintenance having any responsibility for the functioning of the hyperbaric facility. The nature and degree of these hazards are outlined in Appendix C-10 of this document and should be reviewed by all personnel. Since Section 10-3 is expected to be used as a test by those responsible for the mitigation of hazards of hyperbaric facilities, the requirements set forth herein are frequently accompanied by explanatory text.

10-3.1.3 Responsibility.

10-3.1.3.1 Responsibility for the maintenance of safe conditions and practices both in and around hyperbaric facilities falls mutually upon the governing body of the institution, all personnel using or operating the hyperbaric facility, the administration of the institution and those responsible for licensing, accrediting, or approving institutions or other facilities in which hyperbaric installations are employed.

10-3.1.3.2 A safety director shall be in charge of all hyperbaric equipment. The safety director shall have authority to restrict potentially hazardous supplies and equipment from the chamber [see 10-3.1.3.3 and 10-3.1.5.5(c)].

10-3.1.3.3 The complexity of Class A chambers is such that one person should be designated as chamber operator, as one in a position of responsible authority. Before starting a hyperbaric run, this person should acknowledge, in writing, in an appropriate log, the purpose of the run or test, duties of all personnel involved, and a statement that he or she is satisfied with the condition of all equipment. Exceptions should be itemized in the statement.

10-3.1.3.4 The ultimate responsibility for the care and safety of patients (in the case of a hospital) and personnel (in any institution) is that of the governing board. Hence it is incumbent upon that body to insist that adequate rules and regulations with respect to practices and conduct in hyperbaric facilities be adopted by the medical or administrative staff of the institution, and that adequate regulations for inspection and maintenance are in use by the administrative, maintenance and ancillary (and in the case of a hospital, nursing and other professional) personnel.

10-3.1.3.5 By virtue of its responsibility for the professional conduct of members of the medical staff of the health care facility, the organized medical staff shall adopt adequate regulations with respect to the use of hyperbaric facilities located in health care facilities (see Appendix C-10-2 and C-10-3) and through its formal organization shall ascertain that these regulations are regularly adhered to. The safety director shall be included in the planning phase of these regulations.

10-3.1.3.6 In meeting its responsibilities for safe practices in hyperbaric facilities, the administration of the facility shall adopt or correlate regulations and standard operating procedures to assure that both the physical qualities and the operating maintenance methods pertaining to hyperbaric facilities meet the standards set in this chapter. The controls adopted shall cover the conduct of personnel in and around hyperbaric facilities, and the apparel and footwear allowed. They shall cover periodic inspection of static dissipating materials and of all electrical equipment, including testing of ground contact indicators. Electrical, monitoring, life support, protection, and ventilating arrangements in the hyperbaric chamber shall be inspected and tested regularly.

NOTE: In the case of a hyperbaric facility located in a hospital, hospital licensing and other approval bodies, in meeting their responsibilities to the public, should include in their inspections not only compliance with requirements for physical installations in hyperbaric facilities, but also compliance with the requirements set forth in Section 10-3 of this chapter.

10-3.1.4 Rules and Regulations.

10-3.1.4.1 General. It is recommended that administrative, technical and professional staffs jointly consider and agree upon necessary rules and regulations for the control of personnel concerned with the use of hyperbaric facilities. Upon adoption, rules and regulations shall be prominently posted in and around the hyperbaric chamber. Positive measures are necessary to acquaint all personnel with the rules and regulations established and to assure enforcement. Training and discipline are mandatory.

10-3.1.4.2 It is recommended that all personnel, including trainees and those involved in the operation and maintenance of hyperbaric facilities, and including professional personnel and (in the case of hospitals) others involved in the direct care of patients undergoing hyperbaric therapy be familiar with this chapter. Personnel concerned should maintain proficiency in the matters of life and fire safety by periodic review of this chapter, as well as any other pertinent material.

10-3.1.4.3 All personnel shall become familiar with emergency equipment — its purposes, applications, operation and limitations. This paragraph includes those involved in maintenance and repair of the facility.

10-3.1.4.4 Emergency procedures best suited to the needs of the individual facility shall be established. All personnel shall become thoroughly familiar with these procedures and the methods of implementing them. Individual circumstances dictate whether such familiarization can best be afforded through the medium of a procedure manual. Personnel shall be trained to safely decompress occupants when all powered equipment has been rendered inoperative.

10-3.1.4.5 A suggested outline for emergency action in the case of fire is contained in Appendix C-10-2.

10-3.1.4.6 Fire training drills shall be carried out at regular intervals.

NOTE: A calm reaction (without panic) to an emergency situation can be expected only if the above recommendations are familiar to and rehearsed by all concerned.

10-3.1.5 General Requirements.

10-3.1.5.1 Open Flames and Hot Objects. Smoking, open flames, hot objects and ultraviolet sources which would cause premature operation of flame detectors, when installed, shall be prohibited from hyperbaric facilities, both inside and outside but in the vicinity of the chamber. The immediate vicinity of the chamber is defined as the general surrounding area from which activation of the flame detector can occur.

10-3.1.5.2 Flammable Gases and Liquids. The use of flammable agents inside a hyperbaric facility or in proximity to the compressor intake shall be forbidden. Burners employing natural or bottled gas for laboratory purposes, and cigarette lighters fall into this category.

Exception: When potentially flammable agents must be used for patient treatment (e.g., alcohol swabs, parenteral alcohol-based pharmaceuticals, topical creams), such agents shall be approved by a board of competent authorities.

NOTE: Many "inert" halogenated compounds have been found to act explosively in the presence of metals, even under normal atmospheric conditions, despite the fact that the halogen compound itself does not ignite in oxygen, or, in the case of solids such as polytetrafluoroethylene, is self-extinguishing. Apparently these materials are strong oxidizers whether as gases, liquids (solvents, greases) or solids (electrical insulation, fabric or coatings). Some halogenated hydrocarbons that will not burn in the presence of low-pressure oxygen will ignite and continue to burn in high-pressure oxygen. Customarily, Class A chambers maintain internal oxygen concentration that does not exceed 23.5 percent.

10-3.1.5.3 Parts of this chapter deal with the elements required to be incorporated into the structure of the chamber to reduce the possibility of electrostatic spark discharges which are a possible cause of ignition in hyperbaric atmospheres. The elimination of static charges is dependent on the vigilance of administrative activities in materials, purchase, maintenance supervision, and periodic inspection and testing. It cannot be emphasized too strongly that an incomplete chain of precautions generally will increase the electrostatic hazard. For example, conductive flooring may contribute to the hazard unless all personnel wear conductive shoes, all objects in the room are electrically continuous with the floor, and humidity is maintained. Maximum precautions within reason shall be taken.

10-3.1.5.4 Personnel.

(a) The number of occupants of the chamber shall be kept to the minimum number necessary to carry out the procedure.

(b) All personnel entering a Class A chamber equipped with a conductive floor shall be in electrical contact with the conductive floor through the wearing of conductive footwear or an alternative method of providing a path of conductivity. In Class A chambers which are not equipped

with conductive floors, antistatic procedures as directed by the safety director shall be employed whenever oxygen-enriched atmospheres are used.

(c) In Class A chambers with oxygen-enriched atmospheres, and in all Class B chambers, electrical grounding of the patient shall be assured by the provision of conductive strap in contact with the patient's skin, with one end of the strap fastened to the metal frame of an operating table (or other equipment) meeting the requirements of Chapter 3, Use of Inhalation Anesthetics.

(d) Because of the possibility of percussion sparks, shoes having ferrous nails which may make contact with the floor shall not be permitted to be worn in Class A chambers.

(e) Equipment of cerium, magnesium, magnesium alloys and similar manufacture shall be prohibited. (See also Note under 10-3.2.2.)

10-3.1.5.5 Textiles.

(a) Cotton, silk, wool or synthetic textile materials shall not be permitted in Class A hyperbaric chambers, unless the fabric meets the requirements of 10-3.1.5.5(d).

(b) Only garments of cotton or antistatic synthetic materials (see Section 3-3 of Chapter 3, Use of Inhalation Anesthetics) shall be permitted in Class B hyperbaric chambers.

(c) Suture material, alloplastic devices, bacterial barriers, surgical dressings, and biologic interfaces of otherwise prohibited materials may be used at the discretion of the physician or surgeon in charge with the concurrence of the safety director. This permission shall be stated in writing, for all prohibited materials employed (see 10-3.1.3.3).

(d) Where flame resistance is specified, the fabric shall meet the requirements set forth for the small scale test in NFPA 701, *Standard Methods of Fire Tests for Flame-Resistant Textiles and Films*, except that the test shall be performed in an atmosphere equivalent to the maximum oxygen concentration and pressure proposed for the chamber.

10-3.1.5.6 All chamber personnel shall wear garments of the overall or jumpsuit type, completely covering all skin areas possible, and should be as tight fitting as possible.

10-3.1.5.7 Whenever possible patients shall be stripped of all clothing, particularly if it is contaminated by dirt, grease or solvents, and then reclothed as specified in 10-3.1.5.6. All cosmetics, lotions and oils shall be removed from the patient's body and hair.

NOTE: It may be impractical to clothe some patients (depending upon their disease or the site of any operation) in such garments. Hospital gowns of flame-resistant textile should be employed in such a case.

10-3.1.5.8 All other fabrics used in the chamber such as sheets, drapes and blankets shall be of inherently flame-resistant materials. Free-hanging drapes should be minimized.

10-3.1.5.9 The use of flammable hair sprays, hair oils and skin oils shall be forbidden for all chamber occupants — patients as well as personnel.

10-3.2 Equipment.

10-3.2.1 All equipment used in the hyperbaric facility shall comply with Section 10-2. This includes all electrical and mechanical equipment necessary for the operation and maintenance of the hyperbaric facility, as well as any medical devices and instruments used in the facility. Use of unapproved equipment shall be prohibited. (See 10-3.1.5.5(c).)

10-3.2.1.1 Portable X-ray devices, electrocautery equipment, and other similar high-energy devices shall not be operated in the hyperbaric chamber unless approved for such use. Photographic equipment employing photoflash, flood lamps, or similar equipment shall not remain in the hyperbaric chamber when the chamber is pressurized. Lasers shall not be used under any condition.

10-3.2.1.2 Equipment known to be, or suspected of being, defective shall not be introduced into any hyperbaric chamber or used in conjunction with the operation of such chamber until repaired, tested and accepted by qualified personnel and approved by the safety director (see 10-2.5.2).

10-3.2.1.3 The use of paper shall be kept to an absolute minimum in hyperbaric chambers, and any paper brought into the chamber shall be stored into a closed metal container. Containers shall be emptied after each chamber operation.

10-3.2.2 Oxygen containers, valves, fittings and interconnecting equipment shall be all metal to the extent possible. Valve seats, gaskets, hoses, and lubricants shall be selected carefully for oxygen compatibility under service conditions.

NOTE: Users should be aware that many items if ignited in pressurized oxygen-enriched atmospheres are not self-extinguishing. Iron alloys, aluminum and stainless steel are, to various degrees, in that category as well as human skin, muscle and fat, and plastic tubing such as polyvinyl chloride (Tygon). Testing for oxygen compatibility is very complicated. Very little data exists and many standards still have to be determined. Suppliers do not normally have facilities for testing their products in controlled atmospheres, especially high-pressure oxygen. Both static conditions as well as impact conditions are applicable. Self-ignition temperatures normally are unknown in special atmospheres.

10-3.2.3 Equipment requiring lubrications shall be lubricated with oxygen-compatible flame-resistant material.

10-3.3 Handling of Gases.

10-3.3.1 General.

10-3.3.1.1 Flammable gases shall not be used or stored within, or in the immediate vicinity of, the hyperbaric facility. Nonflammable gases may be piped into the hyperbaric facility. Pressurized containers of gas may be introduced into the hyperbaric chamber, provided the container and contents are approved for such use. The institution's administrative personnel shall ensure that rules and regulations are provided to ensure the safe handling of gases in the hyperbaric facility (see 10-3.1.5.2 and Appendix C-10-1.1.3.2).

10-3.3.2 Quantities of oxygen stored in the chamber shall be kept to a minimum. Oxygen and other gases shall not be introduced into the chamber in the liquid state.

10-3.4 Maintenance.

10-3.4.1 General.

10-3.4.1.1 The hyperbaric safety director shall be ultimately responsible for ensuring that all valves, regulators, meters, and similar equipment used in the hyperbaric chamber are properly compensated for safe use under hyperbaric conditions, and tested periodically. Pressure relief valves shall be tested and calibrated periodically.

10-3.4.1.2 The hyperbaric safety director shall also be ultimately responsible for ensuring that all gas outlets in the chambers are properly labeled or stenciled in accordance with ANSI Z48.1, *Standard Method of Marking Portable Compressed Gas Containers to Identify the Material Contained*.

10-3.4.1.3 Before piping systems are initially put into use, it shall be ascertained that the gas delivered at the outlet be shown on the outlet label and that proper connecting fittings are checked against their labels, in accordance with NFPA 56F, *Standard for Nonflammable Medical Gas Systems*.

10-3.4.1.4 The guidelines set forth in Chapter 3, Use of Inhalation Anesthetics, concerning the storage, location, and special precautions required for compressed gases shall be followed.

10-3.4.1.5 All storage areas shall be located remotely from the hyperbaric environment and flammable gases shall not be used or stored in the facility.

10-3.4.2 Radiation equipment, whether infrared or roentgen ray, can make hyperbaric chambers even more hazardous. In the event that such equipment is introduced into a hyperbaric chamber hydrocarbon detectors shall be installed. In the event that flammable gases are detected in excess of 1,000 parts per million, such radiation equipment shall not be operated until the chamber atmosphere is cleared.

10-3.4.3 Maintenance Logs.

10-3.4.3.1 Installation, repairs, modifications of equipment, etc. related to a chamber should be evaluated by engineering personnel, tested under pressure, and approved by the safety director. Logs of the various tests shall be maintained.

10-3.4.3.2 Operating equipment logs shall be maintained by engineering personnel. They shall be signed before chamber operation by the person in charge (see 10-3.1.3.3).

10-3.4.3.3 Operating equipment logs shall not be taken inside the chamber.

10-3.5 Electrical Safeguards.

10-3.5.1 Electrical equipment shall be installed and operated in accordance with 10-2.7.

10-3.5.1.1 All electrical circuits shall be tested before chamber pressurization. This test shall include a continuity check to verify that no conductors are grounded to the chamber, as well as a test of normal functioning (see 10-2.7.2.3).

10-3.5.1.2 In the event of fire, all nonessential electrical equipment within the chamber shall be de-energized insofar as possible before extinguishing the fire. Smouldering, burning electrical equipment shall be de-energized before extinguishing a localized fire involving only the equipment (*see 10-2.5.5*).

10-3.6 Electrostatic Safeguards.

10-3.6.1 Administration.

10-3.6.1.1 General. The elimination of static charges is dependent on the vigilance of administrative activities in materials purchased, maintenance supervision, and periodic inspection and testing.

10-3.6.1.2 Textiles. Textiles used or worn in the hyperbaric chamber shall conform to 10-3.1.5.5 through 10-3.1.5.8.

10-3.6.2 Maintenance.

10-3.6.2.1 Conductive Floors. (*See Chapter 3, Use of Inhalation Anesthetics.*)

10-3.6.2.2 Furniture.

(a) Periodic inspection shall be made of leg tips, tires, casters, or other conductive devices on furniture and equipment to ensure that they are maintained free of wax, lint or other extraneous material which may insulate them and defeat the purpose for which they are used; also to avoid transporting to conductive floors such materials from other areas. Metals capable of impact sparking shall not be allowed for casters or furniture leg tips.

NOTE: Ferrous metals may cause such sparking. So may magnesium or magnesium alloys if contact is made with rusted steel.

(b) Casters shall not be lubricated with oils or other flammable materials. Such lubricants shall be oxygen compatible and flame resistant.

10-3.6.2.3 Conductive Accessories. Replacement belting, rubber accessories, plastics, covers, sheeting, and other conductive accessories shall be of conductive material, and shall meet the requirements of Chapter 3, Use of Inhalation Anesthetics.

10-3.6.3 Testing. Conductive testing, if required, shall be in accordance with requirements in Section 3-3 of Chapter 3, Use of Inhalation Anesthetics.

10-3.6.3.1 Materials containing rubber shall be inspected regularly, especially at points of kinking.

NOTE: Materials containing rubber deteriorate rapidly in oxygen-enriched atmospheres.

10-3.6.4 Fire Protection Equipment. Electrical switches, valves and electrical monitoring equipment associated with fire detection and extinguishment shall be visually inspected before each chamber pressurization. Fire detection equipment shall be tested each week and full testing, including discharge of extinguishing media, conducted annually. Testing shall include activation of trouble circuits and signals. Discharge of extinguishant may be limited to 10 percent of the system capacity.

10-3.6.5 Housekeeping. It is absolutely essential that all areas of, and components associated with, the hyperbaric chamber be kept meticulously free of grease, lint, dirt and dust. A regular housekeeping program shall be implemented whether or not the facility is in regular use. The persons assigned to this task shall be thoroughly indoctrinated in the hazards to occupants under normal operation.

Chapter 11 Hypobaric Facilities

NOTICE: Information on referenced publications can be found in Chapter 12 and Appendix B.

11-1 General.

11-1.1 Introduction.

11-1.1.1 There is currently a widespread interest in high altitude flight and space exploration. For this purpose, high altitude chambers and space simulators have been developed and put to use. Equipment, experimental animals, and humans have been exposed to various artificial atmospheres under varying pressures ranging from 760 mmHg atmospheric pressure to close to 0 mmHg.

11-1.1.2 In some chambers the atmosphere may be enriched with oxygen or contain 100 percent oxygen. The increased combustibility of materials in those oxygen-enriched atmospheres has resulted in several fires in such chambers, with loss of life.¹

11-1.1.2.1 There is continual need for human diligence and expertise in the establishment, operation and maintenance of hypobaric facilities.

11-1.1.2.2 The partial pressure of oxygen present in the atmosphere of a hypobaric facility is one of the determining factors of the amount of available oxygen. This pressure will rise if the percentage of oxygen increases proportionately more than the fall in total pressure. Even more important than partial pressure of oxygen from the standpoint of fire hazards compared with normal air, however, is the decrease in percentage of nitrogen available. The absence of the inerting effect of this nitrogen generally will lower the ignition energy and markedly elevate the burning rate of combustible and flammable substances. (See *Appendix C-11-1.2.2.1 and C-11-1.2.2.2*.)

11-1.1.2.3 It is the responsibility of the chief administrator or commanding officer of the facility possessing the hypobaric chamber to adopt and enforce appropriate regulations for hypobaric facilities. In formulating and administering the program, full use should be made of technical personnel highly qualified in hypobaric facility operations and safety.

11-1.1.2.4 It is essential that hypobaric chamber personnel having responsibility for the hypobaric facility establish and enforce appropriate programs to fulfill the provisions of this chapter.

11-1.1.3 Potential hazards can be controlled only when continually recognized and understood by all pertinent personnel. The Committee realizes that such facilities are not normally used to treat patients. Nevertheless, human beings are being exposed; hence the need for preparation of this chapter.

11-1.1.4 This chapter was prepared with the intent of offering standards for the design, maintenance and operation of such facilities.

11-1.2 Purpose.

11-1.2.1 The purpose of this chapter is to set forth minimum safeguards for the protection of personnel involved in the use of facilities which may contain an oxygen-enriched atmosphere,² and which are operated at pressures less than 760 mmHg. Its purpose is also to offer some guidance for rescue personnel who may not ordinarily be involved in the operation of hypobaric facilities, but who would become so involved in an emergency.

11-1.3 Scope.

11-1.3.1 This chapter applies to all hypobaric facilities in which humans will be occupants, or are intended to be occupants. Facilities employed for animal experimentation are not included if the size of the facility precludes human exposure.

11-1.3.1.1 This chapter covers the recognition of, and protection against, hazards of an electrical, explosion and implosion nature, as well as fire hazards.

11-1.3.1.2 Medical complications of hypobaric procedures are discussed primarily to acquaint rescue personnel with these problems.

11-1.4 Application of this Chapter. This chapter shall be applied only to new construction and new equipment. It shall not require the alteration or replacement of existing construction or equipment. Existing construction or equipment shall be permitted to be continued in use when use does not constitute a distinct hazard to life as determined by the administration of the institution.

11-1.5 Classification of Chambers.

11-1.5.1 General.

11-1.5.1.1 Chambers shall be classified according to occupancy in order to establish appropriate minimum essentials in construction and operation.

11-1.5.2 Occupancy.

(a) Class D — Human rated, air atmosphere not oxygen enriched.

(b) Class E — Human rated, oxygen-enriched atmosphere (partial pressure of oxygen is above 0.235 atmospheres absolute).

(c) Class F — Human rated, artificial atmosphere.

NOTE 1: Chapter 10, Hyperbaric Facilities, classifies hyperbaric chambers as A, B or C. To avoid confusion, hypobaric facilities are classified D, E and F.

NOTE 2: Chambers designed for animal experimentation equipped for access of personnel to care for the animals are classified as Class D, E or F for the purpose of this chapter depending upon atmosphere. Animal chambers, of a size which cannot be entered by humans, are not included in this chapter.

NOTE 3: Chambers used for high altitude training are classified as Class D for the purpose of this chapter.

¹See NFPA 53M, *Fire Hazards in Oxygen-Enriched Atmospheres*, for description of some of these accidents.

²See Section 2-2 in Chapter 2, Definitions.

11-1.6 Nature of Hazards.

11-1.6.1 This chapter for the use of hypobaric facilities is intended to provide protection against fire, implosion and other hazards without unduly limiting the activities of professional personnel involved in training or research. This principle, without minimizing the hazards, recognizes that all involved personnel should be aware of the hazards to life that are inherent in and around hypobaric facilities.

11-1.6.2 Potential hazards involved in the design, construction, operation and maintenance of hypobaric facilities are formidable. For further information on the nature of these hazards, see Appendix C-11-1.

11-2 Construction and Equipment.

11-2.1 Housing for Hypobaric Facilities.

11-2.1.1 Hypobaric chambers and all ancillary service equipment shall be housed in fire-resistant construction of not less than one-hour classification which shall be a building either isolated from other buildings or separated from contiguous construction by one-hour noncombustible (under standard atmospheric conditions) wall construction.

NOTE: This chapter does not restrict the number of chambers that can be placed in the same room or building.

11-2.1.1.1 If there are connecting doors through such common walls of contiguity, they shall be at least B label, one-hour fire doors. All construction and finish materials shall be noncombustible under standard atmospheric conditions.

NOTE: Characteristics of building construction housing hypobaric chambers and ancillary facilities are no less important to safety from fire hazards than are the characteristics of the hypobaric chambers themselves. It is conceivable that a fire emergency occurring immediately outside a chamber, given sufficient fuel, could seriously endanger the life or lives of those inside the chamber. Service facilities will in all probability be within the same building. These will also need protection while in themselves supplying life-maintaining service to those inside.

11-2.1.1.2 The room or rooms housing the hypobaric chambers and service equipment, such as described in 11-2.1.1, shall have an automatic sprinkler system installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

Exception: The sprinkler requirement in 11-2.1.1.2 is not applicable if the air intake for the emergency repressurization valve cannot be exposed to smoke or fumes.

11-2.1.2 The room housing the hypobaric chamber shall be vented sufficiently to the outside or be equipped with blow-in paneling so that the execution of the emergency "dump" procedure (see Appendix C-11-2) will not disrupt the integrity of the walls of the building. As an alternative, the piping for the "dump" valve may be exteriorized (see 11-2.2.5) provided that the valve will function within the parameters set forth in 11-2.2.5 and provided that the source of repressurization air cannot be contaminated.

11-2.2 Fabrication of the Hypobaric Chamber.

11-2.2.1 Hypobaric chambers shall be designed and fabricated to comply with the ASME *Boiler and Pressure Vessel Code*, Section VIII, "Unfired Pressure Vessels,

Division 1 or Division 2", by personnel qualified to fabricate vessels under such codes. Metal cutting and welding shall be done only by certified welders.

11-2.2.2 Flooring of Class E and Class F chambers shall be noncombustible.

11-2.2.2.1 If the procedures to be carried out in a Class E and Class F hypobaric chamber require antistatic flooring, the flooring shall be installed in accordance with Chapter 3, Use of Inhalation Anesthetics.

11-2.2.2.2 Where feasible, it is recommended that hypobaric chambers be constructed without a bilge or other enclosures that will collect dirt, dust or liquids. If a bilge is installed, the floor overlying it shall be removable for cleaning the bilge.

NOTE: It may not be feasible or practical to construct certain chambers without a bilge.

11-2.2.3 The interior of Class E and Class F chambers shall be unfinished, or treated with a finish which is inorganic zinc based or high quality epoxy or equivalent, or which is flame resistant.

11-2.2.3.1 If sound-deadening materials are employed within a hypobaric chamber, they shall be flame resistant.

11-2.2.4 A sufficient number of viewing ports and access ports for piping and monitoring and related leads shall be installed during initial fabrication of the chamber. Prudent design considerations suggest that at least 150 percent excess pass-through capacity be provided.

11-2.2.4.1 Electrical circuits that are compromised by water extinguishing agents from the external sprinkler fire extinguishing system shall be weather/drip protected.

11-2.2.4.2 Viewports shall be designed and fabricated according to ANSI/ASME PVHO-1, *Safety Standard for Pressure Vessels for Human Occupancy*.

11-2.2.5 Hypobaric chambers shall have capability for emergency repressurization of locks and chamber. Repressurization schedules shall be compatible with requirements for subject safety and with emergency rescue modes. Redundant means for repressurization shall be provided.

11-2.3 Illumination.

11-2.3.1 Whenever possible all power sources for illumination shall be mounted outside the chamber and chamber lock.

Exception: Class D chambers are exempt from this requirement.

11-2.3.1.1 Lighting fixtures used in conjunction with viewports shall be designed as specified in ANSI/ASME PVHO-1, *Safety Standard for Pressure Vessels for Human Occupancy*. Means shall be provided for changing lamps outside the chamber without disturbing inner gaskets or seals.

11-2.3.1.2 Wherever a tungsten filament lamp is employed for illumination of a hypobaric chamber or

chamber lock, a heat shield or other suitable means shall be incorporated in the fixture to prevent excessive surface temperatures.

11-2.3.1.3 Gasket material shall be of a type which permits thermal expansion and shall be suitable for the temperatures and vacuum involved. Gasket material for Class E and F chambers shall be fire resistant.

11-2.3.2 Permanent lighting fixtures installed within Class E and F chambers or locks shall comply with the requirements of NFPA 70, *National Electrical Code*, Articles 500 and 501, Class I, Division I, Group C atmospheres and shall be approved for the maximum vacuum and oxygen concentration attainable within the chamber.

11-2.3.3 Portable spot illumination, if used, shall comply with 11-2.7.3.3. In addition, the flexible cord (1) shall be of the type designated for extra-hard usage as defined in NFPA 70, *National Electrical Code*, Section 501-11; (2) shall contain a grounding conductor; and (3) shall be manufactured of fire-resistive materials approved for use in the presence of 95 ± 5 percent oxygen.

NOTE: Flexible cord may be hazardous in the limited confines of the chamber, and its use should be avoided.

11-2.4 Ventilation.

11-2.4.1 Whenever a hypobaric chamber is occupied, it shall be ventilated to avoid concentrating CO₂ and O₂ levels inside the chamber.

11-2.4.2 Individual breathing apparatus should be supplied for each occupant of the chamber for use in case air in the chamber is fouled by combustion or otherwise. Each breathing apparatus shall be available for immediate use and the source of the breathing mixture shall be independent of chamber atmosphere. The breathing gas supply shall be sufficient for simultaneous use of all breathing apparatus. Such apparatus shall function at all pressures which may be encountered in the chamber.

11-2.4.3 Sources of air for the Class D and E chamber atmosphere and for individual breathing apparatuses if these do not have self-contained supplies, shall be such that toxic or flammable gases are not introduced. Intakes shall be located so as to avoid air contaminated by exhaust from vehicles, stationary engines, or building exhaust outlets.

11-2.4.3.1 Warming or cooling of the atmosphere within the chamber may be accomplished by circulating the ambient air within the chamber over or past coils through which a constant flow of warm or cool water is circulated. Dehumidification may be accomplished through the use of cold coils; humidification, by the use of a gas-powered water nebulizer. Suitable noncombustible packing and nonflammable lubricant shall be employed on the fan shaft.

Exception: Class D chambers are exempt from this requirement.

11-2.5 Fire Extinguishment Requirements for Class E and Class F Hypobaric Facilities.

11-2.5.1 Detection of fire shall be automatic using either an ultraviolet or infrared detection system. The detection

system shall be capable of discriminating between normal chamber illumination and fire radiation. Detectors shall be located to provide constant surveillance of all areas of the chamber, its equipment and occupants. Electronic devices shall be housed and constructed of materials compatible with expected atmospheres and ambient pressures.

11-2.5.1.1 A fixed automatic extinguishing system shall be installed within all Class E and Class F chambers. The system shall discharge automatically within one-half second of sensible flame development and shall be manually operable as well.

11-2.5.1.2 Each electro-hydraulic or electro-mechanical control device should respond in less than 80 milliseconds. Each shall be furnished and installed in duplicate so as to provide redundancy of control device for even greater rapidity of system operations.

11-2.5.1.3 All chambers, manways, and air locks which communicate with each other shall be equipped with detectors, manual actuation means and water spray systems. If the communicating chambers are each to be protected by separate extinguishing systems, the water supply's hydraulic characteristics shall be capable of simultaneous operation of all systems.

11-2.5.2 A suitable control panel shall be provided to control each fire extinguishing system.

11-2.5.2.1 Standby power shall be composed of trickle-charged batteries with sufficient capacity to furnish necessary system operating energy for four continuous hours if charging source should fail. A trouble signal shall sound if charging voltage shall fail.

11-2.5.2.2 Detector wiring shall be electrically supervised to determine continuity. Integrity of all components shall be regularly checked manually with portable or fixed radiation source at each detection device. A disabling "test" switch shall be provided in the panel to prevent discharge of water from nozzles during tests.

11-2.5.2.3 Circuitry to solenoid valves or other remote system actuators shall be equipped with necessary end of line resistors and/or relays to assure maintenance of continuity. An indicating light shall be operated and an audible trouble signal shall sound if standby circuitry fails.

11-2.5.2.4 The automatic control system shall provide for double complements of remote electro-hydraulic or mechanical devices which shall be connected in a redundant manner.

11-2.5.2.5 A timer shall be furnished and adjusted to allow actuation of the fire protection system for 20-second consecutive intervals, so long as the flame detectors report a fire condition.

11-2.5.2.6 The design of the control panel shall preclude use of all time delay relays and other time-consuming devices in the system actuation circuitry.

11-2.5.2.7 Supervisory lights and audible signals shall be provided to monitor position of water supply main control valves.

11-2.5.2.8 Audible signals shall be initiated by the control panel upon either the actuation of any flame detector or initiation of water flow into the chamber.

11-2.5.2.9 Auxiliary contacts shall be made available to actuate relays or contactors in lighting and power circuits.

11-2.5.3 Suitable supervisory monitor switches shall be attached to all main water supply gate valves and connected to the fire protection control panel.

11-2.5.3.1 Audible signals shall be located exterior to the chamber at the fire protection control panel and at other designated points in the facility to alert all concerned personnel of fire or water flow in the chamber. Only water or water containing thickening or wetting agents shall be used in hypobaric chambers for fire fighting.

11-2.5.3.2 Total water demand shall be determined by multiplying total chamber floor area by 7.5 gal/ft²/min (202.9 L/m²/min). Thirty (30) psi (206.8 kPa) minimum operating water pressure at the nozzle shall be provided. Water supply shall be constantly and fully available and shall not be delayed by starting of fire pumps. Total quantity of water available for exclusive fire protection of chambers shall be adequate to furnish at least one-minute duration (three consecutive 20-second applications).

NOTE: The quantities and pressure of water for fire extinguishing indicated above are based on limited testing and should be considered subject to change as additional data become available.

11-2.5.3.3 Spray nozzles shall be placed to produce overlapping cones of water spray covering all chamber areas. They shall be equipped with remotely controlled internal valve mechanisms which will accommodate priming all piping fully with operating standby water pressure.

11-2.5.3.4 Connecting piping system shall be proven by calculation to be hydraulically adequate to produce uniform distribution of water.

11-2.5.3.5 The system design shall be such that prior to activation of the water deluge system, whether operated in the automatic or manual mode, interior chamber power shall be automatically deactivated, and the emergency lighting and communication system activated.

11-2.6 Fire Extinguishment Requirements for Class D Chambers.

11-2.6.1 A manual, portable, or fixed extinguishing capability shall be provided inside Class D chambers.

11-2.6.1.1 If installed, spray nozzles shall be capable of producing directed full cone patterns and shall be so located to impinge from all directions on all surfaces of chamber, equipment and occupants.

11-2.6.2 Only water or water containing thickening or wetting agents shall be used in hypobaric chambers for fire fighting.

11-2.6.3 Provisions shall be made to manually disconnect all power in the chamber by providing a control switch in the operator panel.

11-2.6.4 Manual fire alarm switches shall be located at the operator console or at other designated points in the facility to alert all concerned personnel of fire in or around the chamber.

11-2.7 Electrical Systems.

11-2.7.1 It is the intention of this chapter that no electrical equipment be installed or used within the chamber that is not intrinsically safe or designed and tested for use under hypobaric conditions. Control devices, whenever possible, should be installed outside of the chamber.

11-2.7.2 Source of Power to Hypobaric Chambers.

11-2.7.2.1 All hypobaric chamber service equipment, switchboards and panelboards shall be installed outside of the chamber enclosure, and be so arranged as to readily permit manual supervisory control by operators in visual contact with the chamber interior.

11-2.7.2.2 All critical electrical equipment and circuits associated with the hypobaric chamber, whether within or outside of the chamber, shall have a minimum of two independent sources of electric power.

11-2.7.2.3 All critical electrical circuits contained within the chamber, all emergency lighting, whether within or outside of the chamber, and all circuits used for communication and alarm systems shall be connected to the Emergency System, according to Chapter 8, Essential Electrical Systems for Health Care Facilities.

11-2.7.2.4 The circuits and equipment listed in 11-2.5.1.2, 11-2.5.3.1, 11-2.5.3.2 and 11-2.7.2.3 shall be so installed and connected to an alternate source of power that they will be automatically restored to operation within 10 seconds after interruption of the normal source.

Exception: Class D chambers with emergency power manual switch on the operator console are exempt from this requirement.

11-2.7.3 Electrical Wiring and Equipment.

11-2.7.3.1 All electrical equipment installed or used in a hypobaric chamber or lock shall be approved for use in Class I, Division 1, Group D locations at the highest oxygen partial pressure and lowest total pressure and oxygen concentration attainable in the chamber or lock. Electrical equipment approved as intrinsically safe shall be constructed with noncombustible insulation. (See NFPA 70, National Electrical Code, Article 500.)

Exception: Class D chambers are exempt from this requirement.

NOTE: Electrical equipment which has been tested and found suitable for explosive atmospheres at ambient pressure and normal oxygen concentration may not be suitable when used in the presence of explosive atmospheres below ambient pressure and/or above normal oxygen concentrations.

11-2.7.3.2 All electrical circuits serving equipment located adjacent to, or in the vicinity of, hypobaric chambers, the housing for which is sprinkler-protected as per 11-2.1.1.2, shall be installed to prevent water from interfering with the operation of the equipment or be equipped with a power drop capability should the sprinkler system be activated.

11-2.7.3.3 All power and light electrical circuits contained within the chamber shall be supplied from an ungrounded electrical system, fed from isolating transformers located outside of the chamber, and equipped with a Line Isolation Monitor with appropriate signal lamps as specified in Section 3-2, Requirements for All Facilities of Chapter 3, Use of Inhalation Anesthetics. It is desirable that this monitor be capable of sensing single or balanced capacitive-resistive faults, as well as leakage of current to ground.

Exception: Class D chambers are exempt from this requirement.

11-2.7.3.4 All electrical wiring installed in the hypobaric chamber shall comply with the requirements of NFPA 70, *National Electrical Code*, Articles 500 and 501, Class I, Division 1. Equipment installed therein shall be approved for use in Class I, Group C atmospheres at the maximum proposed vacuum and oxygen concentration. Either threaded rigid metal conduit or Type MI cable with termination fittings approved for the location shall be the wiring method employed. All boxes, fittings and joints shall be explosionproof. (See Article 501, NFPA 70, *National Electrical Code*.)

Exception: Class D chambers are exempt from this requirement.

11-2.7.3.5 Fixed electrical equipment within the chamber enclosure shall comply with the requirements of NFPA 70, *National Electrical Code*, Articles 500 and 501, Class I, Division 1. Equipment installed therein shall be approved for use in Class I, Group C atmospheres at the maximum vacuum and oxygen concentration attainable.

Exception: Class D chambers are exempt from this requirement.

11-2.7.3.6 Overcurrent protective devices shall comply with the requirements of NFPA 70, *National Electrical Code*, Article 240, and shall be installed outside of, and adjacent to, the hypobaric chamber. Equipment used inside the chamber may have its own individual overcurrent devices incorporated within the equipment, provided this device is approved for Class I, Division 1, Group C atmospheres at the maximum vacuum and oxygen concentration attainable. Each circuit shall have its own individual overcurrent protection in accordance with Article 240-11 of NFPA 70.

Exception: Class D chambers are exempt from this requirement.

11-2.7.3.7 Each ungrounded circuit within or partially within the chamber or lock shall be controlled by a switch outside the enclosure having a disconnecting pole for each conductor. These poles shall be ganged.

11-2.7.3.8 Switches, receptacles, and attachment plugs designed for electrical systems used in ordinary locations shall be prohibited from use in hypobaric chambers or locks because of the frequent sparks or arcs that result from their normal use. All receptacles and attachment plugs shall conform to Section 3-3, Requirements for Flammable Anesthetizing Locations of Chapter 3, Use of Inhalation Anesthetics.

Exception: Class D chambers are exempt from these requirements.

NOTE: Because of corona problem, if switches are to be used, it is recommended that they be hermetically sealed.

11-2.8 Intercommunications and Monitoring Equipment.

11-2.8.1 Intercommunications equipment is mandatory to the safe operation of hypobaric chambers.

11-2.8.1.1 All intercommunications equipment shall be approved as intrinsically safe.

11-2.8.1.2 Microphones, loudspeakers, and hand phones located in the chamber and personnel locks shall be approved as intrinsically safe at the maximum proposed vacuum and oxygen concentration. All other components of the intercommunications equipment including audio output transformers shall be located outside of the hypobaric facility.

Exception: Oxygen mask microphones with external relays designed to operate on 28 volts or less and not exceed a current of 0.25 ampere, provided they qualify as intrinsically safe for the condition of use. If push-to-talk or toggle switches are used in Class E or Class F chambers, they shall be of the hermetically sealed, pressure-tested type, with arc-suppressed circuits incorporated in the switch.

11-2.8.1.3 Voice sensors, when part of an oxygen mask, shall be approved as intrinsically safe for 95 ± 5 percent oxygen at atmospheric pressure.

11-2.8.1.4 All electrical conductors inside Class E and Class F chambers or personnel locks immediately adjacent thereto, shall be insulated with insulation that is flame resistant.

Exception: Grounds through the piping system need not be insulated.

11-2.8.1.5 The intercommunications system shall connect all chamber personnel areas and the chamber operator's control panel. All hypobaric chambers shall be equipped with a communications system with redundant capabilities.

11-2.8.2 All personnel monitoring equipment shall be located on the outside of the chamber and the monitoring leads conveyed through appropriate pass-throughs. As an alternative, approved monitors continuously purged with inert gas and designed so as not to exceed maximum safe operating temperatures and pressure changes may be employed.

11-2.8.2.1 The conductors or patient leads extending into the chamber shall be intrinsically safe at the maximum vacuum and oxygen concentration that can be encountered in the chamber or system.

11-2.8.3 Any other electrically operated equipment brought into a Class E or Class F hypobaric chamber, or installed in the chamber, including monitoring and intercommunications equipment, shall be approved for use in Class I, Division I, Group C hazardous locations at the maximum altitude and oxygen concentration that can be encountered in the chamber or system.

NOTE: Because of corona problem, if switches are to be used, it is recommended that they be hermetically sealed.

11-2.8.4 Sensors shall be installed to detect levels of carbon dioxide above 0.2 percent and carbon monoxide above 15 ppm in Class E chambers.

11-3 Administration and Maintenance.

11-3.1 General.

11-3.1.1 Purpose. Section 11-3 contains requirements for administration and maintenance which shall be followed as an adjunct to physical precautions specified in Section 11-2.

11-3.1.2 Recognition of Hazards. The hazards involved in the use of hypobaric facilities can be successfully minimized only when the hazards are recognized. All operations and maintenance personnel shall make conscious efforts to remove these hazards. The nature and degree of the hazards involved are outlined in Appendix C-11 and should be reviewed by all personnel. Since Section 11-3 is expected to be used as a reference by those responsible for preparing local guidelines for hypobaric facilities, the requirements set forth herein are frequently accompanied by explanatory text.

11-3.1.3 Responsibility.

11-3.1.3.1 Responsibility for the maintenance of safe conditions and practices both in and around hypobaric facilities falls mutually upon the governing body of the institution, all personnel using or operating the hypobaric facility, and the administration of the institution.

11-3.1.3.2 A safety director shall be appointed who shall be responsible for the safety of the operations of the hypobaric facility. (See 11-3.7.5.)

11-3.1.3.3 The complexity of hypobaric chambers is such that one person should be designated as flight supervisor, as the one in a position of responsible authority. Prior to commencing the hypobaric profile, the chamber flight supervisor shall ensure that the chamber has been appropriately preflighted and is staffed for the type of profile to be conducted.

11-3.1.3.4 In meeting its responsibilities for safe practices in hypobaric facilities, the administration of the facility shall adopt and correlate regulations and standard operating procedures to assure that both the physical qualities and the operating methods pertaining to hypobaric facilities meet the requirements of this chapter.

11-3.1.4 Rules and Regulations.

11-3.1.4.1 General. In facilities where governing directives have not been established, it is recommended that administrative, technical and professional staffs jointly consider and agree upon necessary rules and regulations for the use of hypobaric facilities. Upon adoption, copies of the rules and regulations shall be prominently posted in and around the hypobaric chamber.

11-3.1.4.2 All personnel who are to be exposed to hypobaric atmospheres shall be given physical examinations to ensure that they have no physical condition which would make exposure more hazardous for them than it would be if they were normal healthy persons.

11-3.1.4.3 All chamber operating personnel shall become familiar with emergency equipment — its purpose, applications, operations and limitations.

11-3.1.4.4 Emergency procedures best suited to the needs of the individual facility shall be established. All operating and maintenance personnel shall become thoroughly familiar with these procedures and the methods of implementing them. Operating personnel shall be trained to safely return chamber to normal atmospheric pressure when all powered equipment has been rendered inoperative.

11-3.1.4.5 A suggested outline for emergency action in the case of fire is contained in Appendix C-11-2.

11-3.1.4.6 Fire training drills shall be carried out at regular intervals.

NOTE: A calm reaction to an emergency situation can be expected only if the above recommendations are familiar to, and rehearsed by, all concerned.

11-3.1.5 General Requirements.

11-3.1.5.1 Open Flames and Hot Objects. Smoking, open flames, hot objects and ultraviolet sources which would cause premature operation of flame detectors (when installed) shall be prohibited in hypobaric facilities, both inside and outside (in the vicinity of the chamber). The immediate vicinity of the chamber is defined as the general surrounding area from which activation of the flame detector can occur.

11-3.1.5.2 The use of flammable agents inside a hypobaric chamber shall be forbidden. Burners employing natural or LP-Gas for laboratory purposes, cigarette lighters, and flammable anesthetic gases fall into this category. The use of flammable hair sprays, hair oils and facial makeup by chamber occupants shall be prohibited in Class E chambers.

Exception: When potentially flammable agents are required inside the chamber (e.g., alcohol swabs, parenteral alcohol-based pharmaceuticals, topical creams), such agents shall be approved by the safety director.

11-3.1.5.3 Parts of this chapter deal with the elements required to be incorporated into the structure of the chamber to reduce the possibility of electrostatic spark discharges which are a possible cause of ignition in hypobaric atmospheres. The elimination of static charges is dependent on the vigilance of administrative activities in materials purchase, maintenance supervision, cleaning procedures and periodic inspection and testing. It cannot be emphasized too strongly that an incomplete chain of precautions generally will increase the electrostatic hazard. For example, in research chambers where use of flammable gases is planned, conductive flooring (see 11-2.2.2.1) may contribute to the hazard unless all personnel wear conductive shoes and unless all objects in the room are electrically continuous with the floor and humidity is maintained. Maximum precautions within reason shall be taken.

11-3.1.6 Personnel.

11-3.1.6.1 All personnel entering Class E and Class F hypobaric chambers in which use of flammable gases is

planned shall be in electrical contact with the conductive floor through the wearing of conductive footwear or an alternative method of providing a path of conductivity.

11-3.1.6.2 If a patient is brought into a chamber, electrical connection to the conductive floor shall be assured by the provision of a conductive strap in contact with the patient's skin, with one end of the strap fastened to the metal frame of the table (or other equipment) meeting the requirements of Section 3-3, Flammable Anesthetizing Locations of Chapter 3, Use of Inhalation Anesthetics.

Exception: When a subject is in direct contact with a conductive mattress which is appropriately grounded.

11-3.1.6.3 Because of the possibility of percussion sparks, shoes having ferrous nails which may make contact with the floor shall not be permitted to be worn in Class E and Class F chambers.

11-3.1.6.4 Equipment of cerium, magnesium, magnesium alloys and similar manufacture shall be prohibited. (Also see Note under 11-3.3.2.)

11-3.1.6.5 The number of occupants of the chamber shall be kept to the minimum number necessary to carry out the procedure.

11-3.1.7 Textiles.

11-3.1.7.1 Cotton, silk, wool or synthetic textile materials shall not be permitted in Class E and Class F chambers, unless the fabric meets the requirements of Section 11-3.1.7.3.

11-3.1.7.2 Any paper and plastic devices or otherwise restricted materials may be used in Class E and Class F chambers at the direction of the person in charge with the concurrence of the safety director. This permission shall be stated in writing for all restricted materials employed (see 11-3.1.3.2).

11-3.1.7.3 Fabric used in Class E and Class F chambers shall meet the requirements set forth for the small scale test in NFPA 701, *Standard Methods of Fire Tests for Flame-Resistant Textiles and Films*, except that the test atmosphere shall be 95 ± 5 percent oxygen at the pressure equivalent to the maximum rating of the chamber.

11-3.1.7.4 All Class E and Class F chamber personnel shall wear garments completely covering all skin areas possible, and should be as tight fitting as possible, especially at the wrists, neck and ankles.

11-3.1.7.5 All other fabrics used in Class E and Class F chambers such as sheets, drapes, and blankets shall be inherently flame-resistant materials.

11-3.2 Denitrogenation. Personnel entering hypobaric chambers for periods of prolonged activity therein generally must be denitrogenated before exposure to reduced barometric pressure. Since fire fighting and rescue techniques require repressurization of the chamber, denitrogenation is not required for fire and rescue personnel.

11-3.3 Equipment.

11-3.3.1 All equipment used in the hypobaric facility shall comply with Section 11-2 of this chapter. This includes all electrical and mechanical equipment necessary for the operation and maintenance of the hypobaric facility, as well as any medical devices and instruments used in the facility. Use of unapproved equipment shall be prohibited.

NOTE: For cleaning of equipment, see 11-3.7.5.2.

11-3.3.1.1 Unmodified portable X-ray devices, electrocautery equipment, and other similar high-energy devices shall not be operated in the hypobaric chamber. Photographic equipment employing photoflash, flood lamps, or similar equipment shall not remain in the hypobaric chamber when the chamber is depressurized.

11-3.3.1.2 Equipment known to be, or suspected of being, defective shall not be introduced into any hypobaric chamber or used in conjunction with the operation of such chamber until repaired, tested and accepted by qualified personnel and approved by the safety director (see 11-3.1.3.2).

11-3.3.1.3 The use of paper shall be kept to a minimum. Combustible paper items such as cups, towels or tissues shall not be brought into a Class E or Class F hypobaric chamber.

11-3.3.2 Oxygen piping systems, containers, valves, fittings and interconnecting equipment shall be all metal to the extent possible. Valve seats, gaskets, hoses, and lubricants shall be selected carefully for oxygen compatibility under service conditions.

NOTE: Users should be aware that many items, if ignited in oxygen-enriched atmospheres, are not self-extinguishing. Iron alloys, aluminum and stainless steel are, to various degrees, in that category, as well as human skin, muscle and fat, and plastic tubing such as polyvinyl chloride. Testing for oxygen compatibility is very complicated. Very little data exist and many standards still have to be determined. Suppliers do not normally have facilities for testing their products in controlled atmospheres. Both static conditions as well as impact conditions are applicable. Self-ignition temperatures normally are unknown in special atmospheres.

11-3.3.3 Equipment in support of Class E and Class F chambers requiring lubrication shall be lubricated with oxygen-compatible, flame-resistant materials.

Exception: The vacuum pumps used by Class D chambers may be exempted from this requirement, depending on user requirements.

11-3.4 Handling of Gases.

11-3.4.1 Flammable gases shall not be piped into, used, or stored within or in the immediate vicinity of Class D or E hypobaric chambers. Nonflammable medical gases and breathing air may be piped into the hypobaric chambers, provided the container and contents are approved. The institution's administrative personnel shall ensure that rules and regulations are provided to ensure the safe handling of gases in the hypobaric facility (see 11-3.1.3.7).

11-3.4.2 Quantities of oxygen stored in the chamber shall be kept to a minimum. Oxygen and other gases shall not be introduced into the chamber in the liquid state.

11-3.5 Maintenance.

11-3.5.1 The hypobaric safety director shall be ultimately responsible for ensuring that all valves, regulators, meters, and similar equipment used in the hypobaric chamber are properly compensated for safe use under hypobaric conditions, and tested periodically. Life support systems, valves, controls, gauges and pressure relief valves shall be tested and calibrated periodically.

11-3.5.1.1 The hypobaric safety director shall be ultimately responsible for ensuring that all gas outlets for piped systems in the chambers are properly labeled or stenciled in accordance with ANSI Z48.1, *Standard Method of Marking Portable Compressed Gas Containers to Identify the Material Contained*; Chapter 4 of NFPA 56F, *Standard for Nonflammable Medical Gas Systems*; or a comparable DOD standard. Class D chambers that are equipped with only oxygen gas sources are exempt from this requirement.

11-3.5.1.2 Before piping systems are initially put into use, it shall be ascertained that the gas delivered at the outlet be shown on the outlet label and that proper connecting fittings are checked against their labels, in accordance with NFPA 56F, *Standard for Nonflammable Medical Gas Systems* or a comparable DOD standard.

11-3.5.1.3 Protection of inlets and outlets against animals, birds, insects and other foreign matter shall be adequate. Location of these openings shall be such as to ensure protection from damage for firesafety.

11-3.5.1.4 The guidelines set forth in Section 3-2 of Chapter 3, *Use of Inhalation Anesthetics*, or a comparable DOD standard concerning the storage, location and special precautions required for compressed gases shall be followed.

11-3.5.1.5 All storage areas shall be located remotely from the hypobaric environment.

11-3.5.2 Roentgen radiation equipment shall not be employed inside hypobaric chambers.

11-3.5.3 Maintenance Logs.

11-3.5.3.1 Installations, repairs, modifications of equipment, etc., related to the chamber should be evaluated by engineering or maintenance personnel, tested under operating pressure and approved by the Safety director. Records of the various tests shall be maintained.

11-3.5.3.2 Maintenance equipment records shall be maintained by maintenance personnel. Operating or maintenance personnel shall certify in writing that the chamber has been appropriately preflighted prior to chamber operation.

11-3.5.3.3 Cleaning routines shall be established.

11-3.5.3.4 Operating equipment logs shall not be taken inside the chamber.

11-3.6 Electrical Safeguards.

11-3.6.1 Electrical equipment shall be installed and operated in accordance with 11-2.7 of this chapter.

11-3.6.1.1 All electrical circuits shall be operationally tested before chamber depressurization. (See 11-2.7.3.3.)

11-3.6.1.2 In the event of fire, all nonessential electrical equipment within the chamber shall be de-energized insofar as possible before extinguishing the fire. Smouldering, burning electrical equipment shall be de-energized before extinguishing a localized fire involving only the equipment.

11-3.7 Electrostatic Safeguards.

11-3.7.1 General. The elimination of static charges is dependent on the vigilance of administrative activities in materials purchased, maintenance supervision, and periodic inspection and testing.

11-3.7.1.1 Textiles. Textiles used or worn in the hypobaric chamber shall conform to 11-3.1.7 of this chapter.

11-3.7.2 Maintenance.

11-3.7.2.1 Conductive Floors Where Applicable. (See Chapter 3, *Use of Inhalation Anesthetics*.)

11-3.7.2.2 Furniture.

(a) In Class E and Class F chambers equipped with conductive floors, periodic inspection shall be made of leg tips, tires, casters, or other conductive devices on furniture and equipment to ensure that they are maintained free of wax, polish, lint or other extraneous material which may insulate them and defeat the purpose for which they are used and also to avoid transporting to conductive floors such materials from other areas. Metals capable of impact sparking shall not be allowed for casters or furniture leg tips.

NOTE: Ferrous metals may cause such sparking. So may magnesium or magnesium alloys if contact is made with rusted steel.

(b) Casters shall not be lubricated with oils or other flammable materials. Such lubricants shall be oxygen compatible and flame resistant.

11-3.7.3 Testing. Conductive testing, if required, shall be in accordance with requirements in Chapter 3, *Use of Inhalation Anesthetics*.

11-3.7.3.1 Materials containing rubber may deteriorate in oxygen-enriched atmospheres. Such materials should be inspected regularly, especially at points of high stress.

11-3.7.4 Fire Protection Equipment. Electrical switches, valves and electrical monitoring equipment associated with fire detection and extinguishing shall be visually inspected before each chamber depressurization. Fire detection equipment shall be tested each week or prior to use and full testing, including discharge of extinguishing media, conducted at least annually. Testing shall include activation of trouble circuits and signals. Discharge of extinguishant may be limited to 10 percent of the system capacity provided simultaneous discharge of all systems is demonstrated.

When portable pressurized water fire extinguishers are provided inside Class D chambers, they shall be inspected prior to each depressurization. Testing of these portable units shall be in accordance with NFPA 10, *Standard on Portable Fire Extinguishers*.

11-3.7.5 Housekeeping.

11-3.7.5.1 It is absolutely essential that all areas of, and components associated with, the hypobaric chamber be kept meticulously free of grease, lint, dirt and dust. A regular housekeeping program shall be implemented whether or not the facility is in regular use. The persons assigned to this task shall be thoroughly indoctrinated in the hazards to occupants under normal operation.

11-3.7.5.2 In Class E and Class F chambers, cleaning materials that leave a flammable film shall not be used in the chamber or on any material entering the chamber; cloths and brushes that may catch and leave flammable

strands should be used with extreme care to prevent this from happening. Vacuum cleaning of walls, floors, under-flooring, shelves, cabinets, etc., of the chamber and its contents is recommended. Equipment to be used in the chamber should be cleaned, not only on the exterior, but on the interior of its cabinet where fine flammable dust may collect. The area of the facility around the chamber shall be kept tidy and clear of all unnecessary material.

Intakes and exhausts of piping within the facility or passing through exterior walls of the facility shall be inspected regularly to ensure that animal, bird and insect guards are adequate and clean, and that the area is suitably protected and has no rubbish or other storage posing a threat to proper and safe operation.

Chapter 12 Mandatory References

12-1 This chapter lists publications referenced within this document which, in whole or in part, are part of the requirements of this document.

12-1.1 NFPA Publications. The following publications are available from the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

NFPA 10-1981, *Standard for Portable Fire Extinguishers*

NFPA 13-1983, *Standard for the Installation of Sprinkler Systems*

NFPA 30-1981, *Flammable and Combustible Liquids Code*

NFPA 45-1982, *Standard for Laboratories Using Chemicals*

NFPA 49-1975, *Hazardous Chemicals Data*

NFPA 51-1983, *Standard for the Installation and Operation of Oxygen-Fuel Gas Systems for Welding and Cutting*

NFPA 54-1980, *National Fuel Gas Code*

NFPA 56F-1983, *Standard for Nonflammable Medical Gas Systems*

NFPA 58-1983, *Standard for the Storage and Handling of Liquefied Petroleum Gases*

NFPA 70-1984, *National Electrical Code*

NFPA 78-1980, *Lightning Protection Code*

NFPA 80-1983, *Standard for Fire Doors and Windows*

NFPA 90A-1981, *Standard for the Installation of Air-Conditioning and Ventilating Systems*

NFPA 101-1981, *Life Safety Code*

NFPA 220-1979, *Standard on Types of Building Construction*

NFPA 701-1977, *Standard Methods of Fire Tests for Flame Resistant Textiles and Films*

NFPA 704-1980, *Standard System for the Identification of Fire Hazards of Materials*

NFPA 801-1980, *Facilities Handling Radioactive Materials*

12-1.2 Other Publications.

12-1.2.1 The following publications are available from the Compressed Gas Association, Inc., 1235 Jefferson Davis Highway, Arlington, VA 22202.

Pamphlet C-4-1978, *Standard Method of Marking Portable Compressed Gas Containers to Identify the Material Contained* (ANSI Z48.1)

Pamphlet G-4-1980, *Oxygen*

Pamphlet G-7.1-1973, *Commodity Specification for Air* (ANSI Z86.1)

Pamphlet G-10.1-1976, *Commodity Specification for Nitrogen*

Pamphlet P-1-1974, *Safe Handling of Compressed Gases*

Pamphlet P-2-1978, *Characteristics and Safe Handling of Medical Gases*

Pamphlet P-2.5-1981, *Transfilling of High Pressure Gaseous Oxygen to be Used for Respiration*

Pamphlet V-1-1977, *Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections* (ANSI B57.1)

Pamphlet V-5-1978, *Diameter-Index Safety System*

12-1.2.2 The following publication is available from the American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ANSI/ASME PVHO-1-1978, *Safety Standard for Pressure Vessels for Human Occupancy*

12-1.2.3 The following publications are available from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D-2240-68, *Test for Indentation Hardness of Rubber and Plastics by Means of a Durometer*

ASTM D5-71, *Test for Penetration of Bituminous Material*

12-1.2.4 US Government.

(1) Printing Office, Superintendent of Documents, Washington, DC 20402.

Federal Test Method Standard No. 101B, Method 4046

Code of Federal Regulations, Title 49, parts 171 through 190

(US Dept. of Transportation, *Specifications for Transportation of Explosives & Dangerous Articles*). (In Canada, the regulations of the Board of Transport Commissioners, Union Station, Ottawa, Canada, apply).

(2) Dept. of Defense, Naval Publications & Form Center (NPFC 103), 5801 Tabor Avenue, Philadelphia, PA 19120.

MIL-Standard 104B, *Limit for Electrical Insulation Color*

12-1.2.5 The following publication is available from the American Association of Textile Chemists & Colorists, PO Box 886, Durham, NC.

AATCC Test Method 76-1972 (ANSI L14.112-1973), *Determination of the Electrical Resistivity of Fabrics*, included in 1962 Technical Manual

12-1.2.6 The following publication is available from the Underwriters Testing Laboratories, Inc., 333 Pfingsten Rd., Northbrook, IL 60062.

UL Subject 94, *Burning Tests for Plastics*

12-1.2.7 The following publications are available from the National Committee for Clinical Laboratory Standards, 771 East Lancaster Avenue, Villanova, PA 19085.

NCCLS ASI-5, *Power Requirements for Clinical Laboratory Instruments and for Laboratory Power Sources*

NCCLS ASI-1, *Preparation of Manuals for Installation, Operation and Repair of Laboratory Instruments*

12-1.2.8 The following publications are available from the American Society of Heating, Refrigeration & Air Conditioning Engineers, Inc., 345 East 47th Street, New York, NY 10017.

ASHRAE Guide and Data Book — Applications *Table on Pressure Relationships and Ventilation of Certain Hospital Areas*, published annually.

ASHRAE *Handbook of Fundamentals* (1981)

12-1.2.9 The following publications are available from the American National Standards Institute, Inc., 1430

Broadway, New York, NY 10018.

ANSI C73-1973, *Plugs and Receptacles*

ANSI C84.1-1977 (1980 Supplement), *Voltage Ratings for Electrical Power Systems and Equipment*

ANSI Z66.1-1964 (R1972), *Specifications for Paints and Coatings Accessible to Children to Minimize Dry Film Toxicity*

Appendix A Explanatory Notes to Chapters 1-11

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

A-2-2 Hazardous Area in a Flammable Anesthetizing Location. The definition in Chapter 2 of this standard is based upon the following considerations:

(a) Available data and recent investigations indicate that under customary operating procedures, flammable anesthetic mixtures are diluted by air in the anesthetizing area to a nonflammable range before reaching a vertical height of about 30 cm (or 1 ft) from any source of leakage or spillage involving quantities of anesthetics used in anesthesia procedures. These findings corroborate the premises on which safeguards required in this standard were originally based and do not negate the need for any of the protective measures required; however, they do provide a sound basis for the statement that recirculation of air in ventilating systems serving anesthetizing locations does not increase the hazards of fire and explosions from flammable anesthetic vapors.

(b) The mobile character of the operating table and portable equipment and the variety of the surgeon's techniques and surgical positions that will alter the physical relationship of the anesthesia gas machine, the surgeon, the anesthetist, and the patient's head, and all of these with respect to their relative location within the room, must be considered in the determination of the electrical safeguards to be provided.

(c) The portion of the flammable anesthetizing location extending 152 cm (5 ft) above the floor as defined in Chapter 2 constitutes a "hazardous area." Because persons entering such anesthetizing locations may have accumulated electrostatic charges, the floor of corridors and rooms contiguous to the flammable inhalation anesthetizing location must be conductive and at the same potential as the floor in the flammable anesthetizing location. Patients should not be transported while flammable anesthetics are being administered. Rooms such as sterilizing rooms directly communicating with flammable anesthetizing locations are required by 3-3.2.3 to be provided with conductive floors to equalize static charges. Such charges, if not used as flammable anesthetizing locations, are not required to be served by explosionproof wiring specified in 3-3.4.1.1. Where flammable anesthetizing locations open directly on a passageway not a part of an operating room or delivery room, the conductive floor should extend 3 m (9.84 ft) either side of the door frame and the width of the passageway of 3 m (9.84 ft). It is desirable to demarcate the hazardous location of such a corridor by a physical barrier (doors) and cautionary signs to check smoking, use of open flame, wearing of improper clothing and shoes, and the application of insulating floor wax.

(d) Designated areas in which the use and handling of flammable anesthetic agents are prohibited by hospital regulations, such as corridors in the surgical suite and rooms adjacent to flammable anesthetizing locations and nonflammable anesthetizing locations, should be indicated by prominent signs permanently installed (*see Appendix A-3-3.7.2.2*).

(e) Post-operative recovery units which are not immediately adjacent to flammable anesthetizing locations and in which the use of flammable anesthetic agents is prohibited are not considered to involve explosion hazards and therefore do not require the installation of static-dissipation systems nor explosionproof equipment required for explosive atmospheres. Prohibition of the use of flammable anesthetic agents by hospital regulation and the proper indication of such prohibition by prominent signs, as recommended in subsection (c) above, is recommended.

A-2-2 Hazardous Chemical. For hazard ratings of many chemicals, see NFPA 49, *Hazardous Chemicals Data*, and NFPA 325M, *Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*.

A-2-2 Nonflammable Anesthetic Agent. It is possible to halogenate a compound, and render it partially or totally nonflammable by the substitution of one or more halogens (e.g., fluorine, chlorine, bromine) for hydrogen. Thus halothane (CF_3CHClBr) is almost completely halogenated and is nonflammable. Methoxyflurane ($\text{CF}_2\text{CCl}_2\text{OCH}_3$) is partially halogenated and is nonflammable in conditions which are encountered during clinical anesthesia (if it is heated its vapor concentration will increase enough to burn). Fluroxene ($\text{CF}_3\text{CH}_2\text{OCHCH}_2$) is halogenated even less; it is flammable in concentrations of four percent or greater.

The following agents are considered flammable during conditions of clinical use in anesthesia:

cyclopropane	ethylene
divinyl ether	ethyl ether
ethyl chloride	

The following agent is flammable during use in clinical anesthesia in higher concentrations:

fluroxene

NOTE: Because fluroxene is flammable under certain conditions of use, it is listed as a flammable agent. Concentrations required for induction of anesthesia generally exceed four percent, and are flammable. Maintenance of fluroxene anesthesia may be accomplished with concentrations of less than four percent, however.

The following agents are nonflammable during conditions of use in clinical anesthesia:

chloroform	nitrous oxide
halothane	trichloroethylene
methoxyflurane	enflurane

A-2-2 Oxygen-Enriched Atmosphere. The degree of fire hazard of an oxygen-enriched atmosphere varies with the concentration of oxygen and diluent gas, and the total pressure. The definition contained in the current edition of NFPA 53M, *Manual on Fire Hazards in Oxygen-Enriched Atmospheres*, and in editions of NFPA 56D prior to 1982, did not necessarily reflect the increased fire hazard of hyperbaric and hypobaric atmospheres.

The present definition for Chapters 10 and 11 defines an oxygen-enriched atmosphere with an increased fire hazard, as related to the increased burning rate of material in the atmosphere. It is based upon a 1.2 cm/second burning rate (at 23.5 percent oxygen at 1 atmosphere absolute) as described in Figure A-2-2 from "Technical Memorandum UCRI-721, Chamber Fire Safety," by Schmidt, Dorr & Hamilton (Ocean Systems Inc., Research & Development Lab, Tarrytown, NY 01591). (*See Figure A-2-2*).

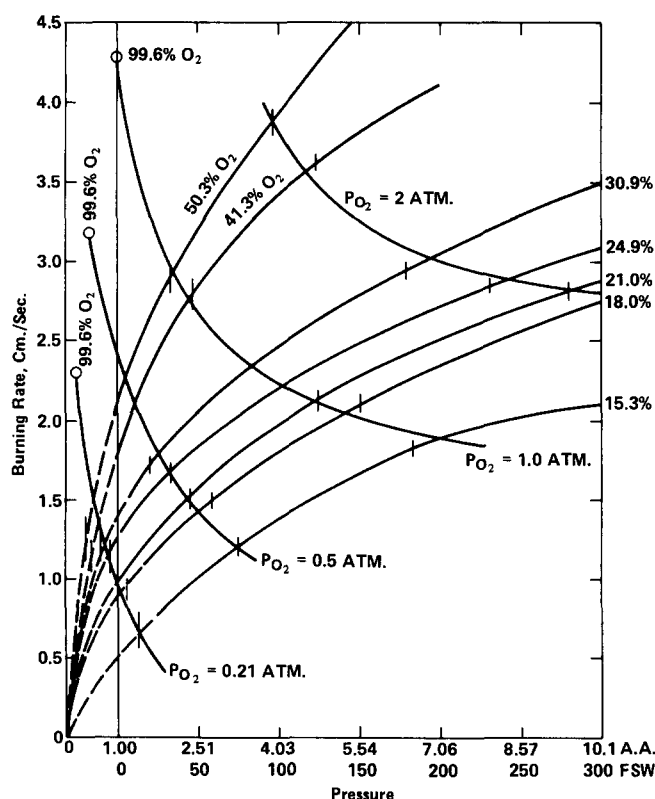


Figure A-2-2. Burning rates of filter paper strips at an angle of 45 degrees in N_2-O_2 mixtures. (From Figure 4, "Technical Memorandum UCRI-721, Chamber Fire Safety," T. C. Schmidt, V. A. Dorr and R. W. Hamilton Jr., Ocean Systems, Inc. Research and Development Laboratory, Tarrytown, New York 10591. Work carried out under US Office of Naval Research, Washington, DC, Contract No. N00014-67-A-0214-0013.)

A-2-2 Storage Cabinet. Some local jurisdictions require bottom-venting of flammable liquids storage cabinets. While this is not required by NFPA 30, *Flammable and Combustible Liquids Code*, some manufacturers provide a plugged vent connection on one side of the cabinet, close to the base, to accommodate these local jurisdictions.

A-3-1.4 In determining whether existing construction or equipment does or does not constitute a hazard to life, due consideration should be given the record of incidents or accidents of the facility in question and whether equipment used in the facility is subject to documented preventive maintenance. Absence of incidents and accidents, and the existence of a well-documented preventive maintenance program covering all electrical equipment used in anesthetizing locations in the facility, indicates that minimal hazard to life exists.

For example, isolated power systems would not be required in existing anesthetizing locations in health care facilities meeting the above criteria.

A-3-2.1.1 Ventilation of Anesthetizing Locations. Mechanical ventilation is required as a means of diluting flammable gases and maintaining the proper humidity. It is also the most effective and aseptic method of maintaining a uniform humidity within the area.

General: Anesthetizing locations used solely for the induction of anesthesia need only be ventilated at a rate sufficient to maintain the proper humidity.

Anesthetizing locations in which clinical procedures are performed, such as operating rooms, delivery rooms, and certain treatment rooms, require special ventilation as described below. This special ventilation serves not only to maintain humidity but also reduces the hazard of infection which is accomplished by dilution and removal of airborne microbial contamination and dilutes flammable gases. It also contributes to odor control and comfort of personnel.

The Committee recognizes that a hazard may be created by the chronic exposure of anesthesia and other operating room personnel to low concentration of vapors or commonly employed volatile liquid inhalation anesthetic agents. For further information see:

(a) Cohen, E. N., et al. "Anesthesia, Pregnancy and Miscarriage; A Study of Operating Room Nurses and Anesthetists." *Anesthesiology* 35:343, 1971.

(b) Whitcher, C. E., et al. "Chronic Exposure to Anesthetic Gas in the Operating Room," *Anesthesiology* 35:348, 1971.

(c) Yanagida, H., et al. "Nitrous Oxide Content in the Operating Suite," *Anesthesia and Analgesia* 53:347, 1974.

(d) Frey, R., et al. "How Strong Is the Influence of Chronic Exposure to Inhalation Anesthetics on Personnel Working in Operating Theatres?" *W.F.S.A. Newsletter* No. 10, June 1974.

The Health Hazard

(a) Cohen, E. N., et al. "Occupational disease among operating room personnel — a national study," *Anesthesiology* 41:321-340, 1974.

(b) Spence, A. A., et al. "Occupational hazards for operating room-based physicians," *J. Am. Med. Assoc.* 238:955-959, 1977.

(c) Cohen, E. N., et al. "A survey of anesthetic health hazards among dentists," *J. Am. Dent. Assoc.* 90:1291-1296, 1975.

(d) Greene, N., "Report on American Cancer Society study of causes of death amongst anesthetists." Annual Meeting, American Society of Anesthesiologists, New Orleans, Louisiana, October 18, 1977.

(e) Hazleton Laboratories America, Inc. Final Reports, CDC-99-74-46, National Institute for Occupational Safety and Health, 1014 Broadway, Cincinnati, Ohio. "Long-term inhalation reproductive and teratogenic toxicity evaluation of nitrous oxide plus halothane," 14 Nov. 1975. "Cytogenic evaluation of spermatogonial cells in the rat following long-term inhalation exposure to nitrous oxide plus halothane," 17 Nov. 1976.

(f) Chang, W. C., et al. "Ultrastructural changes in the nervous system after chronic exposure to halothane," *Exp. Neurol.* 45:209-219, 1974.

(g) Quimby, K. L., et al. "Behavioral consequences in rats from chronic exposure to 10 ppm halothane during early development," *Anesth. Analg.* 54:628-633, 1975.

(h) Kripke, B. J., et al. "Testicular reaction to prolonged exposure to nitrous oxide," *Anesthesiology* 44:104-113, 1976.

(i) Fink, B. R., ed. *Toxicity of Anesthetics*. Part Four, "Teratogenic effects." Baltimore, Williams & Wilkins Co., 1968, 308-323.

(j) Bruce, D. L., et al. "Trace anesthetic effects on perceptual, cognitive and motor skills," *Anesthesiology* 40:453-458, 1973.

(k) Bruce, D. L., Bach, M. J. "Psychological studies of human performance as affected by traces of enflurane and nitrous oxide," *Anesthesiology* 42:194-196, 1975.

(l) Smith, G., Shirley, A. W. "Failure to demonstrate effects of low concentrations of nitrous oxide and halothane on psychomotor performance," *Br. J. Anaesth.* 48:274, 1976.

(m) Davison, L. A., et al. "Psychological effects of halothane and isoflurane anesthesia," *Anesthesiology* 43:313-324, 1975.

(n) Walts, L. F., et al. Critique: "Occupational disease among operating room personnel," *Anesthesiology* 42:608-611, 1975.

(o) Cohen, E. W., Brown, B. W. Comment on the critique, *Anesthesiology* 42:765-766, 1975.

(p) Fink, B. R., Cullen, B. F. "Anesthetic pollution: what is happening to us?" *Anesthesiology* 45:79-83, 1976.

(q) Lecky, J. H. "Chronic exposure to anesthetic trace levels," *Complications in Anesthesia* edited by L. H. Cooperman and F. K. Orkin. J. B. Lippincott Co., Phila. In press.

Reduction and Control Methods

(a) Pisiali, R. L., et al. "Distribution of waste anesthetic gases in the operating room air," *Anesthesiology* 45:487-494, 1976.

(b) Whitcher, C. E. et al. "Control of occupational exposure to nitrous oxide in the dental operatory," *J. Am. Dent. Assoc.* 95:763-766, 1977.

(c) Muravchick, S. "Scavenging enflurane from extracorporeal pump oxygenators," *Anesthesiology* 47:468-471, 1977.

(d) Whitcher, C. E., et al. "Development and evaluation of methods for the elimination of waste anesthetic gases and vapors in hospitals," HEW Publication No. (NIOSH) 75-137, GPO stock no. 1733-0071. Supt. of Documents, Govt. Print. Off., 1975.

(e) Whitcher, C. E. et al. "Control of occupational exposure to N₂O in the dental operatory," HEW Publication No. (NIOSH) 77-171. Cincinnati, US Department of Health, Education and Welfare, Public Health Services Center for Disease Control, National Institute for Occupational Safety and Health.

(f) Lecky, J. H., et al. *In-House Manual for the Control of Anesthetic Gas Contamination in the Operating Room*, University of Pennsylvania Hospital publication.

(g) Lecky, J. H. "The mechanical aspects of anesthetic pollution control," *Anesthesia and Analgesia* 56:769, 1977.

Dealing with Personnel

(a) Lecky, J. H. "Notice to Employees on the Potential Health Hazards Associated with Occupational Expo-

sure to Anesthetics." University of Pennsylvania Hospital publication.

NIOSH — OSHA

(a) "Criteria for a Recommended Standard: Occupation Exposure to Waste Anesthetic Gases and Vapors," HEW Publication No. (NIOSH) 77-140. Cincinnati, US Department of Health, Education and Welfare, Public Health Service Center for Disease Control, National Institute for Occupational Safety and Health.

ANSI-Z79

(a) American National Standards Institute, Committee Z-79, SC-4 *Anesthesia Gas Scavenging Devices and Disposal Systems*, J. H. Lecky, M.D., Chairman, ANSI/Z79.11-1982.

A prudent course of action pending further data on this topic lies in the installation of a gas scavenging system for use when inhalation anesthetic techniques are employed with gas flows in excess of metabolic and anesthetic requirements. Care must be taken in the selection and application of any such system to a gas anesthesia apparatus or anesthesia ventilator to avoid exposing the breathing circuit to any pressure less than atmospheric, and also to avoid the dumping of any flammable vapors into a central suction system not designed for such operation.

Operating Rooms, Delivery Rooms, and Special Procedure Rooms: Ventilation air should be supplied from several outlets located on the ceiling or high on the walls of the location. Air should be exhausted by several inlets located near the floor on opposite walls. The air distribution pattern should move air down and through the location with a minimum of draft to the floor for exhaust.

Studies indicate that an air change rate equivalent to 25 room volumes of air per hour dilute bacteria dispersed into the room by human activity. When properly filtered, 80 percent may be recirculated with no more microbial contamination than 100 percent outdoor air filtered in the same manner. (See ASHRAE Guide and Data Book—Applications, Chapter 14, "Table on Pressure Relationships and Ventilation of Certain Hospitals Areas," 1969.)

A positive air pressure relative to the air pressure of adjoining areas should be maintained in the anesthetizing location. This is accomplished by supplying more air to the location than is exhausted from it. Such pressurization will eliminate the infiltration of contaminated air around perimeter openings of door closures or other wall openings during clinical procedures.

Ventilation systems should incorporate air filters with an efficiency of not less than 90 percent when tested in accordance with methods for *Testing Air Cleaning Devices Used in General Ventilation for Removing Particulate Matter*, ASHRAE 52-68 (summarized in ASHRAE Guide and Data Book—Equipment, 1969, Chapter 10).

Humidity Control: The ventilation system must incorporate humidity equipment and controls to maintain a relative humidity of at least 50 percent or as provided in 3-2.1.1.1. Although the high level of humidity is not sufficiently reliable for complete dissipation of electrostatic charges, this humidity does reduce the hazard of electro-

static spark discharges under many conditions. The control of air-borne bacteria is facilitated in this range of humidity.

Temperature: The temperature to be maintained in operating rooms should be chosen on the basis of the well-being of patient and operating teams. It is recommended that the equipment provide for a room temperature in a range of 20°C (68°F) to 24°C (75°F) with controls for selecting any desired temperature within this range.

A-3-2.2.2.5 Pin-Index Safety System. The Pin-Index Safety System consists of a combination of two pins projecting from the yoke assembly of the apparatus and so positioned as to fit into matching holes drilled into the cylinder valves. It is intended to provide against the possibility of error in attaching the flush-type valves, with which gas cylinders and other sources of gas supply are equipped, to gas apparatus having yoke connections.

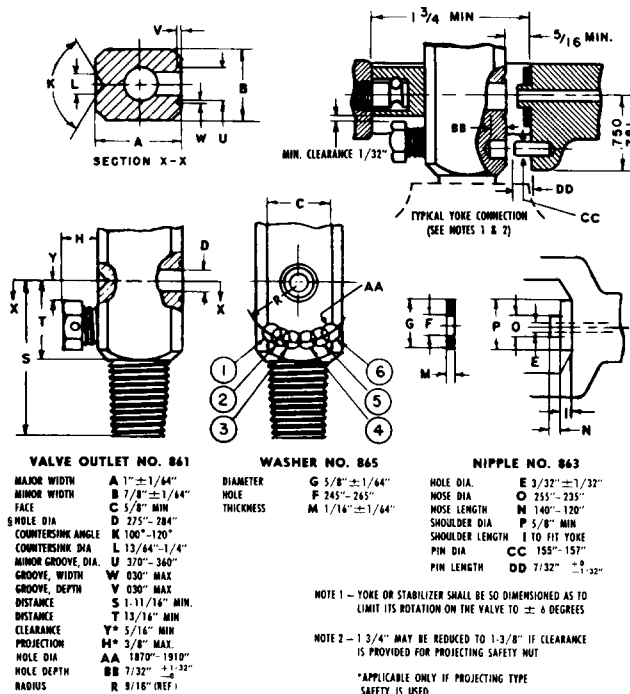
Fabrication specifications are contained in CGA Pamphlet V-1 (ANSI B57.1), *Compressed Gas Cylinder Valve Outlet and Inlet Connections*. Connection No. 860 shown in Figure A-3-2.2.2.5 illustrates the system. Connection Nos. 870 (Oxygen, Medical), 880 (Oxygen-Carbon Dioxide Mixture), 890 (Oxygen-Helium Mixture), 900 (Ethylene), 910 (Nitrous Oxide), 920 (Cyclopropane), 930 (Helium), and 940 (Carbon Dioxide) are for specific medical gases and gas mixtures and utilize the basic dimensions of Connection 860.

COMPRESSED GAS ASSOCIATION, INC.
NEW YORK, N. Y.

CONNECTION NO. 860

YOKE OUTLET FOR MEDICAL GASES

STANDARD FLUSH OUTLET CYLINDER VALVE YOKES CONNECTION
BASIC DIMENSIONS FOR CONNECTION NUMBERS 870 THRU 940, INCLUSIVE



§Must be central within .010". Break sharp edge on outlet hole and gasket groove.

Figure A-3-2.2.5

A-3-3.3 Electric Distribution. The ungrounded electrical distribution system specified in 3-3.3.1.1 is intended to reduce the possibility of electric shocks and recurring arcs and sparks in the event of insulation failure of the electrical wiring system in anesthetizing locations. Because of the difficulty of achieving a sufficiently high level of insulation to permit operation of a Line Isolation Monitor, and in recognition of evolving capabilities in medical care, an Exception has been made so that permanently installed equipment as well as nonadjustable lighting fixtures in specified locations need not be supplied by the ungrounded system.

A-3-2.3.2 Grounding. Patient protection is provided primarily by an adequate grounding system. The ungrounded secondary of the isolation transformer reduces the cross-sectional area of grounding conductors necessary to protect the patient against voltage resulting from fault current by reducing the maximum current in case of a single probable fault in the grounding system. The Line Isolation Monitor is used to provide warning when a single fault occurs. Excessive current in the grounding conductors will not result in a hazard to the patient unless a second fault occurs. If the current in the grounding system does not exceed 10 milliamperes, even under fault conditions, the voltage across 3 m (9.84 ft) of AWG No. 12 wire will not exceed 0.2 millivolt, and the voltage across 3 m (9.84 ft) of AWG No. 18 grounding conductor in a flexible cord will not exceed 0.8 millivolt. Allowing 0.1 millivolt across each connector, the voltage between two pieces of patient-connected equipment will not exceed two millivolts.

The reference grounding point is intended to assure that all electrically conductive surfaces of the building structure, which may receive heavy fault currents from ordinary (grounded) circuits, are grounded in a manner to bypass these heavy currents from the operating room.

A-3-2.3.2.1 Grounding and Leakage Current Measurement Circuits. Effective grounding to safely handle both fault and leakage currents requires both following the requirements of Chapter 3 and NFPA 70, *National Electrical Code*, having good workmanship and using some techniques that are not in these documents.

The performance of the grounding system is made effective both through the existence of the green grounding wire, the metal raceway and all of the other building metal. Measurements have shown that it is the metal raceway and building steel that provides most of the effective grounding path of less than 10 milliohms at the receptacle including plug to receptacle impedance. The green grounding wire become a back-up, not a primary grounding path performer.

Good practice calls for each receptacle to have a good jumper grounding connection to the metal raceway at the receptacle location in addition to having the green grounding wire connecting these points to the grounding bus in the distribution panel. The good workmanship includes seeing that these grounding connections are tight at each receptacle and that all metal raceway joints are secure and tight.

The voltage difference measurements listed in 3-2.3.2.1 in connection with power distribution grounding systems should ideally be made with an oscilloscope or spectrum analyzer in order to observe and measure components of leakage current and voltage differences at all frequencies.

For routine testing, such instruments may be inconvenient. An alternative is to use a metering system which weighs the contribution to the meter reading of the various components of the signal being measured in accordance with their probable physiological effect.

A meter specifically designed for this purpose would have an impedance of approximately 1000 ohms, and a frequency characteristic which was flat to 1 kHz, dropped at the rate of 20 decibels per decade to 100 kHz, and then remained flat to 1 MHz or higher. This frequency response characteristic could be achieved by proper design of the internal circuits of the amplifier which probably precedes the indicating instrument, or by appropriate choice of a feedback network around the amplifier. These details are, of course, left to the instrument designer.

If a meter specifically designed for these measurements is not available, a general purpose laboratory millivoltmeter can be adapted for the purpose by adding a frequency response shaping network ahead of the meter. One such suggested network is shown in Figure A-3-2.3.2.1(a).

The circuit shown in Figure A-3-2.3.2.1(a) is especially applicable to measurements of leakage current, where the current being measured is derived from a circuit whose

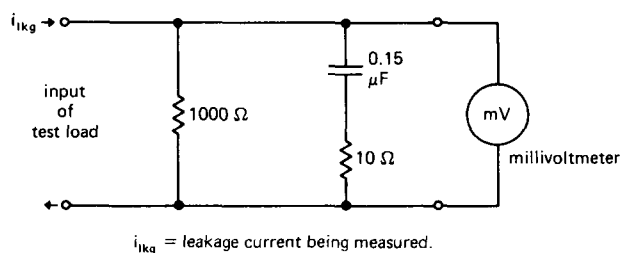


Figure A-3-2.3.2.1(a)

source impedance is high compared to 1000 ohms. Under these conditions, the voltage developed across the millivoltmeter will be proportional to the impedance of the network. The network impedance will be 1000 ohms at low frequencies, 10 ohms at high frequencies, and the transition between these two values will occur in the frequency range between 1 kHz and 100 kHz.

The basic low-frequency sensitivity will be one millivolt of meter reading for each one microampere of leakage current.

The millivoltmeter's own input impedance needs to be very large compared to 1000 ohms (100 kilohms), and the meter should have a flat frequency response to well beyond 100 kHz (if the meter impedance is lower than 100 kilohms, then the 1000-ohm resistor can be raised to a higher value, such that the impedance of that resistor in parallel with the meter will still be 1000 ohms).

The circuit of Figure A-3-2.3.2.1(a) can be used for the voltage difference measurements required in Section 3-2, but, because the source impedance will be very low compared to 1000 ohms, the frequency response of the measurement system will remain flat. If any high-frequency components, produced, for example, by pickup from nearby radio frequency transmitters, appear on the circuit being measured, then they will not be attenuated and the meter reading will be higher than it should be.

For meter readings below any prescribed limits this possible error is of no consequence. For borderline cases it could be significant. To avoid this uncertainty when making voltage difference measurements a slightly more elaborate version of a frequency response shaping network is given in Figure A-3-2.3.2.1 (b).

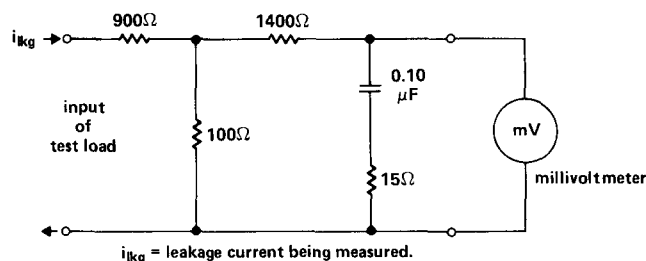


Figure A-3-2.3.2.1(b)

Here the source being measured is separated from the frequency response shaping network by the combination of the 900-ohm and 100-ohm resistors. The frequency response characteristic is now independent of the circuit being tested.

This independence is achieved, however, at a loss in signal delivered to the millivoltmeter. The basic low-frequency sensitivity of this metering circuit is one millivolt of meter reading for ten microamperes of leakage current, or on a voltage basis, one millivolt of meter reading for ten millivolts at the input terminals of the network.

The millivoltmeter should have an input impedance of 150 kilohms, and a frequency response flat to well beyond 100 kHz.

For either of the suggested networks, the resistors and capacitors should be mounted in a metal container close to the millivoltmeter to avoid stray pickup by the leads going to the meter.

A-3-2.7.3.7 Hazards During Transport of Anesthetized Patients. Transportation of patients while an inhalation anesthetic is being administered from a machine separate from the table supporting the patient has resulted in injury or death of patients. Two hazards have been recognized: significant accumulation of electrostatic charge and mechanical disruption of the anesthesia circuit. Respiratory tract damage has resulted due to tugging of indwelling tubes when the anesthesia machine was not moved with the operating table. Asphyxiation resulted when the rebreathing tubes became detached and were reconnected to the wrong nipples.

A-3-2.7.5 Safe Practice for Cylinders Containing Compressed Gases.

Specifications for Cylinders. All cylinders containing compressed gases, such as anesthetic gases, oxygen, or other gases used for medicinal purposes, whether these gases are flammable or not, should comply with the specifications and shall be maintained in accordance with regulations of the US Department of Transportation.

A-3-3.6.2 Conductive Flooring. A conductive floor serves as a convenient means of electrically connecting persons and objects together to prevent the accumulation of electrostatic charges.

A resistance not exceeding 50 megohms between objects or persons is generally sufficient to prevent accumulation of dangerous voltages. The upper limit of 1,000,000 ohms for the resistance of the floor has been chosen as meeting this requirement with a reasonable factor of safety and with reasonable provision for other resistances in the conductive path.

The resistance of some flooring materials changes with age. Floors of such materials should have an initial resistance that permits changes in resistance with age without exceeding the limits prescribed in 3-3.6.2.3 and 3-3.6.2.4.

A-3-3.6.9 In its requirement for furniture in a flammable anesthetizing location to be constructed of conductive materials, the Committee specifically intends that any shelves within such furniture as well as the top also be conductive. Furniture is intended to include movable and permanently installed objects in the room, such as stools, tables and cabinets. Wooden racks, however, are permitted for storage of cylinders of flammable as well as nonflammable gases.

A-3-3.7.2.2 The use of flammable anesthetic agents is not uncommon in such areas as in cystoscopy rooms and in emergency units. Such areas must be properly equipped for safe administration of flammable agents, and administrative regulations must apply unless the use of flammable anesthetics in the area is specifically prohibited by an official and specific resolution of the governing board of the hospital, and a conspicuous sign detailing the prohibition is posted in the area.

A-3-3.7.3.1 Personnel. One method for electrically connecting all persons to conductive floors is through the wearing of shoes conforming to the following specifications:

Each shoe having a sole and heel of conductive rubber, conductive leather, or equivalent material, should be so fabricated that the resistance between a metal electrode placed inside the shoe and making contact with the inner sole equivalent in pressure and area to normal contact with the foot, and a metal plate making contact with the bottom of the shoe, equivalent in pressure and area to normal contact with the floor, be not more than 250,000 ohms.

A-3-4.4 The provision for testing the conductivity of floors once in nonflammable anesthetizing locations is intended to circumvent the need for monthly tests of the approximately 90 percent of such floors which increase in resistivity (decrease in conductivity) as they age.

A-4-3.4.2 Fabrication specifications are contained in CGA Pamphlet V-1 (ANSI B57.1), *Compressed Gas Cylinder Valve Outlet and Inlet Connections*. Connection No. 860 shown in that document illustrates the system. Connection Nos. 870 (Oxygen, Medical), 880 (Oxygen-Carbon Dioxide Mixture), 890 (Oxygen-Helium Mixture), 900 (Ethylene), 910 (Nitrous Oxide), 920 (Cyclopropane), 930 (Helium), and 940 (Carbon Dioxide) are for specific medical gases and gas mixtures and utilize the basic dimensions of Connection 860.

A-4-3.4.3 Pin-Index Safety System: The Pin-Index Safety System consists of a combination of two pins projecting from the yoke assembly of the apparatus and so positioned as to fit into matching holes drilled into the cylinder valves. It is intended to provide against the possibility of error in attaching the flush-type valves, with which gas cylinders and other sources of gas supply are equipped, to gas apparatus having yoke connections.

A-6-2.2 Number of Terminals (Inlets) and Usage Groups.

Table A-6-2.2 sets forth the recommended minimum number of system terminals (inlets) and Table A-6-2.2(a) establishes usage Groups A and B. Table A-6-2.2(a) should be used in conjunction with Table A-6-2.2(b) and Appendix C-6-1 for determining proper pipe and pump sizing. The Group A classification represents a more critical and more frequently used vacuum terminal (inlet) than the Group B classification.

A-6-3.1 Recommended Vacuum Source Sizing.

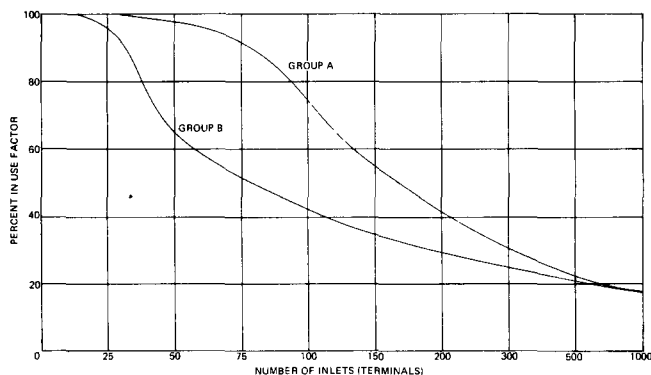
Unweighted System Demand. Pump sizing is based upon first determining the total number of terminals (inlets) in each of Groups A and B. These totals, each multiplied by 0.25 SCFM, provide the two basic figures necessary to calculate total demand on the system.

Table A-6-2.2(a)
Number of Vacuum Terminals (Inlets) Without
Waste Anesthetic Gas Disposal

	Minimum Terminal Units Recommended	Usage Group
Anesthetizing Locations		
Operating Rooms	3/rm	A
Cystoscopy	3/rm	A
Delivery	3/rm	A
Special Procedures	3/rm	A
Other Anesthetizing Locations	3/rm	A
Acute Care Locations (Non-Anesthetizing Locations)		
Recovery Room	3/bed	A
ICUs (Except Cardiac)	3/bed	A
Special Procedures	2/rm	A
Emergency Room	1/bed	A
Emergency Rooms - Major Trauma	3/bed	A
Cardiac ICU (CCU)	2/bed	A
Catheterization Lab	2/rm	B
Surgical Excision Rooms	1/rm	B
Dialysis Unit	(1/2)/bed	B
Subacute Care Areas (Non-Anesthetizing Locations)		
Nurseries	1/bed	B
Patient Rooms	1/bed	B
Exam & Treatment Rooms	1/bed	B
Respiratory Care	Convenience	
Other		
Autopsy	1/table	B
Central Supply	Convenience	B
Equipment Repair, Calibration & Teaching	Convenience	B

[See Table A-6-2.2(b).]

Table A-6-2.2(b) Simultaneous Use Curves



NOTE 1: If the medical-surgical vacuum system is to be used for the disposal of waste anesthetic gases caution must be taken to ensure that the system is designed for the additional volume required. It is recommended that 6-6.2.3, Waste Anesthetic Gas Disposal, be consulted as well. It is essential that the design team consult with medical and hospital staff when determining the minimum terminal units.

NOTE 2: It should be understood that the percentage in use factors obtained from Table A-6-2.2(b) represent an average hospital. Hospitals with heavier-than-average use may require higher use factors.

Percentage in Use Factor. The two SCFM totals thus determined (one for each group) are multiplied by the appropriate "percent in use" factor as shown on the curves illustrated in Table A-6-2.2(b), Simultaneous Use Curves.

Total Weighted System Demand. Adding these two calculated demand totals (for Groups A and B) and, in addition, allowing 1.5 SCFM for each operating room provides the total system demand and the required vacuum pump capacity. The pump should be selected to handle this flow or the maximum flow established for mains, whichever is higher.

Summary. The basic sizing formula is:

Vacuum Pump Size (SCFM) =

$$N_A \times 0.25 \times U.F._A + N_B \times 0.25 \times U.F._B + N_{OR} \times 1.5$$

Where: N_A = number of A type terminals

N_B = number of B type terminals

$U.F._A$ = use factor for A type terminal total

$U.F._B$ = use factor for B type terminal total

N_{OR} = number of operating rooms

A-6-3.1.8 Vibration can possibly cause motor deterioration and premature piping failures. Excessive noise can interfere with trouble alarms being heard.

A-6-3.2.2 Recommended Minimum Pipe Sizing.

Branch and Riser Sizing. Branch sizing should be on the basis of a flow into the system of 1.5 SCFM per terminal (inlet) served, as described in Table A-6-2.2(a), commencing with the terminal (inlet) on the branch furthestmost from the vacuum source(s) until all of the terminals in a room have been accommodated. Branch lines serving more than one room should be sized as mains in

accordance with A-6-3.2.2.2. Operating room suites, ICU suites, and the like, comprising several rooms, should be treated as one room. Risers should be sized in the same manner as for branches.

Mains. Sizing should be on the basis of 0.25 SCFM per terminal (inlet) served, as described in Appendix C-6-1, with the further provision that the size of any main line should not be less than the largest pipe in any branch served by that main. The flow rate to be handled at any point in the main should be computed on the number of A and B terminals connected thereto, multiplied by 0.25 SCFM, the simultaneous use percentage plus the allowance of 1.5 SCFM per operating room, or the flow from the largest branch served, whichever is greater.

A-7-1.3.1 Chapter 7 includes many special operational requirements which should be used in all laboratories affiliated with health care facilities, even those located in separate buildings where there may be no patients incapable of self-preservation.

NFPA 45, *Fire Protection Standard for Laboratories Using Chemicals*, contains comprehensive general requirements for laboratories which can be used for additional reference.

A-7-2.1 Before a hazardous chemical is ordered, controls should be established to assure that adequate facilities and procedures are available for receiving, storing, using, and disposing of the material. Information sources include:

NFPA 49, *Hazardous Chemicals Data*

NFPA 491M, *Manual of Hazardous Chemical Reactions*

NFPA 325M, *Fire Hazard Properties of Flammable Liquids, Gases and Volatile Solids*

Flash Point Index of Trade-Name Liquids

Class IA and IB flammable liquids in glass containers larger than the 1 quart (0.91 L) sizes should be transported in suitable containers of sufficient size to hold the contents of the glass containers.

A-7-2.2.3.3 Laboratory personnel should be thoroughly indoctrinated in procedures to follow in cases of clothing fires. The single most important instruction, one which should be stressed until it becomes second nature to all personnel, is to immediately drop to the floor and roll. All personnel should recognize that, in case of ignition of another person's clothing, they should immediately knock that person to the floor and roll that person around to smother the flames. Too often a person will panic if his clothing ignites and will run, resulting in more severe, often fatal burn injuries.

It should be emphasized that safety showers or fire blankets are of secondary importance. They should be used only when immediately at hand. It should also be recognized that rolling on the floor not only smothers the fire, but also helps to keep flames out of the victim's face and reduce inhalation of smoke. Improper use of fire blankets can increase the severity of smoke and fire injuries if the blanket funnels smoke towards the face or if the blanket is not removed after the flames have been extinguished.

A-7-3.1 The types of construction are defined in NFPA 220, *Standard on Types of Building Construction*. Also, for a discussion of fire-resistive construction and fire resistance of building materials and construction assemblies, see NFPA *Fire Protection Handbook*. For information on the fire resistance, installation, and maintenance of fire doors, see NFPA 80, *Standard for Fire Doors and Windows*.

A-7-3.2.1 A door to an adjoining laboratory work area or laboratory unit is considered to be a second access to an exit.

A-7-3.3.1.2 One method of safeguarding unattended processes is to place the equipment in a pan large enough to contain any spilled materials, preferably within a fume hood protected by some form of automatic fire extinguishment or detection.

A-7-3.3.2.2 One reason for requiring testing of all electrical equipment used in the laboratory is to provide minimum assurance against electrical macroshock hazards.

A-7-3.3.2.3 Electrical equipment has been a frequent source of ignition of flammable concentrations of gases and vapors when combustible and flammable liquids and gases have been used in or near equipment not designed or safe for such use. While general and special ventilation will usually prevent the accumulation of flammable concentrations of gases and vapors in health care laboratories, the hazards should be recognized. Recommended practice is to evaluate at least annually what combustible and flammable liquids and gases are being used in the laboratory, what electrical equipment is exposed to flammable vapors and gases routinely or under reasonably foreseeable circumstances, whether special listed and labeled electrical equipment is available and justified or whether equivalent safety can be provided more economically and practically by ventilation or quantity limitations.

As an educational measure in laboratories which have many personnel and electrical devices and which handle combustible or flammable liquids in containers larger than 1.69 oz (50 ml), electrical equipment not listed or labeled for use in hazardous atmospheres should be marked with precautionary signs or labels with a legend such as:

May ignite flammable vapors or gases. Not safe for use with exposed organic liquids with flash point temperatures below 100°F (37.8°C) (or the temperature of the high-limit cutoff if the equipment is designed for heating, e.g., oil bath or hot plate).

A-7-3.3.4.1 Ventilation Design. Prevalent practice when laboratories are provided with supply and exhaust ventilation is to design the fume hood exhaust as an integral part of the balanced ventilating system, so that the fume hood exhaust is in constant operation.

A-7-3.3.5 The American Industrial Hygiene Association, the American Conference of Governmental and Industrial Hygienists, and the American Society of Heating, Refrigeration, and Air Conditioning Engineers have published guidelines on the design, installation, face velocities, location, and test procedures for laboratory hoods. The

Scientific Apparatus Makers Association also has published a standard on laboratory hoods. (See *Appendix B*.)

A-7-3.3.5.6 The minimal face velocity of a fume hood is generally considered to be 100 ft (30.5 m) per minute; unusual conditions may require velocities greatly in excess of this flow. Engineers require complete data on the function of a fume hood for the adequate design of its exhaust facilities.

A-7-3.4 Fire Protection. Examination of laboratory fire records demonstrates the extra vulnerability of premises with substantial amounts of combustible contents. The use of noncombustible shelving, benches and furniture will reduce production of smoke and damage to facilities and with substantial savings where expensive laboratory equipment is present, even in sprinklered areas.

Self-contained breathing apparatus should be considered for equipping personnel for rescue operations in areas with special fire hazards. Training is required for effective use of such equipment. It is desirable to coordinate equipment and training with local fire department personnel.

A-7-3.4.1 The hazard level of a laboratory is considered severe if quantities of flammable, combustible or hazardous materials are present which are capable of sustaining a fire condition of sufficient magnitude to breach a one-hour fire separation.

To determine the combustible content or heat potential of flammable or combustible materials capable of breaching or penetrating a one-hour rated fire separation, one method is included in the 14th edition of the NFPA *Fire Protection Handbook*, where formulas and tables for calculating the equivalence of time versus fire severity are given. Specific reference is made to Section 6, Chapter 8, "Confinement of Fire and Smoke in Buildings" and Table 6-8A. Heat of combustion (BTU/lb) for materials common to laboratories can be found in Section 3, Chapter 11, "Fire Hazard of Materials — Tables and Charts" of the *Handbook*. Specific reference is made to Table 3-11B, Table 3-11G, Table 3-11H and Table 3-11L.

NOTE: The weights of combustible contents in Table 6-8A are those of ordinary combustible materials taken at 8000 BTU/lb. For converting other than ordinary combustibles to pounds per square foot (psf), divide the total BTU value by 8000/BTU/lb.

The above, it should be noted, is only one of several methods for calculating hazard level of a laboratory with regard to combustibles breaching a one-hour fire separation.

The following chart can be used as a guide in making the above determination:

Wall Rating	Hazard	
	Not Severe	Severe
Less than 1-Hour	Automatic fire extinguishing system required.	Not allowed.
1-Hour	No automatic fire extinguishing system required.	Automatic fire extinguishing system required.
2-Hour	No automatic fire extinguishing system required.	No automatic fire extinguishing system required.

A-7-3.5 Protective Devices. Showers should be controlled by a nonautomatic shutoff device. Although a

self-closing shower valve (favored by most designers) would minimize flooding of the building if, for example, maliciously activated, it does not afford maximum help to the injured user. Since a person would have to use one hand to keep the valve open, efforts to remove clothing or wipe away offending materials would be greatly hampered.

Although emergency showers are rarely used, their use when necessary can mean the difference between superficial burns and serious disfigurement, or loss of life. In some cases where such showers have not been activated for long periods, they have been found inoperative. It is essential that emergency showers be provided and tested from time to time to determine that their valves are in good operating condition. Advance planning must be made to handle the water that will flow in a test.

Floor drains are not recommended for hospital areas because traps tend to dry out and permit passage of gases, vermin and odors.

Another consideration is to be sure that all holes in floor slabs that have not been sealed around pipes to prevent the passage of smoke, be so sealed, and in a manner that will prevent water from flowing to lower floors from the discharge of an emergency shower or sprinkler head.

Wall-mounted portable eye wash stations do not contain an adequate supply of water for the 15-minute flushing recommended by chemical manufacturers.

A-7-4.2 Flammable Liquid. Plastic containers are sometimes used to avoid breakage problems posed by glass containers or contamination problems with metal containers. Plastic containers must be chosen with particular attention to their compatibility with the liquid to be contained. For example, polyethylene containers are generally unsuitable for aldehydes, ketones, esters, higher molecular-weight alcohols, benzene, toluene, various oils, silicone fluids and halogenated hydrocarbons. In addition to labeling containers for identification of contents, it is important to label plastic containers for identification of their constituent materials to avoid misuse.

In some cases, listed or labeled stainless steel or tin-lined safety containers offer a solution to contamination problems.

A-7-4.2.1 The following is a portion of Table 4-2.3 in NFPA 30, *Flammable and Combustible Liquids Code*.

Maximum Allowable Size of Containers and Portable Tanks

Container Type	Flammable Liquids			Combustible Liquids	
	Class IA	Class IB	Class IC	Class II	Class III
Glass	1 pt	1 qt	1 gal	1 gal	5 gal
Metal (other than DOT drums) or approved plastic	1 gal	5 gal	5 gal	5 gal	5 gal
Safety Cans	2 gal	5 gal	5 gal	5 gal	5 gal

For SI Units: 1 pt = .49 L; 1 qt = .95 L; 1 gal = 3.8 L.

A-7-4.2.2 Constant effort must be exerted to prevent the overstocking of hazardous chemicals. The laboratory chief can help keep stocks at a safe level by encouraging small and more frequent requisitions, by developing a reliable stock inventory system, by assuring convenient and prompt deliveries from the central stock room, by selecting brands

which are the most popular and, not necessarily, the cheapest, and by discouraging (except perhaps for large-scale research type projects) the practice of purchasing the largest containers, including bulk supplies in 55 gal (208.2 L) drums.

A-7-4.2.5

Walk-in Thermal Controlled Boxes. Procedures likely to result in toxic or flammable atmospheres should be discouraged within "walk-in" refrigerators or other type temperature-controlled boxes. A warning sign such as the one indicated here should be posted on every box.

DANGER
NOT EXPLOSIONPROOF
NOT VENTILATED

GROUND ALL ELECTRICAL EQUIPMENT

DO NOT STORE DRY ICE
DO NOT SMOKE

New boxes should include at least the following features: a latch which can be released by a person inside the box when the door is locked from the outside; the latch and door frames should be designed to allow actuation under all conditions of freezing; a floor with a nonconductive surface; neoprene matting to insulate up to 10,000 volts; a view-window in the door; an independently circuited high-temperature thermostat and alarm (for warm boxes); vaporproof duplex electrical receptacles; an alarm which can be heard throughout the occupied work area and an alarm button at the inside door frame which will keep operating after actuation; conduits sealed (in cold boxes) in a manner to prevent accumulation of water vapor such as in the globe protectors of the light fixtures; and adjustable exhaust vent and air intake of at least 15 CFM for general ventilation, with provisions for installing a flexible hose and miniature canopy in a manner to provide local ventilation at a specific work site. As explosionproof laboratory apparatus becomes available, it should be substituted for less safe equipment used in enclosed thermal-control boxes.

Non-Walk-in Refrigerators. The use of domestic refrigerators for the storage of typical laboratory solvents presents a significant hazard to the laboratory work area. Refrigerator temperatures are almost universally higher than the flash points of the flammable liquids most often stored in them. In addition to vapor accumulation, a domestic refrigerator contains readily available ignition sources, such as thermostats, light switches, and heater strips, all within or exposing the refrigerated storage compartment. Furthermore, the compressor and its circuits are typically located at the bottom of the unit, where vapors from flammable liquid spills or leaks may easily accumulate.

Explosionproof refrigeration equipment is designed to protect against ignition of flammable vapors both inside and outside the refrigerate storage compartment. This type is intended and recommended for environments such as pilot plants or laboratory work areas where all electrical equipment is required to be explosionproof.

The design concepts of the flammable material storage refrigerators are based on the typical laboratory environment. The primary intent is to eliminate ignition of vapors inside the storage compartment from sources also within the compartment. In addition, flammable material storage refrigerators incorporate such design features as thresholds, self-closing latch doors, friction latches or magnetic door gaskets and special methods for the inner shell. All of these features are intended to control or limit the loss potential should an exothermic reaction occur within the storage compartment. Finally, the compressor and its circuits and controls are often located at the top of the unit to further reduce the potential for ignition of floor level vapors. In general, the design features of a commercially available flammable material storage refrigerator are such that they provide several safeguards not available through modification of domestic models.

Every laboratory refrigerator should be clearly labeled to indicate whether or not it is acceptable for storage of flammable materials. Internal laboratory procedures should ensure that laboratory refrigerators are being properly used. The following are examples of labels which can be used on laboratory refrigerators:

DO NOT STORE FLAMMABLE SOLVENTS
in this refrigerator

NOTICE

This is not an "explosionproof" refrigerator, but it has been designed to permit storage of materials producing flammable vapors. Containers should be well stoppered or tightly closed.

A-7-4.5 Disposal of Hazardous Materials. Because disposal techniques for various hazardous materials produced in hospital research involve complicated problems, they cannot be adequately discussed herein. Such materials may include: the toxic product of mixing sodium cyanide and acids in the drain system; nuisance or alarming odors such as produced by mercaptans or lutidine; violently water-reactive solids or liquids like phosphoric anhydride and thionyl chloride; potential explosives like picric acid; strong oxidizers like perchloric acid; radioactive, pathogenic, corrosive, or potentially harmful wastes, such as TV picture tubes, syringes, and aerosol cans.

Many chemicals can be disposed of at the bench through the ingenuity of the chemist, such as the reacting of small quantities of potassium with tertiary butyl alcohol.

Flammable and combustible liquids which are miscible with water in all proportions may be flushed down a drain within a laboratory room in quantities not exceeding one pint (.45 L), thoroughly mixed with at least 3 gal (11.4 L) of cold water. This precaution for minimizing flammable vapor concentrations in building drains may not be acceptable to pollution control authorities.

Vaporization should not be used for routine disposal of liquids.

Drain lines and traps from laboratory benches, safety showers, hood floors, mechanical equipment rooms, storage rooms, etc. should have water added at regular intervals to assure that traps will not be the source of flammable or toxic vapor release. Where self-priming traps are provided,

an annual inspection for proper operation should be made. Addition of mineral oil or similar liquids is sometimes used to reduce evaporation of water from traps.

A-7-5.1 Handling of Gas Containers. The precautions outlined in Compressed Gas Association Pamphlet P-1, *Safe Handling of Compressed Gases*, and Pamphlet P-2, *Characteristics and Safe Handling of Medical Gases*, should be observed. (See Appendix B.) These publications cover such items as moving and storage of containers, labeling, withdrawing of container contents and handling of leaking containers. Cryogenic fluids must be used only in containers designed for the purpose, such as a double-walled thermos bottle.

Caps must be replaced promptly after each use to prevent the solidification of atmospheric water vapor in the pouring neck, which otherwise could convert a safe container into a potential bomb.

Protective clothing and eye shields should be used to prevent burns from issuing gases or spilled liquids. Effects of flammable and oxidizing properties are intense and demand special fire protection measures and handling. Inadvertent saturation of clothing by oxygen or spills on asphalt flooring, for example, require prompt and accurate corrective measures. Ample ventilation is needed to prevent hazardous concentrations, for example, of nitrogen, which could cause asphyxiation. For routine cooling operations, liquid air or oxygen should never be used as substitutes for liquid nitrogen.

A-7-5.4 Piping Systems. Piping systems supplying medical gases to patients should be reserved exclusively for that purpose so as to protect the patients from administration of gas other than that intended for their use. Therefore laboratory gas piping systems should not be used to pipe gas for use by hospital patients. This warning is also intended to apply to piping systems intended to supply gas to patients within a laboratory facility. Such a system should not be used to supply laboratory equipment other than that directly involved with the patient procedure.

A-7-6 Maintenance and Inspection. Detailed specifications for the contents of manuals intended to describe the installation, operation and maintenance of medical equipment are established in a standard developed by the National Committee for Clinical Laboratory Standards (ASI-1, *Preparation of Manuals for Installation, Operation and Repair of Laboratory Instruments*). (See Appendix B.) Whenever such manuals accompany new equipment, they should be carefully preserved and consulted for guidance in all phases of the setting up and safe operation of the equipment.

A-7-6.1.4 Regulations should be adopted for routine housekeeping and laboratory cleanup practices.

The laboratory safety officer should make periodic inspections of the laboratory premises to determine that electric cords in use are of adequate conductor size with safe insulation and that circuits are not overloaded through the use of multiple taps.

Several good laboratory safety checklists are available, such as the one developed by the College of American Pathologists Inspection and Accreditation Program (see Appendix B). The laboratory safety officer may wish to augment or modify one of these for his own facility.

A-7-6.1.6 Information sources for safe handling and disposals of hazardous chemicals include NFPA 49, *Hazardous Chemicals Data*. The guidance of a technically qualified person is recommended for the disposal of hazardous chemicals.

A-8-1.2 Installation of Generator Sets. For additional material on diesel engines see *Diesel Engines for Use with Generators to Supply Emergency and Short Term Electric Power*, National Research Council Publication 1132, available as Order No. O.P.52870 from University Microfilms, a Xerox Company, P.O. Box 1366, Ann Arbor, Michigan 48106.

A-8-2.1.2 (a) Design Considerations. Consideration should be given to properly designed and installed bypass arrangements to permit testing and maintenance of system components that could not be otherwise maintained without disruption of important hospital functions.

(b) Connection to Dual Source of Normal Power. For the greatest assurance of continuity of electrical service, the normal source should consist of two separate full-capacity services, each independent of the other. Such services should be selected and installed with full recognition of local hazards of interruption, such as icing and flooding.

Where more than one full-capacity service is installed, they should be connected in such a manner that one will pick up the load automatically upon loss of the other, and so arranged that the load of the Emergency and Equipment System will be transferred to the alternate source (generator set) only when both utility services are de-energized, unless this arrangement is impractical and waived by the authority having jurisdiction. Such services should be interlocked in such a manner as to prevent paralleling of utility services on either primary or secondary voltage levels.

NOTE: In any installation where it is possible to parallel utility supply circuits, for example, to prevent interruption of service when switching from one utility source to another, it is imperative to consult the power companies affected relative to problems of synchronization.

A-8-2.2.4.3 Voltage Sensing. Consideration should be given to monitoring all ungrounded lines of the alternate source of power when conditions warrant.

A-8-2.2.4.6 Time Delay on Retransfer to Normal Power. It is recommended that the timer be set for 30 minutes (see A-8-2.4.2.1). Consideration should also be given to an unloaded engine running time after retransfer to permit the engine to cool down before shutdown.

A-8-2.3.4.5 Cranking Battery. The engine automatic starting system should have an overcrank device to terminate cranking with enough reserve battery power to permit additional cranking after an investigation to find the reason for a failure to start.

A-8-2.4.2.1 Test Interval. When indications such as the issuance of storm warnings indicate that power outages may be likely, good practice recommends the warming up of generator sets by a regular exercise period. Operation of generator sets for short intervals should be avoided, particularly with compression ignition engines, since it is harmful to the engines.

A-8-3.1 Separation of Wiring on Emergency System of a Hospital. In principle, Chapter 8 is designed to seek security of electrical function by protection against internal disruption as well as the loss of primary power sources. In keeping therewith, Chapter 8 aims to limit the security deterioration which may occur when poorly maintained and heavy current consuming items are connected to the same feeders that supply critical patient care functions.

For greater protection, such segregation of suspect and critical connections is best carried out throughout the length of a feeder system, preferably including the transfer device. This practice gives rise to the phrase "protected feeder."

While Chapter 8 must leave details of wiring and overcurrent protection to engineering judgment, in view of wide variations of conditions, the Committee consensus is that feeders serving anesthetizing locations, special nursing care units, and special treatment areas where continuity of care may be vital to life should be given security through the segregation of protected feeders and that, to the greatest extent practical, feeders should connect to the alternate source of power by means of separate transfer devices.

As a further protection against internal disruption, it is also recommended that, when practical, critical areas served by the Essential Electrical System have some portion of lighting and receptacles connected to feeders supplied by the general system.

A-8-3.2.2(d), A-8-3.2.3(g), and A-8-4.3.2(d) Communication Systems. Departmental installations such as digital dialing systems used for intradepartmental communications may have impaired use, during a failure of electrical service to the area. In the event of such failure, those systems which have lighted selector buttons in the base of the telephone instrument or in the desk units known as "Director Sets" will be out of service to the extent that the lights will not function and that the buzzer used to indicate incoming calls will be silenced. The lack of electrical energy will not prevent the use of telephones for outgoing calls, but incoming calls will not be signaled, nor will intercommunicating calls be signaled. This communication failure should be taken into consideration in planning Essential Electrical Systems.

A-8-3.2.3 Critical Branch. It is recommended that hospital authorities give consideration to providing and properly maintaining automatic battery-powered lighting units or systems to provide minimal task illumination in operating rooms, delivery rooms, and certain special procedure radiology rooms where the loss of lighting due to failure of the Essential Electrical System might cause severe and immediate danger to a patient undergoing surgery or an invasive radiographic procedure.

A-8-4.4.3 Equipment for Automatic or Manual Connection. Other selected equipment may be served by the Critical System.

NOTE 1: Consideration should be given to selected equipment in kitchens, laundries, and to selected central refrigeration.

NOTE 2: It is desirable that, where heavy interruption currents can be anticipated, the transfer load may be reduced by the use of multiple transfer devices. Elevator feeders, for instance, may be less hazardous to electrical continuity if they are fed through an individual transfer device.

A-9-1.8 Nature of Hazards. The major concern in this chapter is electric shock resulting from degradation or some type of failure within normally safe electrical appliances or the facility's electrical distribution system. The defect may be in the wiring, a component, or the result of deteriorating insulation. The failure may be caused by mechanical abuse or by improper use of the equipment.

Hospital service presents unusually severe environmental stress to equipment, similar to hard industrial use. Appliances are frequently subjected to large mechanical stresses in the course of being transported around the facility. Patients and staff, particularly those in operating rooms, critical care areas, clinical laboratories, and some physical therapy areas, are frequently surrounded by exposed, electrically grounded conductive surfaces which increase the risk of serious injury in the event of certain types of electrical failure.

A-9-1.8.2 Shock Prevention. Since electric shock results from the effect of an electric current flowing through a part of the human body, three conditions must be satisfied simultaneously before a patient or staff can be shocked. [See Figure A-9-1.8.2(a).] There must be:

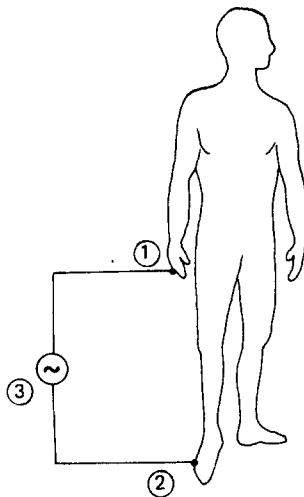


Figure A-9-1.8.2(a) The three basic conditions required to produce an electric shock.

- (a) One part of the body in contact with a conductive surface. (Point 1)
- (b) A different part of the same body in contact with a second conductive surface. (Point 2)
- (c) A voltage source that will drive current through the body between those two points of contact. (Point 3)

In the general case, six or seven independent and separable factors must combine simultaneously to satisfy these three conditions. [See Figure A-9-1.8.2(b).]

Several separate factors should be analyzed when evaluating a potential electric shock hazard:

General Factors that Should be Considered When Analyzing Electrical Safety. [Numbers refer to Points in Figure A-9-1.8.2(b).]

1. The likelihood that a piece of line-powered equipment will be within reach of the patient.

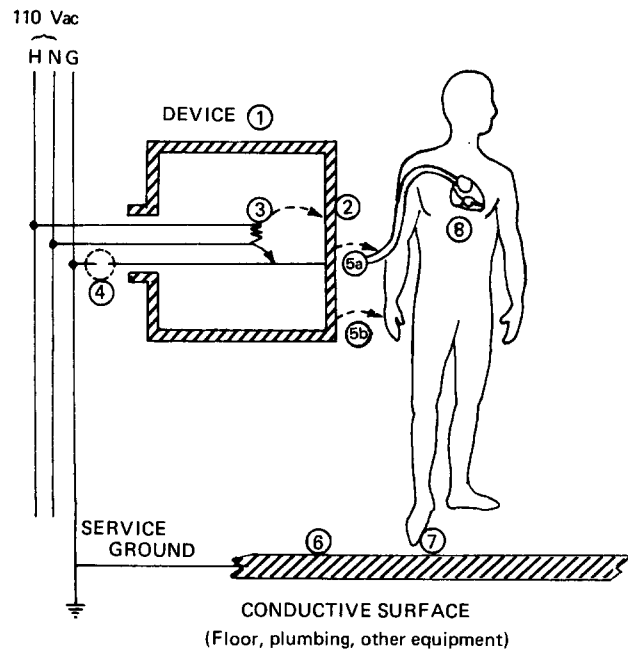


Figure A-9-1.8.2(b)

2a. The possibility of direct exposure of a "live" 110-volt conductor through a damaged line cord or attachment plug.

2b. The likelihood that the equipment will have exposed metal parts that through some reasonably credible accident could become "live."

3. The likelihood that equipment is accidentally damaged or malfunctions in some way and the metal becomes "live," i.e., electrified.

4. The likelihood of the exposed metal parts not being grounded or accidentally becoming ungrounded.

5. The likelihood that the patient (or member of staff, or visitor) will make good contact with this exposed, potentially "live" surface.

6. The likelihood that a second exposed conductive surface that is, or that could, through a reasonably credible event, become grounded is also within reach.

7. The likelihood that the patient (or member of staff, or visitor) will make good contact with this grounded, or potentially grounded, surface.

8. The probability that the resultant current flow will be sufficient to cause an injury.

The chance of the patient actually sustaining an electric shock is a product of the likelihood that each of the above events will occur. If the likelihood of occurrence of any one event is very close to zero, then the risk of electric shock will be very close to zero. Put another way, six or seven links in a chain need to be intact, in order for a shock to be sustained. If any one link can be made extremely weak, by design or operating procedure, chance of receiving a shock will be minimal.

Working to minimize the occurrence of one factor (i.e., one safety factor) can achieve one layer of protection. A second "layer of protection" is achieved by working to make the chance of occurrence of a second factor in the overall chain also very close to zero. However, extending

this process to minimize the occurrence of all factors can lead to overdesign, overspecification and less than cost-effective utilization of resources to control any problem.

Consider briefly each of the component factors. First, more could be done operationally to ensure that the minimum amount of line-powered equipment is within reach of the patient. Second, equipment that does not have a significant amount of exposed metal is to be preferred. Third, the staff should be instructed to report all obviously damaged equipment, even if it is still functional. Fourth, all grounding circuits should be tested frequently. Fifth, minimize the amount of grounded metal that is within reach of the patient. Avoid when possible attaching any grounded leads directly to the patient. Do not deliberately ground any metal part such as a curtain rail or a metal cabinet which cannot become accidentally "live." Insulate the patient from ground as much as possible.

In consideration of these objectives, four basic principles can be examined to avoid electric shock:

Shock Prevention by Insulation and Enclosure.

Shock Prevention by Grounding.

Shock Prevention by Device Design.

Shock Prevention Through User Procedures.

Shock Prevention by Insulation and Enclosure. Physical provision should be made to prevent personal hazardous contact between energized conductors or between an energized conductor and ground.

(a) Noninsulated current-carrying conductors which could produce hazardous currents should be protected from contact through suitable enclosure.

(b) Energized conductors which could produce hazardous currents not in protective enclosures should be insulated by materials suitable to the voltage and environment.

Exposed conductive surfaces not likely to be energized from internal sources should not be intentionally grounded to minimize the probability of completing a hazardous circuit. Insulated covering of such surfaces is desirable.

NOTE 1: Past measures recommended by earlier editions of NFPA and other standards associated with equipotential grounding and bonding of "dead metal" served to increase likelihood that a patient or staff would complete an undesirable pathway for electric shock.

NOTE 2: This principle does not intend to mandate construction of an insulated environment, but rather to avoid intentional grounding of otherwise dead metal surfaces.

Shock Prevention by Grounding. A grounding system for fault currents should be supplied to minimize the fraction of the fault current that might flow through an individual during the fault condition, and to operate overcurrent devices to minimize the possibility of damage and fire. This system should also be utilized to provide a safe path for leakage currents.

(a) Unless doubly insulated, each line-powered electrical appliance within the patient vicinity should have a grounding wire, which normally carries the leakage current directly to ground, in the same power cable as the energized conductors.

(b) Each receptacle for line-powered electrical appliances should provide a low-impedance grounding connection and path.

Shock Prevention by Device Design. Leakage current should be minimized.

New device designs should not intentionally provide a low-impedance path at 60 Hz from patient to ground.

Shock Prevention Through User Procedures.

General: A total electrical safety program incorporates the best features of design, manufacture, inspection, maintenance and operation. The design should be such that limited departures from ideal conditions of maintenance and use will not cause unreasonable risks.

Where existing equipment which does not meet new equipment requirements is to be used, such use is permissible if procedures of use and maintenance can establish an equivalent level of safety.

User procedures should include:

(a) Establishing a policy to prohibit the connection of nonisolated input equipment to externalized intracardiac electrodes,

(b) Establishing user educational and training programs, and

(c) Establishing a testing and routine maintenance program.

A-9-2.3.1 Electrical Power Distribution System.

(a) *Integrity of Insulation on Conductors.* At the time of installation, steps should be taken to ensure that the insulation on each conductor intended to be energized, or on quiet grounds, has not been damaged in the process of installation. When disconnected and unenergized the resistance should be at least 20 megohms when measured with an ohmmeter having an open circuit test voltage of at least 500 volts dc.

(b) *Accessibility of Overcurrent Protection Devices.* Consideration should be given to providing reasonable accessibility to branch circuit switching and overcurrent protection devices by the hospital staff in the patient care area. Consideration should also be given to providing labels at each receptacle and on installed equipment as to the location and identity of the distribution panel serving that power outlet or equipment, especially where the location or identity may not be readily apparent.

A-9-2.3.1.1 Branch Circuits in a Patient Vicinity. The requirement that branch circuits shall be fed from not more than one distribution panel was introduced for several reasons. A general principle is to minimize possible potential differences between the grounding pins of receptacles in one area by bringing the grounding conductors to a common point. A special reason is to simplify maintenance by making it easier to find the source for the receptacles in a room. This is particularly a problem in hospitals where emergency conditions may require rapid restoration of power.

A-9-2.3.1.2.1 Types of Receptacles. It is best, if possible, to employ only one type of receptacle (standard three-prong type) for as many receptacles being served by same line voltage to avoid the inability to connect life support equipment in emergencies. The straight blade, three-prong receptacle is now permitted in all locations in a hospital. Previously, special receptacles were specified in operating room locations and have caused compatibility problems.

A-9-2.3.2.2 Reliability of Grounding. This requirement is usually met by appropriate mounting hardware, and not by wire jumpers.

A-9-2.3.2.3 Grounding Interconnection with Essential Electrical System. The requirement for grounding interconnection between the normal and essential power systems follows the principle of minimizing possible potential differences between the grounding pins of receptacles in one area by bringing the grounding conductors to a common point.

A-9-2.4 Grounding Circuit Considerations. In a conventional "grounded" power distribution system one of the line conductors is deliberately grounded, usually at some distribution panel or the service entrance. This grounded conductor is identified as the "neutral" conductor. The other line conductor (or conductors) is (are) the "high" side of the line. The loads to be served by this distribution system are fed by the high and neutral conductors.

In addition to the "high" and "neutral" conductors, a grounding conductor is provided. One end is connected to the neutral at the point where the "neutral" is grounded, and the other end leads out to the connected loads. For our purposes here, we will consider the load connection point to be a convenience receptacle, and the grounding conductor terminates at the grounding terminal of that receptacle.

This grounding conductor may be a separate wire running from the receptacle back to the remote grounding connection (where it joins the neutral conductor). If that separate conductor does not make any intermediate ground contacts between the receptacle and the remote ground, then the impedance of the connection between the receptacle and the remote ground is primarily the resistance of the grounding conductor itself, and is, therefore, predictable.

If, however, the receptacle is also interconnected with the remote ground point by metallic conduit or other metallic building structures, the impedance of the circuit between receptacle and remote ground is not easily predictable, nor is it easy to measure accurately, although one can be sure that the impedance will be less than that of the grounding wire itself because of the additional parallel paths.

Fortunately, as will become apparent in the following paragraphs, the absolute value of the apparent impedance between the grounding contact of an outlet and the remote ground point need not be known or measured with great accuracy.

Ideally, and under no fault conditions, the grounding system described above is supposed to be carrying no current at all. If that were true, then no voltage differences would be found between exposed conductive surfaces of any electrical appliances which were grounded to the grounding contacts of the receptacles from which they were powered. Similarly, there would be no voltage differences between these appliances and any other exposed metal surface which was also interconnected with the grounding system, provided that no currents were flowing in that interconnection.

Ideal conditions, however, do not prevail, and even when

there are no "faults" within an appliance, residual "leakage" current does flow in the grounding conductor of each of the appliances, producing a voltage difference between the chassis of that appliance and the grounding contact of the receptacle which feeds it. Furthermore, this current can produce voltage differences among other appliances plugged into various receptacles on the system.

Fortunately, these leakage currents are small, and for reasonably low grounding circuit impedances, the resulting voltage differences are entirely negligible.

If, however, a breakdown of insulation between the high side of the line and the chassis of an appliance should occur, the "leakage" current becomes a "fault" the magnitude of which is limited by the nature of the breakdown or, in the case of a dead short circuit in the appliance, the magnitude of the fault current is limited only by the residual resistance of the appliance power cord conductors and that of the power distribution system.

In the event of such a short circuit, the impedance of the grounding circuit, as measured between the grounding contact of the receptacle which feeds the defective appliance and the remote ground point where the neutral and grounding conductors are joined, should be so small that a large enough fault current will flow to ensure a rapid breaking of the circuit by the overcurrent protective device which serves that receptacle.

For a 20-ampere branch circuit a fault current of 40 or more amperes would be required to ensure a rapid opening of the branch circuit overcurrent protective device. This corresponds to a circuit impedance of three ohms or less, of which it is desired that the grounding system contribute one ohm or less.

During the time this large fault current flows in the grounding system, the chassis of the defective appliance is raised many volts above other "grounded" surfaces in the same vicinity. The hazard represented by this condition is minimized by the fact that it exists for only a short time, and unless a patient simultaneously contacts both the defective appliance and some other grounded surface during this short time interval, there is no hazard. Furthermore, the magnitude of an applied voltage required to produce a serious shock hazard increases as its duration decreases, so the rapidity with which the circuit is interrupted helps reduce shock hazard even if such a patient contact should occur.

If, however, the defect in the appliance is not such as to cause an immediate circuit interruption, then the effect of this intermediate level of fault current on the voltages appearing on various exposed conductive surfaces in the patient vicinity must be considered.

Since all of this fault current flows in the grounding conductor of the defective appliance's power cord, then the first effect is to raise the potential of this appliance above that of the receptacle which feeds it by an amount proportional to the power cord grounding conductor resistance. This resistance is required to be less than 0.15 ohm, so fault currents of 20 amperes or less, which will not trip the branch circuit overcurrent protective device, will raise the potential of the defective appliance above the grounding contact of its supply receptacle by only three volts or less. This value is not hazardous for casual contacts.

The accurate measurement of fractional ohm resistance values is usually beyond the capability of conventional ohmmeters. However, a relatively simple test method will be suggested for making the measurements.

The fault current which enters the grounding system at the grounding contact of any receptacle in the patient vicinity could affect the potential at the grounding contacts of all the other receptacles, and, more importantly, it could produce significant voltage differences between them and other "grounded" surfaces, such as exposed piping and building structures.

If one grounded point is picked as a reference (a plumbing fixture in or near the patient vicinity, for example), and then the voltage difference is measured between that reference and the grounding contact of a receptacle, produced by driving some known current into that contact, one will have a direct measure of the effectiveness of the grounding system within the patient vicinity. The "figure of merit" can be stated as so many volts per ampere of fault current. The ratio "volts per ampere" is, of course, impedance; but since the exact path taken by the fault current is not known, and since the way in which the reference point is interconnected with the grounding system is not known, it cannot be stated that this value is the impedance between the receptacle and some specific point, such as the joining of the neutral and grounding conductors. But it can be stated that this measured value of "effective impedance" is indicative of the effectiveness with which the grounding system minimizes voltage differences between supposedly grounded objects in the patient vicinity which are produced by ground faults in appliances used in that vicinity. It is this impedance, which characterizes the ability of the grounding system to maintain nearly equipotential conditions within the patient vicinity, which is of prime importance in assessing shock hazard; but this impedance is not necessarily the same as the impedance between receptacle and remote ground point which controls the magnitude of the short circuit current involved in tripping the branch circuit overcurrent protective device.

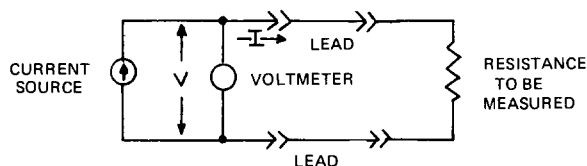
Fault currents on the grounding system can also come from neutral to ground faults which permits some current to flow in the neutral and some in the ground. This type of fault is often the cause of interference on EEG and ECG equipment. It is often not recognized easily because except for 60 Hz interference the equipment works perfectly properly. It is most easily found by causing a substantial change in the line-to-line load and noting changes in the ground to reference voltage.

A-9-2.6 and A-9-3.4.6 Documentation. While several approaches to documentation exist in hospitals, the minimum acceptable documentation should convey what was tested, when it was tested and if it performed successfully. Adopting a system of exception reporting can be the most efficient form of recordkeeping for routine rechecks of equipment or systems and thereby minimize technicians' time in recording the value of each measurement taken. For example, once a test protocol is established, which simply means testing the equipment or system consistent with this chapter, the only item (value) which needs to be recorded is what failure or what deviation from the requirements of the chapter was detected when a corrective

action (repair) was undertaken. This approach can serve to eliminate, for example, the need to keep individual room sheets to record measured results on each receptacle or to record measurement values of all types of leakage current tests.

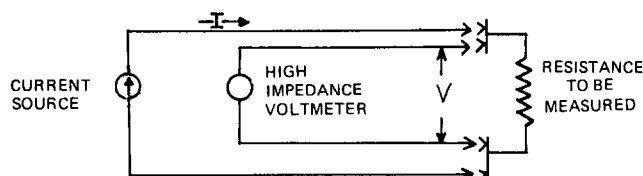
A-9-3.4.2 There are several methods for measuring ground wire resistance accurately. Three examples are described below:

(a) Two Wire Resistance Technique.



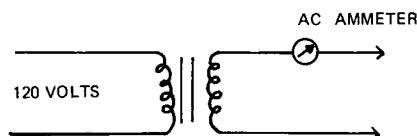
A known current is fed through the unknown resistance. A high input impedance voltmeter measures the voltage drop across the resistance and R is calculated as V/I . This technique measures the lead resistance in series with the unknown resistance. When the unknown resistance is a ground wire (less than 0.15 ohm), the lead resistance is appreciable. This is accounted for by shorting the lead wires together and "zeroing" the voltmeter. The actual resistance in effect subtracts out the lead wire resistance. In order for this technique to be reasonably accurate for measuring ground wires, an active high-impedance millivoltmeter must be used.

(b) Four Wire Resistance Technique.



This technique is very similar to the two wire resistance technique. The difference is that the known current is fed to the resistance to be measured through a pair of leads separate from the pair of leads to the voltmeter. The voltmeter is measuring the true voltage across the resistance to be measured regardless of the resistance of the measuring leads. This method eliminates the need for zeroing out the measuring lead resistance.

(c) AC Current Method.



This technique utilizes a step down transformer of known voltage output to feed current through the ground wire and measure the current that flows. The impedance of the ground wire is then calculated by Ohm's Law.

NOTE: The internal impedance of the measuring circuit must be established with the test leads shorted. This value needs to be subtracted from the test measurement.

A-9-3.4.3 and A-9-5.3.3.1 Leakage Current Measurements. For complex leakage current waveforms, a single reading from an appropriate metering system can represent the physiologically effective value of the composite waveform, provided that the contribution of each component to the total reading is weighted in accordance with 9-3.4.3(c) or 9-5.3.3.1(b).

This "weighting" can be achieved by a frequency response shaping network which precedes a flat response meter, or by a meter whose own frequency response characteristic matches 9-3.4.3(c) or 9-5.3.3.1(b).

If the required performance is obtained by a meter with integral response shaping properties, then that meter should have a constant input resistance of 1000 ohms. (A high input impedance meter may be used by shunting a 1000 ohm resistor across the meter's input terminals.)

If, however, the required frequency response is obtained by a network which precedes an otherwise flat response meter, then the input impedance of the network should be 1000 ohms $\pm$ 10 percent, over the frequency range from 0 to 1 MHz, and the frequency response of the network-meter combination must be substantially independent of the impedance of the signal source.

A suggested input network is shown below.

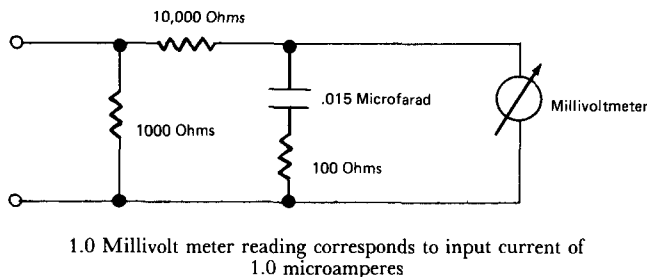


Figure A-9-3.4.3/A-9-5.3.3.1 Leakage Current Measurements.

A-9-4.4.3 Manuals For Appliances. Consideration should be given to require the vendor to sell parts to the individual or group designated by the hospital to service the equipment following the warranty period.

A-9-5.1.9.1.1 Signal Transmission. This may be accomplished by using a signal transmission system which is isolated from ground or presents a high impedance to ground; which employs a common signal grounding wire between appliances served from the same reference grounding point; which employs an additional grounding path between the common signal grounding wire and reference grounding point in the patient vicinity; or by other means intended to reduce potential differences in the patient vicinity due to grounding currents to a safe level.

A-9-5.1.9.2.2(d) Electrosurgery. Electrosurgical unit output circuits are commonly designated as isolated or ground-referenced on the basis of their isolation at their operating (RF) frequency. No assumption about isolation at 60 Hz should be made unless the device is specifically labeled as having an "isolated patient circuit (60 Hz)" in which case the device is to conform to the requirements of 9-5.3.5.3, Isolation Test.

A-9-5.3.3 Leakage Current Tests.

These currents usually derive from the line power by resistive paths, or capacitive or inductive coupling. However, they also include currents from other sources generated within the appliance and are measured by the tests described in this chapter.

These leakage current limits are based on acute events, i.e., sensation, duration tetany, or ventricular fibrillation. Appliance design should aim to reduce such current as much as possible. In properly grounded appliances, maximum chassis leakage current is in the grounding conductor and not through the patient.

These tests are not known to be adequate where currents (such as dc or high frequency) are introduced into the patient for long periods and where low level effects must be considered.

A-9-5.3.4.3 Chassis Leakage Current Limits. The chassis leakage current limits given in 9-5.3.4.3 and in other sections, combined with the grounding wire requirements, are based on a concept of two layers of protection. Either the limited leakage current or an intact grounding system will provide protection. However, it is becoming generally agreed that, not only with medical equipment but also with conventional appliances, there should be two levels of protection. This means that both safeguards must fail before the subject is at hazard.

For general application (household appliances) the leakage current limit is generally set at 500 microamperes at 60 Hz. The limit of 500 microamperes is based on the work of Dalziel and others which indicates that different individuals in the general population will exhibit responses to electrical shock at differing levels. A small percentage, perhaps 5 percent, will react to a current level of 500 microamperes with an involuntary movement that could trigger a secondary accident. Some individuals are sensitive to an electric shock sensation as low as 100 microamperes. A reasonable compromise seems to be to set the limit at 500 for the general public. It should be noted that in 9-3.4.4, Hospital-Owned Household Appliances, this is the limit for household-type appliances.

References:

- Dalziel, C. F., and Lee, W. R., "Reevaluation of Lethal, Electric Currents Effects of Electricity on Man." *Transactions on Industry and General Applications*, Vol. IGA-4, No. 5, September/October 1968.
- Roy, O. A., Park, G. R., and Scott, J. R., "Intracardiac catheter fibrillation thresholds as a function of duration of 60 Hz current and electrode area." *IEEE Trans. Biomed. Eng. BME* 24: 430-435, 1977.
- Roy, O. Z., and Scott, J. R., "60 Hz ventricular fibrillation and pump failure thresholds versus electrode area." *IEEE Trans. Biomed. Eng. BME* 23: 45-48, 1976.
- Weinberg, D. I., et al. "Electric shock hazards in cardiac catheterization." *Electrical Engineering* 82: 30-35, 1963.
- Watson, A. B., Wright, J. S., and Loughman, J., "Electrical thresholds for ventricular fibrillation in man." *Med. J. Australia* 1: 1179-1181, 1973.

For equipment in the patient vicinity it seems reasonable to reduce this limit by a safety factor of 5 to 100 microamperes, because of the special circumstances involved in hospitals. Some of these factors are:

(a) Some patients may be wet or have some other low-impedance connection to the ground. For this reason the assumption usually made for the general public that they are moderately insulated from ground is not valid.

(b) Patients are sick, tend to be unresponsive, tend to be obtunded, and may not be able to perform the evasive maneuvers that an alert adult would perform when experiencing an electrical shock.

(c) The nature of the patient's illness may exacerbate the response to electric shock.

(d) Hospital patients are increasingly in close proximity to more and more electrical equipment.

(e) Hospital equipment is subject to industrial-type abuse. It is handled roughly, is sometimes wet, and sometimes not properly maintained. All of this increases the probability of deterioration and consequent increase in leakage.

(f) The economics of the problem has been considered. The medical appliance industry has responded to the requirement for 100 microamperes maximum leakage by designing equipment within that limit. It has been shown to be feasible and not unduly uneconomical. In the few cases where, for technical reasons, it is impractical to reach these limits, other solutions are available.

For the above reasons it has not been considered unreasonable to utilize a safety factor of 5 below conventional equipment. It should be emphasized that this number is not based on clear technical evidence but represents considered opinion. Therefore, if a particular

appliance has a leakage current somewhat above 100 microamperes, it is not implied that it is dangerously unsafe. It does indicate that such an appliance should be examined to determine if there is a reason for the higher leakage. If the leakage cannot be reduced it can be compensated for by more intensive preventive maintenance to ensure that the grounding conductor is intact.

It should be further noted that the shock hazards produced by these current levels apply to external contacts, e.g., body surface ECG lead or a skin contact with the chassis of an appliance. These current values do not apply to intracardiac leads. For such leads the hazard is not startle, involuntary muscular motion, or "let-go." It is frank fibrillation of the heart, and is caused at levels a factor of 1000 below those necessary to cause fibrillation by external contacts. It is impractical to provide protection to the patient who has an intracardiac lead by means of the control of chassis leakage current, isolated power systems, ground fault interrupter circuits, or other similar external devices. Protection for such patients can be achieved only by the protection of the intracardiac lead. This is discussed in 9-5.2, Direct Electrical Pathways to the Heart. For such patients the limit of such leads has been placed at 10 microamperes. Again there is a safety factor involved. The lower limit of hazardous currents seems to be about 100 microamperes at 60 Hz. A safety factor of 10 has been established because of most of the reasons above, and because of the following:

(a) Patients with intracardiac leads are usually ones whose hearts are already in jeopardy.

(b) Such patients usually have even more electrical equipment near them than does the average patient.

(c) It has been shown to be economically quite feasible to maintain such leads at a limit of 10 microamperes.

Appendix B Informatory Referenced Publications

B-1 This Appendix lists publications which are referenced within this NFPA document for information purposes only . . . and thus is not considered part of the requirements of the document.

B-1.1 NFPA Publications.

NFPA 49-1975, *Hazardous Chemicals Data*.

NFPA 53M-1979, *Manual on Fire Hazards in Oxygen-Enriched Atmospheres*.

NFPA 80-1983, *Fire Doors and Windows*.

NFPA 220-1979, *Types of Building Construction*.

NFPA 325M-1977, *Fire Hazard Properties of Flammable Liquids, Gases and Volatile Solids*.

NFPA 491M-1975, *Manual of Hazardous Chemical Reactions*.

Flash Point Index of Trade Name Liquids.

NFPA *Fire Protection Handbook*, 14th edition, 1976.

B-1.2 Other Publications. The following publications are available from the addresses listed.

B-1.2.1 American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc., 345 East 47th Street, New York, NY 10017.

ASHRAE *Guide and Data Book-Equipment*, Chapter 10, 1969.

ASHRAE *Guide and Data Book-Applications*, Chapter 14, 1969.

B-1.2.2 Compressed Gas Association, Inc., 1235 Jefferson Davis Highway, Arlington, VA 22202.

CGA Pamphlet P-1, *Safe Handling of Compressed Gases*.

CGA Pamphlet P-2, *Safe Handling of Medical Gases*.

B-1.2.3 Joint Commission on the Accreditation of Hospitals, 875 N. Michigan Avenue, Chicago, IL 60611.

"Accreditation Manual for Hospitals," Available from the Joint Commission on the Accreditation of Hospitals, 875 N. Michigan Avenue, Chicago, IL 60611.

B-1.2.4 National Committee for Clinical Laboratory Standards, 771 East Lancaster Avenue, Villanova, PA 19085.

NCCLS ASI-1, *Preparation of Manuals for Installation, Operation and Repair of Laboratory Instruments*.

B-1.2.5 Ocean Systems, Inc. Research and Development Laboratory, Tarrytown, NY 10591. Work carried out under US Office of Contract No. N00014-67-A-0214-0013.

Technical Memorandum UCR1-721, *Chamber Fire Safety*.

B-2 Published Articles on Fire Involving Respiratory Therapy Equipment, and Related Incidents.

Benson, D. M., and Wecht, C. H., "Conflagration in an Ambulance Oxygen System," *Journal of Trauma*, vol. 15, no. 6 (1975): 536-649.

Dillon, J. J., "Cry Fire!" *Respiratory Care*, vol. 21, no. 11 (1976): 1139-1140.

Gjerde, G. E., and Kraemer, R. "An Oxygen Therapy Fire," *Respiratory Care*, vol. 25 no. 3 (1980): 362-363.

Walter, C. W. 1960. "Fire in an oxygen-powered respirator." *JAMA* 197:44-46.

Webre, D. E.; Leon, R.; Larson, N.W. 1973. "Case History; fire in a nebulizer." *Anes. and Analg.* 52:843-848.

B-3 Addresses of Some Other Organizations Publishing Standards or Guidelines.

American Industrial Hygiene Assoc., 475 Wolf Ledges Parkway, Akron, OH 44311.

American Conference of Governmental and Industrial Hygienists, P.O. Box 1937, Cincinnati, OH 45201.

College of American Pathologists, 7400 Skokie Blvd., Skokie, IL 60077.

Scientific Apparatus Makers Assoc., 1101 16th Street, NW, Washington, DC 20036.

Appendix C Additional Explanatory Notes to Chapters 1-11

This Appendix is not a part of the requirements of this NFPA document. . . but is included for information purposes only.

Appendix C-3 — Additional Explanatory Information on Chapter 3, Inhalation Anesthetics

C-3-1 Nature of Hazards.

C-3-2 Related Hazards and Safeguards.

C-3-3 Text of Suggested Signs and Posters.

C-3-4 Suggested Procedures in Event of Fire.

C-3-5 Cylinder Table.

C-3-1 Nature of Hazards.

C-3-1.1 General. The environment of the modern operating room poses numerous hazards, even in those rooms in which flammable agents are prohibited.

C-3-1.2 Hazards Present in All Anesthetizing Locations.

C-3-1.2.1 Electric Shock and Spark Hazards — High Frequency Burn.

C-3-1.2.1.1 When a human body becomes the connecting link between two points of an electric system which are at different electric potentials, the person is likely to suffer an electric shock or high frequency burns. When there is a highly conductive pathway from outside the body to the heart or great vessels, small electric currents may cause ventricular fibrillation or cardiac arrest. If a conductive material bridges two points of an electric system which are different electric potentials, the contact is likely to create a spark or an arc and intense heating of one or more of the conductors involved.

C-3-1.2.1.2 Electric equipment which is defective or faultily grounded produces a definite shock hazard if connected to conventional grounded electric circuits and employed in the presence of purposely conductive flooring, as installed in corridors adjacent to operating rooms, or wet flooring as may be encountered in sterilizing or scrub rooms during use.

C-3-1.2.1.3 Improper use of the high-frequency electro-surgical unit, alone or in combination with certain items of medical monitoring equipment, may cause serious high-frequency burns to the patient or to personnel. (See *Appendix E, Safe Use of High-Frequency Electricity in Health Care Facilities.*)

C-3-1.2.2 Toxicologic Hazards.

C-3-1.2.2.1 The use of some modern nonflammable inhalation anesthetic agents with high flow techniques and in the absence of venting of the exhaled gases to the atmosphere may create low grade toxicity in personnel who work regularly in the operating room (see *Appendix A-3-2.1.f*).

C-3-1.2.3 Mechanical Hazards.

C-3-1.2.3.1 A large amount of energy is stored in a cylinder of compressed gas. If the valve of a cylinder is struck (or strikes something else) hard enough to break off the valve, the contents of the cylinder may be discharged with sufficient force to impart dangerous reactive movement to the cylinder.

C-3-1.2.3.2 A hazard exists when hospital personnel attempt to transfer the contents of one compressed gas cylinder into another.

C-3-1.3 Hazards Related to the Use of Flammable Substances.

C-3-1.3.1 Flammable Anesthetic Agents.

C-3-1.3.1.1 The use of flammable anesthetic agents is attended by considerable fire and explosion risk because these agents form flammable mixtures with air, oxygen, or nitrous oxide. In many cases, these mixtures are violently explosive. Fatal accidents have resulted from explosions of such mixtures during anesthesia.

C-3-1.3.1.2 The following inhalation agents are considered flammable during conditions of clinical use in anesthesia: cyclopropane, diethyl ether, ethyl chloride, and ethylene.

The flammability of a compound may be reduced by substitution of a halogen (fluorine, chlorine, or bromine) for hydrogen at one or more positions in the molecular structure. Several inhalational anesthetics are thus halogenated. Halogenated agents are not necessarily nonflammable under all conditions.

Conflicting reports in the literature as to flammability limits probably represent differences in experimental techniques. Both the nature of the source of ignition and the configuration of the test chamber are critical. Some agents can be ignited only under optimal conditions never duplicated in clinical anesthesia. In one study, ignition of chloroform in oxygen could be obtained only in a closed steel bomb with a fuse producing an ignition temperature of 2000° to 3000°C (1093° to 1649°F) and with a chloroform concentration of 20 percent to 25 percent.¹

Trichloroethylene, used in concentrations higher than recommended, is flammable in oxygen and nitrous oxide. Methoxyflurane is nonflammable in concentrations obtainable at room temperature; however, a heated vaporizer can produce flammable mixtures.

Halothane, enflurane, and isoflurane are nonflammable under almost all conditions encountered in clinical anesthesia. High concentrations of nitrous oxide increase the range of flammability. Given laboratory conditions employing a closed tube, zero humidity, and sufficient ignition energy (far greater than that obtainable from incidental static electricity) it is possible to ignite a mixture of 4.75 percent halothane in 30 percent oxygen provided the balance of the atmosphere is nitrous oxide. If the oxygen concentration in a mixture with nitrous oxide is allowed to fall to 20

¹Brown, T. A. and Morris, G. "The Ignition Risk with Mixtures of Oxygen and Nitrous Oxide with Halothane," *Brit. J. Anaesth.* 38: 164-173, 1966.

percent, 3.25 percent halothane is flammable. In these same nitrous oxide-oxygen atmospheres, the corresponding minimal flammable concentrations of enflurane are 5.75 percent and 4.25 percent, respectively and of isoflurane, 7.0 percent and 5.25 percent.¹

The fact that halothane has for years been widely employed without significant problems relating to flammability suggests that the data in the preceding paragraph are of more theoretical than practical concern.

C-3-1.3.1.3 The use of closed rebreathing systems for the administration of flammable anesthetic agents normally tends to restrict the region likely to be hazardous. To secure a reasonable measure of protection, however, it has been found necessary to apply certain basic safeguards in any room in which these agents may be used.

C-3-1.3.2 Flammable Medicaments, Including Aerosol Products.

C-3-1.3.2.1 Medicaments, including those dispersed as aerosols, frequently are used in anesthetizing locations for germicidal purposes, for affixing plastic surgical drape materials, for preparation of wound dressings, or for other purposes.

C-3-1.3.2.2 A particular hazard is created if cautery or high-frequency electrosurgical equipment is employed following use of a flammable medicament for preparation of the skin (*see Appendix C-3-1.3.2.1*) since the liquid remaining on the skin or vapors pocketed within the drapes may be ignited.

C-3-1.3.3 Sources of Ignition.

C-3-1.3.3.1 Potential sources of ignition of flammable anesthetics in anesthetizing locations include the following: (a) fixed electric equipment, (b) portable electric equipment, (c) accumulation of static electricity, (d) electrosurgical equipment, (e) open flames and heated objects above the ignition temperature of the flammable gases in use. Other potential sources of ignition may be percussion sparks, ignition of oxidizing and flammable gases from accidental mixing under pressure (3-2.6.1.2), and ignition from improper handling of oxygen cylinders (3-2.7.6.1).

The Technical Committee on Anesthetizing Agents is cognizant of suggestions that the detonation of ether peroxides formed by the oxidation of ether over a period of time may be a cause of explosions in anesthesia machines. Frequent emptying of the ether bottle and cleaning of the ether evaporator inside anesthetizing locations is a simple and desirable precaution.

Many types of hospital construction afford reasonable protection against lightning hazards. However, because of the storage and use of combustible anesthetic agents, the increased protection offered by the installation of lightning rods may be desirable for some types of buildings, particularly those of wood (frame) construction in outlying areas. Lightning protection, if installed, should conform to the requirements of NFPA 78, *Lightning Protection Code*.

C-3-1.3.3.2 Experience indicates that the ignition of flammable mixtures by electrostatic spark is a great hazard. Electrostatic charges may accumulate on personnel and metallic equipment. Electrostatic charges can set up dangerous potential differences only when separated by materials which are electrically nonconducting. Such insulators act as barriers to the free movement of such charges, preventing the equalization of potential differences. A spark discharge can take place only when there is no other available path of greater conductivity by which this equalization may be affected. Such a spark may ignite a flammable mixture of gases.

C-3-1.3.3.3 In many cases, the hazards of electric shock and electrostatic discharge coexist. Measures to mitigate one hazard may enhance the other, however. It is necessary, therefore, to weigh both hazards in recommending precautionary measures for either.

C-3-1.3.3.4 An obvious and, hence, less frequent cause of the ignition of flammable anesthetic agents is by open flame or hot materials at or above the ignition temperature of the agents. The lowest ignition temperature in air of any of the anesthetic agents mentioned in Appendix C-3-1.3.1.2 is that of ethyl ether: 180°C (365°F). The most effective safeguard against this source of ignition is a constant vigilance on the part of the operating room personnel to prevent the introduction of source of flames and hot objects into the anesthetizing locations (*see 3-2-7.3.9 in Chapter 3*).

C-3-1.4 Hazards Which May Be Present in Nonflammable Anesthetizing Locations.

C-3-1.4.1 Electrostatic Hazard.

C-3-1.4.1.1 Conductive flooring is not a requirement for nonflammable anesthetizing locations. The uncontrolled use of static-producing materials in such locations, however, may lead to:

- (a) Electrostatic discharge through sensitive components of electronic equipment, causing equipment failure;
- (b) Inadvertent use of these materials in flammable anesthetizing locations where mixed facilities exist (*see definition of Mixed Facility in Chapter 2*);
- (c) Impaired efficiency because of electrostatic clinging; or
- (d) The involuntary movement of personnel subject to electrostatic discharges.

C-3-1.4.2 Hazard of Flammable Substances.

C-3-1.4.2.1 Nonflammable anesthetizing locations are neither designed nor equipped for the use of any flammable substances, be they inhalation anesthetic agents or medicaments containing benzene, acetone or the like. A hazardous situation is created any time any such flammable substance is inadvertently or intentionally introduced into a nonflammable anesthetizing location (*see also Appendix C-3-1.3.2*).

C-3-1.5 Hazards Which May Be Present in Mixed Facilities.

C-3-1.5.1 Mixed facilities contain both flammable and nonflammable anesthetizing locations. Movable furniture, portable equipment and conductive accessories intended for

¹Cruise, M. S., "Lower Explosion Limits of Three Anesthetics in Mixtures of Oxygen and Nitrous Oxide," Hazards Research Corp. Report 3296 to Ohio Medical Products, Madison, Wisconsin, March 5, 1974.

sole use in nonflammable anesthetizing locations may be introduced inadvertently into a flammable anesthetizing location, with the attendant dangers of ignition of flammable gas mixtures from electrical or electrostatic sparks.

C-3-1.5.2 Personnel working in mixed facilities may not take the proper precautions in reference to wearing apparel and the use of conductive grounding devices when entering flammable anesthetizing locations.

C-3-1.5.3 A particular hazard exists if regulations [*see Appendix C-3-3 Set (3)*] are not adopted, posted, and complied with or if the anesthetizing locations are not identified as noted in 3-4.2, 3-4.3, 3-5.5.1 and 3-5.5.2.

C-3-2 Related Hazards and Safeguards.

C-3-2.1 General.

C-3-2.1.1 The gas anesthesia apparatus and anesthetic ventilators constitute essential items (in most cases) for the administration of inhalation anesthesia. The safe use of these devices is predicated upon their cleanliness and proper function, as well as an understanding of their proper operation, maintenance and repair.

C-3-2.2 Selection of a Gas Anesthesia Apparatus.

C-3-2.2.1 The individual selecting a gas anesthesia apparatus, either for initial purchase or for application in a given case, should be certain that the apparatus is the proper one for the given application or applications and that it is in good repair. See C-3-2.3, Suggested Method for Assuring Proper Delivery of Oxygen and Nitrous Oxide; C-3-2.4, Disposable Masks, Bags, Tubing and Bellows; and C-3-2.5, Decontamination and Routine Cleaning of Reusable Items.

C-3-2.3 Suggested Method for Assuring Proper Delivery of Oxygen and Nitrous Oxide.

C-3-2.3.1 This method is recommended to prevent delivery of a gas different from that indicated by the flowmeters, and to detect mixing of gases inside the machine that may result in delivery of dangerous gas mixtures to the patient. The following materials are needed:

- (a) 91.5 cm (3 ft) of anesthesia delivery hose, and
- (b) An accurate oxygen meter, analyzer or detector (*see 3-2.6.2.3*); this device may be of the paramagnetic, platinum electrode, gas chromatographic or mass spectrometer type.

C-3-2.3.2 Detailed steps of a method of testing anesthesia machines to assure the absence of hazard due to crossed connections between oxygen and nitrous oxide.

C-3-2.3.2.1 Premises.

(a) It is reasonable to conclude that no hazardous cross connections or cross leakages are present if gas from the only source available is delivered by only those valves intended for that gas, and that no gas is delivered by those valves when their intended source is unavailable, but other sources are available.

(b) It is not necessary to know the composition of a gas in order to determine the extent of the circuit it supplies.

(c) The operation of the oxygen circuit is independent, but the operation of some or all of the other circuits may be

at least partially dependent on the operability of the oxygen circuit, e.g., fail-safe valves.

C-3-2.3.2.2 Method.

All anesthesia machines have at least one source of oxygen. This may be a large cylinder, one or two small cylinders, or a pipeline supply. Some machines have two such sources, and a very few have all three. Each should be tested separately. Proceed as follows:

(a) Disconnect all gas sources and open all needle valves and flush valves until all gas has stopped flowing from the machine outlet. Then close all needle valves and flush valves. Be certain that all cylinder pressure gauges read zero. Connect an oxygen cylinder to an oxygen hanger yoke and open the cylinder valve. Pressure must rise in the corresponding oxygen pressure gauge only. Close the cylinder valve.

(b) Repeat step (a) exactly for each oxygen hanger yoke, including any fed by high pressure lines from large cylinders. Leave the cylinder in the last hanger yoke tested, with the cylinder valve open.

(c) Open in succession and leave open all the needle valves for gases other than oxygen. Briefly open any flush valve for a gas other than oxygen. No flow should occur at the machine outlet. An easy way to test for gas flow is to simply place the machine outlet tube in a glass of water and observe bubbling. Stand clear when flush valves are operated.

(d) Open and close in succession each of the oxygen needle valves, including any which provide an independent source of oxygen for vaporizers, and the oxygen flush valve. Flow should occur at the associated flowmeter or the machine outlet each time a valve is opened.

(e) If the machine is equipped for a pipeline oxygen supply, close the oxygen cylinder valve and open the oxygen flush valve. When gas stops flowing at the machine outlet, close the flush valve and all needle valves and connect the oxygen pipeline inlet to an oxygen pipeline outlet with the oxygen supply hose. The repeat steps (c) and (d).

(f) Since it is now established that oxygen is delivered to the oxygen needle and flush valves, and is not delivered to any other needle or flush valve, it remains to determine that it and it alone is also available to perform any other function for which it is essential. A valve which shuts off the supply of any other gas to the appropriate needle valve in the event of oxygen supply pressure failure, commonly called "fail-safe" valve, performs such a function. It should be tested as follows:

(g) Disconnect the pipeline supply and open the oxygen flush valve until flow stops at the machine outlet, then close the flush valve. Install a cylinder of nitrous oxide in one hanger yoke, open the cylinder valve, and note the pressure on all cylinder pressure gauges. Only the nitrous oxide gauge should show any pressure.

(h) Open in succession and leave open all the needle valves for gas other than nitrous oxide. Briefly open any flush valve for a gas other than nitrous oxide. No flow should occur at the machine outlet, nor at any flowmeter.

NOTE: An easy way to test for gas flow is to simply place the machine outlet tube in a glass of water and observe bubbling. Stand clear when flush valves are operated.

(i) Open and close in succession each of the nitrous oxide needle valves and nitrous oxide flush valves. If any delivers flow, all should do so.

(j) If neither the nitrous oxide needle valves nor the nitrous oxide flush valve deliver flow, open the oxygen cylinder valve and repeat steps (h) and (i). Each nitrous oxide needle valve and flush valve should deliver flow to the machine outlet.

(k) Close the nitrous oxide cylinder valve and open a nitrous oxide needle valve until all gas stops flowing, then remove the nitrous oxide cylinder and close the needle valve. Repeat steps (g) through (j) using any other nitrous oxide yoke.

(l) If the machine is equipped for a pipeline nitrous oxide supply, close the nitrous oxide cylinder valve and open a nitrous oxide needle valve until all gas stops flowing, then close all needle valves and flush valves. Connect the nitrous oxide pipeline inlet with a nitrous oxide pipeline outlet with the nitrous oxide supply hose. Then repeat steps (h) through (j).

C-3-2.4 Disposable Masks, Bags, Tubing and Bellows.

C-3-2.4.1 It is well recognized that newer technologies often lead to the introduction of new equipment and techniques, which in turn may lead to new hazards, or the potentiation of old ones. For example, the use of disposable and nondistensible conductive accessories potentiate the hazards of excessive airway pressures. These components should be employed only when it is assured that system pressure cannot become excessive.

C-3-2.4.1.1 Many plastic items are combustible. Most of these materials will emit toxic compounds when subjected to thermal decomposition. Special care must be exercised during storage, use and disposal of these items, to preclude accidental ignition. Due consideration must be given to on-site storage of trash prior to removal from the operating suite. The presence of these items on the hospital premises contributes significantly to the solid waste disposal problem facing the modern hospital.

C-3-2.4.1.2 The Committee recommends that purchasing policies of the institution, as well as the practices of individual physicians and nurses, take into consideration the multiple problems posed by plastic items, and limit purchases and use of them to those items deemed essential for the proper function of the institution.

C-3-2.5 Decontamination and Routine Cleaning of Reusable Items.

C-3-2.5.1 Under certain circumstances, infectious organisms can be cultured from the breathing passages of ventilators, anesthesia valves, absorbers, tubing, bags, masks and connectors. Some of these organisms can remain viable for many days. Although evidence that cross infection from such sources can and does occur is very scanty, it is suggested that the user of such equipment consider implementation of one of the following methods. Mechanical cleansing with soap and water should precede sterilization. Alternative approaches to routine cleansing include:

(a) Mechanical cleansing with soap and water, followed with air drying in a stream of compressed air.

(b) Mechanical cleansing with soap and water, followed by exposure to a preparation such as dialdehyde solution.

(c) Mechanical cleansing with soap and water, followed by ethylene oxide, steam, or dry heat sterilization.

C-3-2.5.2 Following gross contamination, the step outlined in C-3-2.5.1(b) or C-3-2.5.1(c) should be employed.

NOTE 1: Whenever ethylene oxide or dialdehyde is used, care must be taken to assure complete removal of residuals.

NOTE 2: Recommendations for cleansing and sterilization supplied by manufacturer of the item of equipment should be followed.

C-3-2.5.2.1 External contamination of the gas anesthesia apparatus, ventilator and other equipment employed on and around the patient at least at weekly intervals, as well as immediately after use in an infectious case, is likewise recommended.

C-3-3 Text of Suggested Signs and Posters for Inhalation Anesthetizing Locations.

SET (1)

REGULATIONS FOR SAFE PRACTICE IN FLAMMABLE ANESTHETIZING LOCATIONS

The following rules and regulations have been adopted by the Medical Staff and by the Administration. Chapter 3, Inhalation Anesthetics, of NFPA 99-1984 shall apply in all inhalation anesthetizing locations.

(Insert Date)

(Insert Name of Hospital Authority)

By reason of their chemical compositions, the following flammable anesthetic agents present a hazard of explosion in anesthetizing locations:

cyclopropane
ethyl ether

ethyl chloride
ethylene

REGULATIONS

1. Flammable Anesthetizing Location.

(a) **Definition.** The term Flammable Anesthetizing Location shall mean any area of the hospital designated for the use of flammable anesthetizing agents.

2. Equipment.

(a) No electrical equipment except that judged by the Engineering Department of _____ Hospital as being in compliance with Chapter 3, Inhalation Anesthetics, of NFPA 99-1984 shall be used in any flammable anesthetizing location.

(b) When a physician wishes to use his personal electrical equipment, it shall first be inspected by the Engineering Department and, if judged to comply with Chapter 3, Inhalation Anesthetics, of NFPA 99-1984, it shall be so labeled.

(c) Portable X-ray equipment used in flammable anesthetizing locations shall be approved for use in hazardous areas.

(d) Only approved photographic lighting equipment shall be used in flammable anesthetizing locations. Because of occasional bursting of bulbs, suitable enclosures shall be used to prevent sparks and hot particles from falling into the hazardous area.

(e) Covers shall not be used on anesthesia machines designed for flammable anesthetic agents.

3. Personnel.

(a) Outer garments worn by the operating room personnel and visitors shall not include fabrics of silk, wool, or synthetic textile materials such as nylon, polyester, acrylic or acetate, unless such fabrics have been tested and found to be antistatic in accordance with the requirements of Chapter 3, Inhalation Anesthetics, NFPA 99-1984.

(b) Silk, wool, or synthetic textile materials, except untreated rayon, shall not be permitted in anesthetizing locations as outer garments, or for nonapparel purposes, unless such fabrics have been tested and found to be antistatic in accordance with the requirements of Chapter 3, Inhalation Anesthetics, NFPA 99-1984. Hosiery and underclothing in which the entire garment is in close contact with the skin may be of silk, wool or synthetic material.

(c) All personnel and visitors entering flammable anesthetizing locations shall wear conductive footwear or other floor contacting devices which shall have been tested on the wearer and found to be satisfactorily conductive.

(d) It shall be the responsibility of each individual entering a flammable anesthetizing location to determine at least once daily that he is in electrical contact with the conductive floor. Apparatus for testing shall be available.

(e) Moving of patients from one area to another while a flammable anesthetic is being administered shall be prohibited.

(f) Smoking shall be limited to dressing rooms and lounges with the doors leading to the corridor closed.

4. Practice.

(a) Flammable anesthetic agents shall be employed only in flammable anesthetizing locations.

(b) Woolen and synthetic blankets shall not be permitted in flammable anesthetizing locations.

(c) Electrical connection of the patient to the conductive floor shall be assured by a high-impedance (conductive) strap in contact with the patient's skin with one end of the strap fastened to the metal frame of an operating table or shall be electrically interconnected by other means.

(d) If cautery, electrosurgery, or other electrical equipment employing an open spark is to be used during an operation, flammable anesthetics shall not be used. Flammable germicides or flammable fat solvents shall not be applied for the preoperative preparation of the field.

(e) A visual (lighted red lamp) or audible warning signal from the Line Isolation Monitor serving an anesthetizing location indicates that the total hazard current has exceeded allowable limits. This suggests that one or more electrical devices is contributing an excessively low impedance to ground, which might constitute a fault which would expose the patient or hospital personnel to an unsafe condition should an additional fault occur. Briefly and

sequentially unplugging the power cord of each electrical device in the location will usually cause the green signal lamp to light, showing that the system has been adequately isolated from ground, when the potentially defective device has been unplugged. The continuing use of such a device, so identified, should be questioned, but not necessarily abandoned. At the earliest opportunity the device should be inspected by the hospital engineer or other qualified personnel and, if necessary, repaired or replaced.

5. Enforcement.

It shall be the responsibility of _____
(name)

(an anesthesiologist or other qualified person appointed by the hospital authority to act in that capacity) to enforce the above regulations.

SET (2)

REGULATIONS FOR SAFE PRACTICE IN NONFLAMMABLE ANESTHETIZING LOCATIONS

The following rules and regulations have been adopted by the Medical Staff and Administration: NFPA 99-1984, Chapter 3, Inhalation Anesthetics shall apply in all inhalation anesthetizing locations.

(Insert Date)

(Insert Name of Hospital Authority)

The use or storage of any of the following mentioned flammable agents or germicides shall be prohibited from all operating rooms, delivery rooms and other anesthetizing locations in this hospital.

By reason of their chemical composition, these agents present a hazard of fire or explosion:

cyclopropane
diethyl ether

ethyl chloride
ethylene

1. Nonflammable Anesthetizing Location.

(a) **Definition.** The term Nonflammable Anesthetizing Location shall mean any anesthetizing location designated for the exclusive use of nonflammable anesthetizing agents.

2. Equipment.

(a) No electrical equipment except that judged by the Engineering Department of _____ Hospital as being in compliance with NFPA 99-1984, Chapter 3, Inhalation Anesthetics shall be used in any anesthetizing location.

(b) When a physician wishes to use his personal electrical equipment, it shall first be inspected by the Engineering Department and, if judged to comply with NFPA 99-1984, Chapter 3, Inhalation Anesthetics it shall be so labeled.

(c) Photographic lighting equipment shall be of the totally enclosed type or so constructed as to prevent the escape of sparks or hot metal particles.

3. Personnel.

Smoking shall be limited to dressing rooms and lounges with doors leading to the corridor closed.

4. Practice.

(a) The use or storage of flammable anesthetic agents shall be expressly prohibited in a nonflammable anesthetizing location.

(b) If cautery, electrosurgery, or other hot or arcing device is to be used during an operation, flammable germicides or flammable fat solvents shall not be applied for preoperative preparation of the skin.

(c) A visual (lighted red lamp) or audible warning signal from the Line Isolation Monitor serving an anesthetizing location indicates that the total hazard current has exceeded allowable limits. This suggests that one or more electrical devices is contributing an excessively low impedance to ground, which might constitute a fault which would expose the patient or hospital personnel to an unsafe condition should an additional fault occur. Briefly and sequentially unplugging the power cord of each electrical device in the location will usually cause the green lamp to light, showing that the system has been adequately isolated from ground, when the potentially defective device has been unplugged. The continuing use of such a device, so identified, should be questioned, but not necessarily abandoned. At the earliest opportunity the device should be inspected by the hospital engineer or other qualified personnel and, if necessary, repaired or replaced.

(d) Transportation of patients while an inhalation anesthetic is being administered by means of a mobile anesthesia machine shall be prohibited, unless deemed essential for the benefit of the patient in the combined judgment of the surgeon and anesthetist.

(e) If, in the combined judgment of the anesthesiologist responsible for the administering of the anesthetic and the surgeon performing the operation, the life of the patient would be jeopardized by not administering a flammable anesthetic agent the following steps shall be taken:

(1) Both surgeon and anesthesiologist involved in the case shall attest to the reason for administering a flammable anesthetic in a nonflammable anesthetizing location on the patient's record and in the operating room register.

(2) The hazard of static sparks shall be reduced by electrically interconnecting the patient, operating room table, anesthesia gas machine, and anesthesiologist by wet sheets or other conductive materials. Conductive accessories shall be used for the electrically conductive pathways from the anesthesia gas machine to the patient.

(3) If cautery, electrosurgery or other electrical equipment employing an open spark is to be used during an operation, flammable anesthetics shall not be used. Flammable germicides or flammable fat solvents shall not be applied for the preoperative preparation of the field.

5. Enforcement.

It shall be the responsibility of _____
(name)

(an anesthesiologist or other qualified person appointed by the hospital authority to act in that capacity) to enforce the above regulations.

SET (3)**REGULATIONS FOR SAFE PRACTICE IN MIXED FACILITIES**

The following rules and regulations have been adopted by the Medical Staff and by the Administration. NFPA 99-1984, Chapter 3, Inhalation Anesthetics shall apply in all inhalation anesthetizing locations. This hospital is a Mixed Facility. Personnel are cautioned as to the existence of both flammable and nonflammable inhalation anesthetizing locations within the hospital building and the different practices which apply to each location.

(Insert Date)

(Insert Name of Hospital Authority)

By reason of their chemical composition, these flammable anesthetic agents present a hazard of explosion in anesthetizing locations:

cyclopropane
ethyl ether

ethyl chloride
ethylene

REGULATIONS**1. Mixed Facility.**

(a) **Definition.** The term Mixed Facility shall mean a hospital wherein flammable anesthetizing locations and nonflammable anesthetizing locations coexist within the same building allowing interchange of personnel and equipment between flammable and nonflammable anesthetizing locations.

(b) **Definition.** Flammable Anesthetizing Location shall mean any area of the hospital designated for the administration of flammable anesthetic agents.

(c) **Definition.** Nonflammable Anesthetizing Location shall mean any anesthetizing location permanently designated for the exclusive use of nonflammable anesthetizing agents.

2. Equipment.

(a) No electrical equipment except that judged by the Engineering Department of _____ Hospital as being in compliance with NFPA 99-1984, Chapter 3, Inhalation Anesthetics shall be used in any flammable anesthetizing location.

(b) When a physician wishes to use his personal electrical equipment, it shall first be inspected by the Engineering Department and, if judged to comply with NFPA 99-1984, Chapter 3, Inhalation Anesthetics, it shall be so labeled.

(c) Portable X-ray equipment used in flammable anesthetizing locations shall be approved for use in hazardous areas.

(d) Only approved photographic lighting equipment shall be used in flammable anesthetizing locations. Because of occasional bursting of bulbs, suitable enclosures shall be used to prevent sparks and hot particles from falling into the hazardous area.

(e) Covers shall not be used on anesthesia machines designed for flammable anesthetic agents.

(f) All portable electrical equipment shall meet the requirements for flammable anesthetizing locations.

3. Personnel.

(a) Outer garments worn by the operating room personnel and visitors in mixed facilities shall not include fabrics of silk, wool, or synthetic textile materials such as nylon, polyester, acrylic or acetate, unless such fabrics have been tested and found to be antistatic in accordance with the requirements of NFPA 99-1984, Chapter 3, Inhalation Anesthetics.

(b) Silk, wool, or synthetic textile materials, except untreated rayon, shall not be permitted in mixed facilities as outer garments, or for nonapparel purposes, unless such fabrics have been tested and found to be antistatic in accordance with the requirements of NFPA 99-1984, Chapter 3, Inhalation Anesthetics. Hosiery and underclothing in which the entire garment is in close contact with the skin may be made of silk, wool or synthetic material.

(c) All personnel and visitors entering all anesthetizing locations in mixed facilities shall wear conductive footwear or other floor contacting devices which shall have been tested on the wearer and found to be satisfactorily conductive.

(d) It will be the responsibility of each individual entering an anesthetizing location of a mixed facility to determine at least once daily that he is in electrical contact with the conductive floor. Apparatus for testing shall be available.

(e) Moving of patients from one area to another while a flammable anesthetic is being administered shall be prohibited.

(f) Smoking shall be limited to dressing rooms and lounges with the doors leading to the corridor closed.

4. Practice.

(a) Flammable anesthetic agents shall be employed only in flammable anesthetizing locations.

(b) The administration or the intended administration of a flammable anesthetic agent shall be brought to the attention of all personnel within the flammable anesthetizing location by verbal communication by the anesthesiologist and by posting prominent signs in the operating room and at all entrances to the operating room stating that a flammable anesthetic agent is in use.

(c) Woolen and synthetic blankets shall not be permitted in anesthetizing locations.

(d) Electrical connection of the patient to the conductive floor in a flammable anesthetizing location shall be assured by a high-impedance conductive strap in contact with the patient's skin with one end of the strap fastened to the metal frame of an operating table or shall be electrically interconnected by other means.

(e) If cautery, electrosurgery or other electrical equipment employing an open spark is to be used during an operation, flammable anesthetics shall not be used. Flammable germicides and flammable fat solvents shall not be applied for the preoperative preparation of the field.

(f) If, in the combined judgment of the anesthesiologist responsible for the administration of the anesthetic and the surgeon performing the operation, the life of the patient

would be jeopardized by not administering a flammable anesthetic agent in a nonflammable anesthetizing location, the following steps shall be taken:

(1) Both surgeon and anesthesiologist involved in the case shall attest to the reason for administering a flammable anesthetic in a nonflammable anesthetizing location on the patient's record and in the operating room register.

(2) The hazard of static sparks shall be reduced by electrically connecting the patient, operating room table, anesthesia gas machine, and anesthesiologist by wet sheets or other conductive materials. Conductive accessories shall be used for the electrically conductive pathways from the anesthesia gas machine to the patient.

(g) A visual (lighted red lamp) or audible warning signal from the Line Isolation Monitor serving an anesthetizing location indicates that the total hazard current has exceeded allowable limits. This suggests that one or more electrical devices is contributing an excessively low impedance to ground, which might constitute a fault which would expose the patient or hospital personnel to an unsafe condition should an additional fault occur. Briefly and sequentially unplugging the power cord of each electrical device in the location will usually cause the green signal lamp to light, showing that the system has been adequately isolated from ground, when the potentially defective device has been unplugged. The continuing use of such a device, so identified, should be questioned, but not necessarily abandoned. At the earliest opportunity the device should be inspected by the hospital engineer or other qualified personnel and, if necessary, repaired or replaced.

(h) Interchange of personnel and portable equipment between flammable and nonflammable anesthetizing locations shall be strictly controlled.

(i) Transportation of patients while an inhalation anesthetic is being administered by means of a mobile anesthesia machine shall be prohibited, unless deemed essential for the benefit of the patient in the combined judgment of the surgeon and anesthesiologist.

5. Enforcement.

It shall be the responsibility of _____
(name)

(an anesthesiologist or other qualified person appointed by the hospital authority to act in that capacity) to enforce the above regulations.

C-3-4 Suggested Procedures in the Event of a Fire or Explosion.

C-3-4.1 General.

C-3-4.1.1 Fires in hospitals pose unique problems for hospital personnel, patients and fire service personnel. Hospitals store and use relatively large quantities of flammable and combustible substances. Oxygen-enriched atmospheres are often employed in medical therapy, and are utilized routinely during administration of anesthesia. The presence of flammable and combustible substances and oxygen-enriched atmospheres under the same roof with nonambulatory patients presents an extra hazardous situation. All hospital personnel should understand the steps to take to save life, preserve limb, and contain smoke and/or limit fire until the fire department arrives. It is recom-

mended that the procedures delineated herein, or similar ones, become a part of the firesafety regulations of every hospital.

C-3-4.2 Steps to Take in the Event of a Fire or Explosion.

C-3-4.2.1 The following steps, listed in the approximate order of their importance, should be taken by all personnel, should fire occur. If an explosion occurs, and it is not followed by fire, follow the procedure outlined under C-3-4.2.2. If a fire follows an explosion, proceed as follows:

(a) Remove the immediately exposed patient or patients from the site of the fire, if their hair or clothing are not burning. If they are burning, extinguish the flames (*see C-3-4.4 and C-3-4.5*).

(b) Sound the fire alarm by whatever mode the hospital fire plan provides.

NOTE: It is assumed that each hospital has a fire plan, prepared in consultation with representatives of the local fire department. In such a plan, immediate notification of the local fire department is essential.

(c) Close off the supply of oxygen to any equipment involved, if this step can be accomplished without injury to personnel (*see C-3-4.3*).

(d) Close doors to contain smoke and isolate fire.

(e) Remove patients threatened by the fire.

(f) Attempt to extinguish or contain the fire (*see C-3-4.4*).

(g) Direct the fire fighters to the site of the fire.

(h) Take whatever steps are necessary to protect or evacuate patients in adjacent areas.

NOTE 1: In the event of a fire in a operating room while an operative procedure on an anesthetized patient is in progress, it may be necessary to extinguish the fire prior to removing the patient from the room.

NOTE 2: During an operation, it may be more hazardous to move patients than to attempt to extinguish or contain the fire. The attending physician must determine which step would present the lesser hazard — hurriedly terminating an operative procedure or continuing the procedure and exposing the members of the operating team and the patient to the hazards stemming from the fire.

C-3-4.2.2 The following steps are recommended in the event of an explosion involving inhalation anesthesia apparatus:

(a) Disconnect the patient from the apparatus;

(b) Procure a new gas anesthesia apparatus and make every effort to save the life of the patient and prevent injury to the patient.

C-3-4.2.3 It is essential that all equipment involved in a fire or explosion be preserved for examination by an authority attempting to determine the cause. Additionally, pertinent administrative data, including photographs, should be recorded. The report should state:

(a) Whether wearing apparel of all persons in the room at the time of the fire or explosion met the requirements of 3-3-6.7 and 3-3-6.8 of Chapter 3;

(b) Whether portable equipment, low-voltage instruments, accessories and furniture met the requirements of 3-3-5.1, 3-3-5.3, 3-3-6.3, 3-3-6.4, and 3-3-6.9, respectively of Chapter 3;

(c) Whether the ventilating system was being operated in accordance with 3-3.1.1 of Chapter 3.

C-3-4.2.3.1 The area involved, with all involved items in place, should be closed off and secured for later examination by responsible authority.

C-3-4.3 Closing Off Oxygen Supply.

C-3-4.3.1 In the event of a fire involving equipment connected to an oxygen station outlet, the zone valve supplying that station is to be closed [*see C-3-4.6.1(a)*].

C-3-4.3.1.1 Immediately, all patients receiving oxygen through the same zone valve must be supplied with individual oxygen cylinders.

NOTE: Each gas line to an operating room should have an individual zone valve (*see NFPA 56F, Nonflammable Medical Gas Systems*). Thus, closing of all valves to one room would not endanger patients in other rooms.

C-3-4.3.2 If fire involves apparatus supplied by a cylinder of oxygen, it is desirable to close the cylinder valve, if this can be done without injuring personnel.

NOTE: Metal components of regulators and valves can become excessively hot if exposed to flame. Personnel are cautioned not to use their bare hands to effect closure.

C-3-4.4 Extinguishment or Containment of Fire.

C-3-4.4.1 Fire originating in or involving inhalation anesthesia apparatus generally involves combustibles such as rubber. Water or water-based extinguishing agents are most effective in such fires.

(a) Precaution should be observed if line-powered electrical equipment is adjacent to or involved in fire, because of the danger of electrocution of personnel if streams of water contact live circuits.

(b) Before attempting to fight fire with water or a water-based extinguishing agent, electrical apparatus should be disconnected from the supply outlet, or the supply circuit de-energized at the circuit panel.

(c) If such de-energization cannot be accomplished, water should not be employed (*see C-3-4.4.3*).

C-3-4.4.2 Fires involving, or adjacent to, electrical equipment with live circuits must be fought with extinguishers suitable for "Class C" fires in accordance with NFPA 10, *Portable Fire Extinguishers*.

C-3-4.4.3 Fire extinguishers are classified according to the type of fire for which each is suited.

(a) Fires involving ordinary combustibles such as rubber, plastic, linen, wool, paper and the like are called "Class A" fires. These may be fought with water or water-based extinguishing agents. Hose lines are suitable for this purpose. Portable extinguishers suitable for "Class A" fires are identified with the letter "A" contained in a (if colored) green triangle.

(b) "Class B" fires involve flammable liquids and should be fought only with an extinguisher identified by a letter "B" contained in a (if colored) red square.

(c) "Class C" fires involve electrical equipment and should be fought only with an extinguisher identified by a letter "C" contained in a (if colored) blue circle.

(d) Carbon dioxide and some dry chemical extinguishers are labeled for "Class B" and "Class C" fires. Some dry chemical units may be used for all three types (see NFPA 10, *Portable Fire Extinguishers*, Appendix B).

C-3-4.5 Protection of Patients and Personnel.

C-3-4.5.1 Serious and even fatal burns of the skin or lungs, from inhaling heated gases, are possible. Thus, it is essential that patients be removed from the scene of the fire whenever practical. Where an anesthetized patient is connected to a burning piece of equipment, it may be more practical as the initial step to remove the equipment and/or extinguish the fire than to remove the patient.

C-3-4.5.2 Noxious gases produced by fire constitute a threat to life from asphyxia, beyond the thermal burn problem.

(a) Personnel are cautioned not to remain in the fire area after patients are evacuated, unless they are wearing proper emergency apparatus.

C-3-4.6 Indoctrination of Personnel.

C-3-4.6.1 It is highly desirable that personnel involved in the care of patients, including nurses, aides, ward secretaries, and physicians, irrespective of whether they are involved in anesthesia practices, be thoroughly indoctrinated in all aspects of firesafety, including:

(a) The location of zone valves of nonflammable medical gas systems and the station outlets controlled by each valve.

(b) The location of electrical service boxes and the areas served thereby.

(c) The location and proper use of fire extinguishers (see C-3-4.4).

(d) The recommended methods and routes for evacuating patients (see Appendix D, *Health Care Emergency Preparedness*).

(e) The steps involved in carrying out the fire plan of the hospital.

(f) The location of fire alarm boxes, or knowledge of other methods for summoning the fire department.

C-3-4.6.2 To ensure that personnel are familiar with the procedures outlined above, regular instructive sessions and fire drills should be held.

C-3-5 Cylinder Table. See Table C-3-5/C-4-1/C-5-4.

Appendix C-4 Additional Explanatory Information on Chapter 4, Use of Inhalation Anesthetics in Ambulatory Care Facilities

This Appendix is a product of the Compressed Gas Association (CGA) and is printed with its permission.

C-4-1 Typical Gas Cylinders.

C-4-2 Text of Suggested Regulations.

C-4-1 Typical Gas Cylinder Table. (See Table C-3-5/C-4-1/C-5-4.)

Table C-3-5/C-4-1/C-5-4

This Table reprinted with permission from the Compressed Gas Association.

TYPICAL MEDICAL GAS CYLINDERS VOLUME AND WEIGHT OF AVAILABLE CONTENTS*

All Volumes at 70 F. (21.1 C)

Cylinder Style & Dimensions	Nominal Volume Cu In/Liter	Contents	NAME OF GAS								Mixtures of Oxygen	
			Air	Carbon Dioxide	Cyclo- Propane	Helium	Nitrogen	Nitrous Oxide	Oxygen	Helium	CO ₂	
B 3½" od x 13" 8.89 x 33 cm	87/1.43	psig Liters Lbs.-Oz. Kilograms		838 370 1 - 8 .68	75 375 1 - 7¼ .66				1900 200 — —			
D 4½" od x 17" 10.8 x 43 cm	176/2.88	psig Liters Lbs.-Oz. Kilograms	1900 375 — —	838 940 3 - 13 1.73	75 870 3 - 5½ 1.51	1600 300 — —	1900 370 — —	745 940 3 - 13 1.73	1900 400 — —	** 300 ** **	** 400 ** **	
E 4¾" od x 26" 10.8 x 66 cm	293/4.80	psig Liters Lbs.-Oz. Kilograms	1900 625 — —	838 1,590 6 - 7 2.92		1600 500 — —	1900 610 — —	745 1,590 6 - 7 2.92	1900 660 — —	** 500 ** **	** 660 ** **	
M 7" od x 43" 17.8 x 109 cm	1337/21.9	psig Liters Lbs.-Oz. Kilograms	1900 2850 — —	838 7,570 30 - 10 13.9		1600 2260 — —	2200 3200 — —	745 7,570 30 - 10 13.9	2200 3450 122 cuft —	** 2260 ** **	** 3000 ** **	
G 8½" od x 51" 21.6 x 130 cm	2370/38.8	psig Liters Lbs.-Oz. Kilograms	1900 5050 — —	838 12,300 50 - 0 22.7		1600 4000 — —		745 13,800 56 - 0 25.4		** 4000 ** **	** 5330 ** **	
H or K 9¼" od x 51" 23.5 x 130 cm	2660/43.6	psig Liters Lbs.-Oz. Kilograms	2200 6550 — —			2200 6000 — —	2200 6400 — —	745 15,800 64 29.1	2200† 6900 244 cuft —			

NOTES: (*) These are computed contents based on nominal cylinder volumes and rounded to no greater variance than ±1%.

(**) The pressure and weight of mixed gases will vary according to the composition of the mixture.

(†) 275 cu. ft./7800 liter cylinders at 2490 psig are available upon request.

C-4-2 Text of Suggested Regulations for Nonflammable Inhalation Anesthetizing Locations and Gas Storage Areas in Nonhospital-based Ambulatory Care Facilities.

The following rules and regulations have been adopted. The requirements of Chapter 4 of NFPA 99-1984 shall apply to all anesthetizing locations and gas storage areas in this facility.

The use of any of the following mentioned flammable agents shall be prohibited from the premises. By reason of their chemical composition, these agents present a hazard of fire or explosion:

cyclopropane	fluroxene
divinyl ether	ethyl chloride
ethyl ether	ethylene

Smoking shall be limited to those areas of the premises not directly connected with the anesthetizing location or the location for storage of compressed gas cylinders.

Compressed gas cylinders shall be connected to the manifold, and otherwise handled and stored, as provided in Chapter 4 of NFPA 99-1984.

Defective electrical equipment shall not be used on the premises.

Gas pipeline alarm systems shall be monitored, and responsible personnel notified of any fall in pressure or alarm condition.

Appendix C-5 Additional Explanatory Information on Chapter 5, Respiratory Therapy

C-5-1 Medical Safeguards.

C-5-2 Glossary of Respiratory Therapy Terms.

C-5-3 Suggested Fire Response.

C-5-4 Gas Cylinder Table.

C-5-1 Medical Safeguards.

C-5-1.1 General.

C-5-1.1.1 Personnel setting up, operating, and maintaining respiratory therapy equipment, including suction apparatus, should familiarize themselves with the problems of the use of each individual unit.

C-5-1.1.2 Respiratory therapy equipment should be stored and serviced in an area apart from that used for other functions. Preferably the respiratory therapy service should be supplied with its own workroom/storeroom. Such a room or area may be divided into three sections — clean-up and sterilization, repair, storage and reissue.

C-5-1.1.3 Storage of respiratory therapy equipment should be systematic and segregated from areas of storage of other items of medical equipment. If drawers or cabinets are employed, proper labeling should be utilized to assure ready availability of equipment.

C-5-1.1.4 Personnel must be aware of the exact location of equipment in storage to facilitate emergency use.

C-5-1.2 Handling of Equipment. Proper procedures must be established for mechanical cleansing and sterilization of equipment coming in contact with patients or

through which patients breathe. There must be no residual chemical deposits which might be toxic to the patient and no residual bacteria which might cause cross infection.

C-5-1.2.1 Mechanical cleansing and sterilization should be carried out after each patient application.

C-5-1.2.2 Mechanical cleansing should be sufficiently thorough to remove blood, saliva, mucous, residual adhesive tape and other debris.

C-5-1.2.3 Use of improper combinations of medication in therapy equipment should be avoided.

C-5-1.3 Tracheotomy and Endotracheal Tube Connection.

C-5-1.3.1 Pressure breathing apparatus may be connected directly to a tracheotomy or endotracheal tube. Connectors designed to afford a tight fit between breathing tubes of a pressure breathing apparatus and the tracheal tube should have an internal diameter at least as large as that of the tube.

C-5-1.3.2 A tracheotomy collar should not obstruct movement of gas through the tracheotomy tube.

C-5-1.3.3 To avoid reducing the effective lumen of tracheotomy tubes and interfering with movement of gas in and out of the lungs, suction tubes or other devices must not remain in the tracheotomy tubes.

C-5-1.4 Suction Equipment for Respiratory Care.

C-5-1.4.1 Equipment employed for patient suction includes the source of suction, the interconnecting tubing, collection and trap bottles. The bottle used for collection may contain the trap. A trap is a mechanism preventing spillage of liquid contents into the source of suction if the bottle overfills.

C-5-1.4.2 Suction equipment should be set up and applied only by qualified individuals.

C-5-1.4.3 Sources of suction without pressure regulation should not be connected directly to a tube to be inserted into a body cavity for continuous suction. Regulation of suction pressure is not required for clearing of the oral cavity or removal of blood or other body fluids from open wounds.

C-5-1.4.4 Suction regulators should be serviced by qualified individuals. Defective regulators should not be employed.

C-5-1.4.5 Trap bottles should be fixed to the wall or other appropriate stationary object to prevent tipping and subsequent spillage of liquid contents into the source of suction.

C-5-1.4.5.1 Trap bottles should be utilized between collection bottles and the source of suction to prevent spillage (see C-5-1.4.1 and C-5-1.4.5).

C-5-1.4.5.2 Collection bottles should be placed below the site of suction drainage from the patient, thus allowing

gravitational pull to aid rather than impede flow into the collection bottle.

C-5-1.4.5.3 Collection bottles should be placed as close as practical to the patient to reduce the length of tubing required and to increase the efficiency of suction.

C-5-1.4.5.4 The overflow-preventive mechanism of the trap bottle should be cleaned each time the bottle is emptied and should be tested periodically to assure proper functioning.

C-5-1.4.6 Suction tips or tubes with the largest practical internal diameter should be employed.

C-5-1.4.7 Tubing employed for connection of the various components of the suction system should possess an internal diameter of at least 0.25 in. (.64 cm). The wall thickness of the tubing should be sufficient to prevent collapse during all conditions of use.

C-5-1.4.8 Suction tubing employed in a hazardous location is to be electrically conductive.

C-5-2 Glossary of Respiratory Therapy Terminology.

Arrhythmia. Irregularity of heartbeats.

Asphyxia. Suffocation from lack of oxygen and an accumulation of carbon dioxide.

Aspiration. Removal of accumulated mucus by suction.

Bronchi. The two primary divisions of the trachea.

C.P.A.P. Continuous positive airway pressure.

C.P.R. Cardio-pulmonary resuscitation.

Croup Tent. Equipment utilized to provide environmental control inside a canopy in relation to oxygen concentration, temperature, humidity and filtered gas.

Cyanosis. A bluish discoloration of skin and mucous membranes due to excessive concentration of reduced hemoglobin in the blood.

Defibrillate. Use of electrical shock to synchronize heart activity.

Diffusion. Transfer of gases across the alveolar capillary membrane.

EKG, ECG. Electrocardiogram.

Hemoglobin. The chemical compound in red blood cells that carries oxygen.

Hypoxia. An abnormally decreased supply or concentration of oxygen.

I.M.V. Intermittent mandatory ventilation.

I.P.P.B. Intermittent positive pressure breathing.

P.E.E.P. Positive end expiratory pressure.

Respiration. The exchange by diffusion of gases between the alveoli and the blood and the tissue.

R.L.F. A disease entity of the premature infant causing blindness.

Thorax. The chest, the upper part of the trunk between the neck and the abdomen.

Trachea. The windpipe leading from the larynx to the bronchi.

Ultrasonic Nebulizer. A device which produces sound waves that are utilized to break up water into aerosol particles.

Ventilation. Movement of air into and out of the lungs.

Ventilator. Machine used to support or assist non-breathing or inadequately breathing patient.

C-5-3 Suggested Fire Response.

Suggested procedure in the event of fire involving respiratory therapy apparatus.

C-5-3.1 General. Fires in oxygen-enriched atmospheres spread rapidly, generate intense heat, and produce large volumes of heated and potentially toxic gases. Because of the immediate threat to patients and personnel, as well as the damage to equipment and possible spread to the structure of the building, it is important that all personnel be aware of the steps necessary to save life, preserve limb, and within reason to extinguish or contain the fire.

C-5-3.2 Steps to Take in Event of Fire.

C-5-3.2.1 The following steps are recommended in the event of a fire, in the approximate order of importance:

(a) Remove the patient or patients immediately exposed from the site of the fire if their hair and clothing are not burning; if they are burning, extinguish the flames. (See C-5-3.4 and C-5-3.5.)

(b) Sound the fire alarm by whatever mode the hospital fire plan provides.

(c) Close off the supply of oxygen to the therapy apparatus involved if this step can be accomplished without injury to personnel. (See C-5-3.3.)

(d) Carry out any other steps specified in the fire plan of the hospital. For example:

1. Remove patients threatened by the fire.
2. Close doors leading to the site of the fire.
3. Attempt to extinguish or contain the fire. (See C-5-3.4.)
4. Direct fire fighters to the site of the fire.
5. Take whatever steps necessary to protect or evacuate patients in adjacent areas.

C-5-3.3 Closing Off of Oxygen Supply.

C-5-3.3.1 In the event of a fire involving respiratory therapy equipment connected to an oxygen station outlet, the zone valve supplying that station is to be closed.

C-5-3.3.1.1 All personnel are cautioned to be aware of the hazard of such a step to other patients receiving oxygen supplied through the same zone valve. Steps should be taken to minimize such hazards, realizing that closing the valve is of foremost importance.

C-5-3.3.2 In the event of oxygen therapy apparatus supplied by a cylinder or container of oxygen, it is desirable to close the valve of the cylinder or container, provided that such closure can be accomplished without injury to personnel.

NOTE: Metallic components of regulators and valves can become exceedingly hot if exposed to flame. Personnel are cautioned not to use their bare hands to effect closure.

C-5-3.4 Extinguishment or Containment of Fire.

C-5-3.4.1 Fire originating in or involving respiratory therapy apparatus generally involves combustibles such as rubber, plastic, linen, blankets, and the like. Water or water-based extinguishing agents are most effective in such fires.

C-5-3.4.1.1 Precautions should be observed if electrical equipment is adjacent to or involved in the fire, because of the danger of electrocution of personnel if streams of water contact live 115-volt circuits.

C-5-3.4.1.2 Before attempting to fight such a fire with water or a water-based extinguishing agent, such electrical apparatus should be disconnected from the supply outlet, or the supply circuit de-energized at the circuit panel.

C-5-3.4.1.3 If such de-energization cannot be accomplished, water should not be employed. (See C-5-3.4.2.)

C-5-3.4.2 Fires involving or adjacent to electrical equipment with live circuits may be fought with extinguishers suitable for Class C fires, in accordance with NFPA 10, *Standard on Portable Fire Extinguishers*.

NOTE: Chemical extinguishers are not effective against fires in oxygen-enriched atmospheres unless the source of oxygen is shut off, as noted in C-5-3.3.

C-5-3.5 Protection of Patients and Personnel.

C-5-3.5.1 Because of the intense heat generated, serious and even fatal burns of the skin or of the lungs from inhaling heated gases are possible sequelae to the oxygen-enriched atmosphere fire. Thus, it is essential that patients be removed from the site of the fire whenever practical.

NOTE: Where a nonambulatory patient is connected to a burning piece of therapy equipment, it may be more practical as the initial step to remove the equipment and/or extinguish the fire than to remove the patient.

C-5-3.5.2 The large quantities of noxious gases produced constitute a threat to life from asphyxia, beyond the thermal burn problem.

C-5-3.5.2.1 Personnel are cautioned not to remain in the fire area after patients are evacuated if quantities of gaseous combustion products are present.

C-5-3.6 Indoctrination of Personnel.

C-5-3.6.1 It is highly desirable that personnel involved in the care of patients, including nurses, aides, ward secretaries, and physicians, irrespective of whether or not they are involved in respiratory therapy practices, be thoroughly indoctrinated in all aspects of firesafety, including:

(a) The location of zone valves of nonflammable medical gas systems where employed, and the station outlets controlled by each valve.

(b) The location of electrical service boxes, and the areas served thereby.

(c) The location of fire extinguishers, indications for their use and techniques for their application.

(d) The recommended methods of evacuating patients, and routes by which such evacuation shall be accomplished most expeditiously. Reference should be made to the hospital's fire plan.

(e) The steps involved in carrying out the fire plan of the hospital.

(f) The location of fire alarm boxes, or knowledge of other methods, for summoning the local fire department.

C-5-4 Typical Gas Cylinders. See Table C-3-5/C-4-1/C-5-4, Typical Gas Cylinders.

Appendix C-6 Additional Explanatory Information on Chapter 6, Medical-Surgical Vacuum Systems in Hospitals

C-6-1 Examples.**C-6-2 Vacuum Flow Chart and Formulas.****C-6-3 Metric Conversion Factors.****C-6-4 Comments on Derivation of Design Parameters.****C-6-1 Examples.**

C-6-1.1 Example 1. Vacuum Source Sizing Example. Calculate the required vacuum pump capacity to meet the demands of a hypothetical hospital with rooms and terminal quantities described below:

Room Designation	Number of Rooms/ Beds	Number of Terminals	Type/ Usage Group [See Table A-6-2.2(a)]
Operating Rooms	6	18	A
Cystoscopy Rooms	2	6	A
Delivery Rooms	4	12	A
Recovery Beds	13	39	A
ICUs	24	72	A
Emergency Rooms	10	10	A
Emergency Rooms— Major Trauma	2	6	A
Patient Rooms	385	385	B
Nursery	30	30	B
Treatment and Examination	20	20	B
Autopsy	1	1	B
Respiratory Care	1	1	B
Dialysis Unit	4	2	B

	No. of Terminals	SCFM	Use Factor*	Adjusted SCFM
Type A	163	$163 \times .25 = 41$	0.52	21
Type B	439	$439 \times .25 = 110$	0.22	24
Operating Rooms	6	$6 \times 1.5 = 9$	1.0	9
				54**

*per Table A-6-2.2(b)

**does not include waste anesthetic gas evacuation

Pump Sizing for 3 in. Hg Piping Pressure Drop:

Minimum allowable system vacuum	12 in. Hg Vac.
Design pressure drop (Appendix C-6-2)	3 in. Hg Vac.
Minimum operating vacuum at receiver	15 in. Hg Vac.

To maintain the minimum operating vacuum at the receiver, typical control settings for a duplex vacuum pump installation might be as follows (assuming pumps are located at the receiver):

	Start	Stop
Lead Switch	16 in. Hg Vac.	19 in. Hg Vac.
Lag Switch	15 in. Hg Vac.	18 in. Hg Vac.

NOTE: Three-inch vacuum pressure loss used in the illustration can be varied to suit system design.

The pumps are rated for the ACFM load at the lead switch setting of the vacuum pump, in this example, 16 in. Hg vacuum.

Required single pump capacity (ACFM):

$$\begin{aligned} \text{ACFM} &= (\text{Adjusted SCFM}) \times \left(\frac{29.92}{29.92 - V_{\text{vac}}} \right) \times \left(\frac{T + 460}{528} \right) \\ &= 54 \times \left(\frac{29.92}{29.92 - 16} \right) \times \left(\frac{68 + 460}{528} \right) \\ &= 116 \end{aligned}$$

Therefore, the hospital requires two vacuum pumps, each with a minimum capacity of 116 ACFM at 16 in. Hg vacuum.

NOTE: For final vacuum source sizing, see Appendix A-6-3.1, Total Weighted System Demand. The pump size selected should handle this flow (116) or the maximum flow established for mains, whichever is higher.

C-6-1.2 Example 2. Pipe Sizing Example (Not Related to Examples 1 and 3). See Figure C-6-1(a).

C-6-1.3 Example 3. Pipe Sizing Example (Not Related to Examples 1 and 2). See Figure C-6-1(b).

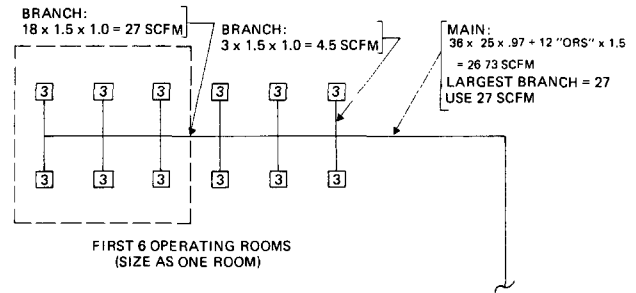


Figure C-6-1(b) Sizing Branch Lines Serving Large Operating Suites.

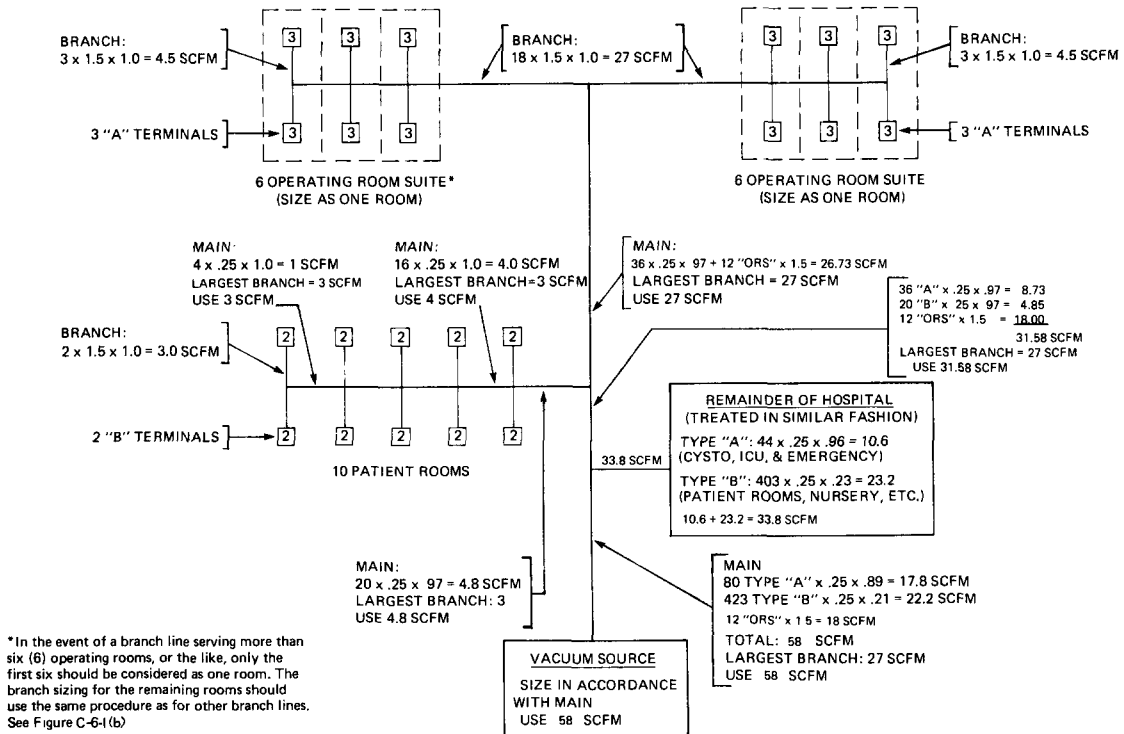
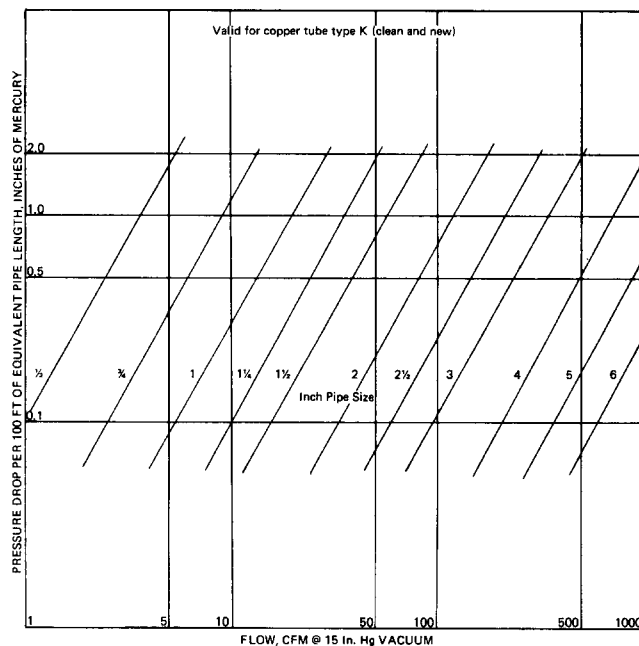


Figure C-6-1(a) Typical Branch and Main Sizing.

C-6-2 Vacuum Flow Chart and Formulas.



NOTE: Pressure drops at other vacuum levels may be closely approximated by multiplying the pressure drop found from the chart (for a given CFM and pipe size) times the ratio:

$$\left[\frac{30 - \text{new vacuum level}}{15} \right]^{0.8}$$

Formulas for Calculating Pressure Drop
for Other Types and Sizes of Pipe

(Eq 1) Darcy's Formula:

$$P = 0.00341 f \left(\frac{L}{D} \right) \frac{\rho V^2}{2g}$$

where:

- P = pressure drop in. Hg abs.
- f = friction factor determined from Moody Diagram
- L = length of pipe, ft
- D = internal diameter of pipe, ft
- ρ = density of air at upstream pressure, lb/ft³
- V = velocity of air at upstream pressure, ft/sec
- g = gravitation constant, 32.2 ft/sec²

For clean new copper tube K, L or M, the friction factor may be closely approximated by the following relation:

(Eq 2)
$$f = \frac{0.184}{(\text{Re}_N)^{0.2}}$$

where:

$$\text{Re}_N = \text{Reynolds's Number}, \quad \frac{\rho V D}{\mu}$$

$$\mu = \text{absolute (dynamic) viscosity}, \quad \frac{\text{lb}}{\text{sec ft}}$$

Friction factors of commercial steel pipe are higher.

C-6-3 Metric Conversion Factors.

- 1 in. = 2.540 cm
- 1 ft = 30.48 cm
- 1 atm = 29.92 in. Hg = 760 mmHg
- 1 lb per sq in. = 4.882 kg per sq m
- 1 cu ft per min = 28.32 L per min

C-6-4 Comments on Derivation of Design Parameters.

While most vacuum system design parameters, such as pressure drop, are derived from the laws of physics, two very important items are almost entirely empirical. These two are first, the number of vacuum terminals (or inlets) needed for various types of rooms or functional areas of a health care facility [Table A-6-2.2(a)]; and second, the number of terminals (or inlets) that are in simultaneous operation at any given time [Table A-6-2.2(b)].

The reasons for this empiricism are obvious. The number of terminals needed for any particular room depends not only on the medical needs of the patients being treated, but also upon the location of those terminals within each room and the individual characteristics of each vacuum device attached to the terminals. The number of terminals in simultaneous use (the diversity factor) depends not only on the type of medical facility involved but also, to some extent, on the geographical area that the facility serves.

The number of vacuum terminals needed and the diversity factor determine the "load" on the vacuum system. This load is then used to determine the required vacuum pump capacity as well as the sizing of the piping between terminals and pumps. One design approach would be to assume a "worst case" situation (such as all installed terminals are in simultaneous use). Another would be to assume a fixed diversity factor regardless of facility size.

All such arbitrary approaches can be criticized as being either unnecessarily expensive or resulting in inadequate systems. Clearly, design recommendations must be based upon the actual vacuum needs in "real life" facilities. Given the obvious limitations of time and money, these recommendations can be based only on a survey of a fraction of the total number of health care facilities in existence at any one time.

In 1974, the Sectional Committee on Medical-Surgical Vacuum Systems¹ examined representative samples of suction apparatus to determine the design requirements (i.e., flow rates and vacuum) for the associated terminals. "As delivered" samples of the apparatus of five leading manufacturers, covering an estimated 90 percent of all equipment then in common use in the United States, were measured in the presence of Committee members at the engineering laboratories of one of the manufacturers. Field conditions were simulated by the use of saline solutions and whole blood samples provided for this purpose by a member of the Sectional Committee. The recommended flow rate given in 6-2.3 and minimum vacuum given in 6-3.1.2 are based on these measurements. Periodic review

¹In 1974, the Committee was actually an *ad hoc* Subcommittee (formed in 1971) of the Committee on Hospitals. In 1975, it became a full Sectional Committee under the jurisdiction of the Correlating Committee on Health Care Facilities. In 1976, Sectional Committees were raised to Technical Committee level.

of these 1974 measurements indicates that they are still valid as of 1980.

In 1976, the Sectional Committee on Medical-Surgical Vacuum Systems examined the vacuum systems of nine hospitals to determine the types and locations of their vacuum terminals (inlets), the number of terminals in use throughout the day, and total demand on the vacuum source(s) as the various terminals were used. These hospitals ranged in size from 100 beds to 1,200 beds, and, in terms of the types of medical procedures performed and demands placed on their vacuum systems, were considered a fair representation of hospitals in the United States. Flow rate and pressure recording instruments were provided by one of the manufacturers. The original data for Table A-6-2.2(a) and Table A-6-2.2(b) were based on these measurements.

Between 1976 and 1977, the vacuum systems of approximately 20 additional hospitals were examined by one or more members of the Sectional Committee. Several of these systems were being examined because of malfunctions or inadequate performance. The others were new systems being designed and installed, or new extensions to existing systems. The information obtained from these hospitals was used to make minor corrections to Table A-6-2.2(a) and Table A-6-2.2(b).

The sampling of hospital vacuum systems was expanded in 1978. Whereas previous data were based upon short 90-minute data observations, newer data were based upon one-week data acquisition. Although 13 hospital systems were studied, only 9 contained usable data. This information was later expanded in 1980 by data from 21 additional hospital systems. In total, data from 67 vacuum systems have been gathered by the CGA, industry members of the Committee, and by the American Society for Hospital Engineering. Hospital sizes varied from 40 to 1200 beds and constituted a broader representation than previous.

The data from the 1978-1980 surveys (30) were analyzed using the existing 1978 formulae. All but eight systems fit the existing formulae. The important conclusions from an analysis indicated that:

1. The number of ORs was found to be the single most important parameter affecting SCFM demand.
2. The total number of A-type and B-type terminals was the second most important parameter.
3. Whether the hospital used the central vacuum system for waste anesthetic gas disposal was not found to be statistically significant in this group of data.

The basic 1978 formulae were subsequently adjusted in 1980 to accommodate an additional 1.5 SCFM requirement for each OR. The formulae were now found to have virtually 100 percent unanimity with all 67 data samples. Additionally, the formulae provide for a sizing that gives $2\frac{1}{2}$ times the observed peak demand, a margin that should be enough for even the most conservative users.

Over the years several members of the Technical Committee on Medical-Surgical Vacuum Systems have planned, designed and supervised the installation of a number of these systems using the procedures outlined in Chapter 6 and its associated Appendices A-6 and C-6. These systems have continued to perform as intended.

Appendix C-7 Additional Explanatory Information on Chapter 7, Laboratories in Health-Related Institutions

C-7-1 Fire Incidents in Laboratories.

C-7-2 Related Definitions.

C-7-1 Fire Incidents in Laboratories.

Descriptions of a few laboratory fires are included in NFPA FR 61-1, "Occupancy Fire Record — Hospitals." Some laboratory fires and explosions are described below:

Tissue Processor Fire — Operated 24 hours per day, but unattended from 11 PM to 7 AM, a tissue processor was suspected of causing \$200,000 damage because the incident occurred after 11 PM and there were no detectors or automatic extinguishing equipment in the laboratory. Flammable liquids in glass containers stored in an open shelf below the equipment contributed to the intensity of the fire.

Aside from damage to the laboratory, electrical cables in the corridor near the incident shorted and caused power to be interrupted in the hospital. Fire doors closed, but the fire alarm was not sounded.

"Walking" Motor Fire — A motor, which had been connected to inadequately secured apparatus, "walked" off a bench and caught fire.

Incinerator Explosion — The operators received minor burns as they dumped contents of GI cans into a top-feed incinerator; detonations were caused by "empty" ether cans.

Perchloric Acid Explosion — A maintenance worker was killed by an explosion resulting from the prodding of the cover plate of a fan which had been routinely exhausting perchloric acid fumes.

Cellulose Nitrate Centrifuge Tubes — A technician suffered severe injuries when an explosion blew the door from a steam autoclave which had been sterilizing blood samples contained in cellulose nitrate tubes. In a different instance, cellulose nitrate culture tubes were destroyed by fire while within the closed compartment.

A technician noticed nitrogen oxide fumes seeping from the oven which was drying cellulose nitrate tubes. Upon opening the door to inspect, a mild explosion occurred followed by the tubes bursting into flames. A new employee had assumed that the oven control dial read in centigrade when actually it was marked with an arbitrary graduation. The damage was slight but the potential was reminiscent of the 1929 Cleveland Clinic X-ray film fire which killed 125 people.

Explosion Hazard of Scintillation Counters — In a refrigerated scintillation counter, enough solvent vapor may penetrate through plastic bottles or leak from plastic snap-type caps to form an explosive concentration in the box. Many organics penetrate at varying rates through some plastics.

Hot Plate Fires — Acetone, being poured at the sink in a patient treatment lab, was ignited by a nearby hot plate which had just been turned off. The technician dropped the container, which was metal and which, fortunately, fell in an upright position. The patient was safely evacuated but the fire was intense enough to melt the sweated water pipe fittings of the window ventilator.

Petroleum ether caught fire while a chemist was pouring it in a fume hood from its large glass container — presumably ignited by a nearby hot plate which had recently been turned off. He dropped the glass container on the floor and ran from the room. The bottle broke; ignition caused enough pressure to blow open the lab escape hatch and slam the entrance door shut.

Refrigerator Explosion — Eighty ml of diazomethane dissolved in ether detonated in a domestic-type refrigerator. The door blew open, the frame bowed out, and the plastic lining ignited, causing a heavy blanket of soot to be deposited far down the adjoining corridor. (See 7-4.2.5.)

Pressure Filter Fire — At an eastern hospital pharmacy, a fire-conscious technician prepared for pressure filtering of 50 gal of isopropyl alcohol by placing a towel on a table adjacent to the pump; in the event of fire he planned to smother flames of alcohol inadvertently spilled on his person. As he attempted to turn on the pump, the defective switch ignited alcohol on his hands. Instinctively, he reached for the towel as he had previously rehearsed in his mind but, in doing so, he tripped over the hose which was conducting alcohol by gravity from a large open kettle to the suction side of the pump. The hose slipped from its fittings thereby dumping 50 gal of the flaming solvent onto the floor. He escaped with minor injuries but the pharmacy was destroyed.

(Many fires are intensified by an unfortunate sequence of minor unsafe practices which in themselves seem almost too insignificant to worry about.)

Ampoules Explode — An ampoule of tissue exploded like a firecracker moments after being removed from a liquid nitrogen refrigerator. The legs of the assistant were peppered with powdered glass. Such an explosion occurs as a result of liquid nitrogen being drawn into an imperfectly sealed ampoule through pinhole imperfections. As the ampoule is removed from the bath, room temperature expands the entrapped nitrogen rapidly, causing it to burst with much violence.

Chromatography Fire Hazard — Chromatography apparatus operating through the night had collected 2,500 ml of cyclohexane with 200 ml remaining in the solvent reservoir when two explosions occurred. Ignition was attributed to sparks from electrical controls on the sampling device. (Based on *DuPont Safety News* of May 24, 1965.)

Water Bath Fire — When the thermostat on a water bath malfunctioned, the bath overheated, causing the acrylic lid to sag and contact the heater elements. A fire resulted. Heater equipment should always be protected by over-temperature shutoffs. (Based on *DuPont Safety News*, June 14, 1965.)

Cyclopropane Explosion — Upon opening the valve of a cylinder supposedly containing only cyclopropane, the cylinder exploded with extensive fragmentation, killing six and mutilating three others. This occurred in a Chilean hospital operating room in 1964.

The cylinder had been partially filled, in error, by oxygen and subsequently charged with cyclopropane. The valve, regulator and fittings were unsuitable for oxygen, thus providing the conditions for a classical organic-oxidizer explosion. (From *NFPA Quarterly*, 1/64, page 222.) (See 7-5.4.1.)

Centrifuge Fire — A small centrifuge, being used under a lab hood to separate a flammable hydrocarbon slurry, flashed in the operator's face. The motor was nonexplosionproof: the exhaust fan had been turned off. (See 7-3.3.2.2.)

Peroxide Explosion — A distillation apparatus exploded within a lab fume hood. It was caused by the detonation of the residual peroxide. The drawn sash prevented injury, although the electric mantle was torn to shreds. The investigator was using "some isopropyl ether" which had been kept in a clear glass bottle. He allowed the distillation to continue to dryness.

Investigators should become more aware of the nature of ether peroxide formations. Dioxane and ethyl and isopropyl ethers are the most common offenders. Age, sunlight, air space above liquid, and clear glass containers help to create these explosive peroxides. Test frequently for peroxide; filter out peroxides through a column of 80 mesh Alorco activated alumina, as suggested by Dasler & Bauer, *Ind. Eng. Chem. Anal.*, Ed. 18, 52 (1964). Never leave distillations unattended.

Spinning Gas Cylinder — While a large uncapped gas cylinder was being loaded on a freight elevator prior to laboratory delivery, it fell over. The valve opened slightly on the floor. A quick-thinking attendant shut off the valve before damaging momentum could be attained. Moving an uncapped cylinder within a limited area is permissible provided it is strapped to a carrying cart. (See 7-5.5.)

Steam Bath Flash — Flammable vapors from a batch of solvent which had been poured into a drain upstairs floated into the chamber of a steam bath fixture. As the investigator lit a Bunsen burner adjacent to the steam bath, the flammable vapors ignited, causing a quick hot flash. The rubber tubing was burned beyond recognition. The hood sash protected the investigator's face so he escaped with no injury other than singed eyebrows. **ROOM OCCUPANTS SHOULD RUN WATER INTO UNUSED STEAM BATH TRAPS AND ALL OTHER UNUSED TRAPS ABOUT TWICE A MONTH.**

Fume Hood Operation — About an hour after the electrical system failed because of a substation fire, toxic gases began to permeate through portions of the hospital.

Closing down the electrical system, either accidentally or announced, cuts off all hood and room ventilation and lack of ventilation may lead to sudden contamination of large areas. Upon announcement that the electrical system has

failed, or is about to be shut down, experimental processes which produce hazardous exhaust should be slowed down or stopped.

C-7-2 Related Definitions. The following definitions are taken from other NFPA documents and are critical to the understanding of Chapter 7.

C-7-2.1 The following definitions are taken from NFPA 30, *Flammable and Combustible Liquids Code*:

(a) Flammable Liquid shall mean a liquid having a flash point below 100°F (37.8°C) and having a vapor pressure not exceeding 40 lb per sq in. (2.76 bar) (absolute) at 100°F (37.8°C) and shall be known as Class I liquid.

Class I liquids shall be subdivided as follows:

1. Class IA shall include those having flash points below 73°F (22.8°C) and having a boiling point below 100°F (37.8°C).

2. Class IB shall include those having flash points below 73°F (22.8°C) and having a boiling point at or above 100°F (37.8°C).

3. Class IC shall include those having flash points at or above 73°F (22.8°C) and below 100°F (37.8°C).

(b) Combustible Liquid shall mean a liquid having a flash point at or above 100°F (37.8°C).

Combustible Liquids shall be subdivided as follows:

1. Class II liquids shall include those having flash points at or above 100°F (37.8°C) and below 140°F (60°C).

2. Class III liquids shall include those with flash points at or above 140°F (60°C). Class III liquids shall be subdivided in two subclasses:

a. Class III A liquids shall include those with flash points at or above 140°F (60°C) and below 200°F (93.4°C).

b. Class III B liquids shall include those with flash points at or above 200°F (93.4°C).

C-7-2.2 The following definition is also taken from NFPA 30, *Flammable and Combustible Liquids Code*:

(a) The flash point of a liquid having a viscosity less than 45 SUS at 100°F (37.8°C) and a flash point below 200°F (93.4°C) shall be determined in accordance with ASTM D 56-75, *Standard Method of Test for Flash Point by the Tag Closed Tester*.

(b) The flash point of a liquid having a viscosity of 45 SUS or more at 100°F (37.8°C) or a flash point of 200°F (93.4°C) or higher shall be determined in accordance with ASTM D 93-73, *Standard Method of Test for Flash Point by the Pensky-Martens Closed Tester*.

C-7-2.3 The following definitions are based on NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*.

C-7-2.3.1 Health Hazard. A health hazard is any property of a material which, either directly or indirectly, can cause injury or incapacitation, either temporary or

permanent, from exposure by contact, inhalation, or ingestion.

C-7-2.3.1.1 Degrees of Health Hazard.

“0” Materials which on exposure under fire conditions would offer no hazard beyond that of ordinary combustible material.

“1” Materials which on exposure would cause irritation but only minor residual injury even if no treatment is given, including those which require use of an approved canister type gas mask. This degree should include:

(a) Materials which under fire conditions would give off irritating combustion products;

(b) Materials which on the skin could cause irritation without destruction of tissue.

“2” Materials which on intense or continued exposure could cause temporary incapacitation or possible residual injury unless prompt medical treatment were given, including those requiring use of respiratory protective equipment with independent air supply. This degree should include:

(a) Materials giving off toxic combustion products;

(b) Materials giving off highly irritating combustion products;

(c) Materials which either under normal conditions or under fire conditions give off toxic vapors lacking warning properties.

“3” Materials which on short exposure could cause serious temporary or residual injury even though prompt medical treatment were given, including those requiring protection from all bodily contact. This degree should include:

(a) Materials giving off highly toxic combustion products;

(b) Materials corrosive to living tissue or toxic by skin absorption.

“4” Materials which on very short exposure could cause death or major residual injury even though prompt medical treatment were given, including those which are too dangerous to be approached without specialized protective equipment. This degree should include:

(a) Materials which can penetrate ordinary rubber protective clothing;

(b) Materials which under normal conditions or under fire conditions give off gases which are extremely hazardous (i.e., toxic or corrosive) through inhalation or through contact with or absorption through the skin.

C-7-2.3.2 Flammability Hazard. Flammability describes the degree of susceptibility of materials to burning. The form or condition of the material, as well as its inherent properties, affects its flammability.

C-7-2.3.2.1 Degree of Flammability Hazard.

“0” Materials that will not burn. This degree should include any material which will not burn in air when exposed to a temperature of 1500°F (816°C) for a period of five minutes.

"1" Materials that must be preheated before ignition can occur. Materials in this degree require considerable preheating, under all ambient temperature conditions, before ignition and combustion can occur. This degree should include:

(a) Materials which will burn in air when exposed to a temperature of 1500°F (816°C) for a period of five minutes or less;

(b) Liquids, solids, and semisolids having a flash point above 200°F (93.3°C). This degree includes most ordinary combustible materials.

"2" Materials that must be moderately heated or exposed to relatively high ambient temperatures before ignition can occur. Materials in this degree would not under normal conditions form hazardous atmospheres with air, but under high ambient temperatures or under moderate heating may release vapor in sufficient quantities to produce hazardous atmospheres with air. This degree should include:

(a) Liquids having a flash point above 100°F (37.8°C), but not exceeding 200°F (93.3°C);

(b) Solids and semisolids which readily give off flammable vapors.

"3" Liquids and solids that can be ignited under almost all ambient temperature conditions. Materials in this degree produce hazardous atmospheres with air under almost all ambient temperatures, or, though unaffected by ambient temperatures, are readily ignited under almost all conditions. This degree should include:

(a) Liquids having a flash point below 73°F (22.8°C) and having a boiling point at or above 100°F (37.8°C) and those liquids having a flash point at or above 73°F (22.8°C) and below 100°F (37.8°C) (Class IB and Class IC flammable liquids);

(b) Solid materials in the form of coarse dusts which may burn rapidly but which generally do not form explosive atmospheres with air;

(c) Solid materials in a fibrous or shredded form which may burn rapidly and create flash fire hazards, such as cotton, sisal and hemp;

(d) Materials which burn with extreme rapidity, usually by reason of self-contained oxygen (e.g., dry nitrocellulose and many organic peroxides);

(e) Materials which ignite spontaneously when exposed to air.

"4" Materials which will rapidly or completely vaporize at atmospheric pressure and normal ambient temperature or which are readily dispersed in air, and which will burn readily. This degree should include:

(a) Gases;

(b) Cryogenic materials;

(c) Any liquid or gaseous material which is a liquid while under pressure and having a flash point below 73°F (22.8°C) and having a boiling point below 100°F (37.8°C) (Class IA flammable liquids).

(d) Materials which on account of their physical form or environmental conditions can form explosive mixtures with air and which are readily dispersed in air, such as

dusts of combustible solids and mists of flammable or combustible liquid droplets.

C-7-2.3.3 Reactivity (Instability) Hazards. Reactivity describes the ability of a material to chemically react with other stable or unstable materials. For purposes of this hazard identification system, the other material is water, if reaction with water releases energy. Reactions with common materials other than water may release energy violently, but are beyond the scope of this identification system.

Unstable materials are those which, in the pure state or as commercially produced, will vigorously polymerize, decompose or condense; become self-reactive, or undergo other violent chemical changes.

Stable materials are those that normally have the capacity to resist changes in their chemical composition, despite exposure to air, water, and heat encountered in fire emergencies.

C-7-2.3.3.1 Degree of Reactivity (Instability) Hazard.

"0" Materials which in themselves are normally stable, even under fire exposure conditions, and which are not reactive with water.

"1" Materials which in themselves are normally stable, but which can become unstable at elevated temperatures and pressures or which may react with water with some release of energy, but not violently.

"2" Materials which in themselves are normally unstable and readily undergo violent chemical change but do not detonate. This degree should include materials which can undergo chemical change with rapid release of energy at normal temperatures and pressures or which can undergo violent chemical change at elevated temperatures and pressures. It should also include those materials which may react violently with water or which may form potentially explosive mixtures with water.

"3" Materials which in themselves are capable of detonation or of explosive decomposition or explosive reaction but which require a strong initiating source or which must be heated under confinement before initiation. This degree should include materials which are sensitive to thermal or mechanical shock at elevated temperatures and pressures or which react explosively with water without requiring heat or confinement.

"4" Materials which in themselves are readily capable of detonation or of explosive decomposition or explosive reaction at normal temperatures and pressures. This degree should include materials which are sensitive to mechanical or localized thermal shock at normal temperatures and pressures.

Appendix C-8 Additional Explanatory Information to Chapter 8, Essential Electrical Systems for Health Care Facilities

C-8-1 Typical Hospital Wiring Arrangement.

C-8-2 Maintenance Guide.

C-8-3 Suggested Format.

The diagram illustrates a power system configuration with two main sections: **Normal Power Sources** and **Alternate Source Generators**.

Normal Power Sources: This section shows two identical power source configurations. Each configuration includes a transformer (represented by a zigzag line symbol) connected to a **Main OCD** (Overcurrent Device with Switching Mechanism). Below the transformer, there is a **Normally Open Secondary Tie** and an **Automatic Throwover Recommended** device. The power is then distributed to **General Power & Lighting** loads.

Alternate Source Generators: This section shows a generator (represented by a circle with a 'G' symbol) connected to a bus. This bus is connected to a **Critical Branch** and a **Life Safety Branch**. The **Life Safety Branch** is further divided into **Delayed Restoration Automatic or Manual** and **Delayed Restoration Automatic Life Safety Branch**.

Emergency System: The **Emergency System** is connected to the **Life Safety Branch** and the **Critical Branch**. It includes a **Delayed Restoration Automatic or Manual** device and a **Delayed Restoration Automatic Life Safety Branch** device.

Symbols:

- Transformer (Zigzag line symbol)
- Generator (Circle with 'G' symbol)
- Overcurrent Device with Switching Mechanism (OCD) (Square symbol with a diagonal line)
- Automatic Transfer Switch (Square symbol with a circle and a diagonal line)
- Automatic or Manual Transfer Device (Square symbol with a circle and a diagonal line)

Drain water from fuel filters (if applicable)

- Drain water from day tank (if applicable)
- Check fuel gauges and drain water from main fuel tanks
- Inspect all main fuel tank vents

Semiannually:

- (1) On generator sets:
 - Engine Lubricating System:
 - Change oil filter (if sufficient hours)
 - Clean crankcase breather
 - Fuel System:
 - General inspection of all components
 - Change fuel filter
 - Change or clean air filter
 - Governor:
 - Check all linkages and ball joints
 - Check oil level (if applicable)
 - Observe for unusual oil leakage
 - Generator:
 - Check brush length and pressure
 - Check appearance of slip rings and clean if necessary
 - Blow out with clean dry compressed air
 - Engine Safety Controls:
 - Check operation of all engine operating alarms and safety shutdown devices (generator not under load during this check)

Annually:

- (1) On generator sets:
 - Fuel System:
 - Diesel:
 - Analyze fuel for condition (replace if required)
 - Gasoline:
 - Replace fuel
 - Natural Gas or Liquid Petroleum Gas:
 - Examine all supply tanks, fittings and lines
 - Lubricating Systems:
 - Change oil
 - Change oil filter
 - Replace carburetor air filter
 - Cooling System:
 - Check condition and rod out heat exchangers if necessary
 - Change coolant on closed systems
 - Clean exterior of all radiators
 - Check all engine water pumps and circulating pumps
 - Examine all duct work for looseness
 - Clean and check motor operated louvers
 - Exhaust System:
 - Check condition of mufflers, exhaust lines, supports and connections
 - Ignition System:
 - Spark ignition engines
 - Replace points and plugs
 - Check ignition timing
 - Check condition of all ignition leads
 - Generator:
 - Clean generator windings
 - Check generator bearings

- Measure and record resistance readings of generator windings using insulation tester (megger)

Engine Control:

- General cleaning
- Check appearance of all components
- Check meters

(2) Transfer Switch:

- Inspect transfer switch and make repairs or replacements if indicated

(3) On main switchgear and generator switchgear:

- Operate every circuit breaker manually
- Visually check bus bars, bracing, and feeder connections for cleanliness and signs of overheating.

Every Three Years:**(1) System Controls:**

- Re-evaluate the settings of the voltage sensing and time delay relays

(2) Main Switchgear and Generator Switchgear:

- Determine if changes to the electrical supply system have been made that require a revision of the main circuit breaker, fuse, or current limiting bus duct coordination. Calibrate and load test main circuit breakers. Spot check bus bar bolts and supports for tightness. Obtain and record insulation tester readings on bus bars and circuit breakers. Obtain and record insulation tester readings on internal distribution feeders.

Periodically:**(1) Prime Mover Overhaul:**

- Each prime mover should have a periodic overhaul in compliance with the manufacturer's recommendation or as conditions warrant.

(2) Connected Load:

- Update the record of demand and connected load and check for potential overload.

C-8-3 A Suggested Format for Listing Functions to be Served by the Essential Electrical System in a Hospital.

Explanation. It may be advantageous, in listing the specific functions for a given construction project or building review, to list them, at the outset, by geographical location within the project, in order to assure comprehensive coverage. Every room or space should be reviewed for possible inclusion of:

- (a) Lighting (partial or all),
- (b) Receptacles (some or all),
- (c) Permanently wired electrical apparatus.

The format suggested herein is offered as a convenient tool, not only for identifying all functions to be served and their respective time intervals for being re-energized by the alternate electric source, but also for documenting other functions that were considered, discussed and excluded as nonessential. This last column is considered worthy of due attention. It may be that the hospital engineer or the

Hospital _____ Date _____

[illegible]

Indicate time interval.

Although this suggested format is intended for use by a hospital it may, with suitable changes, be useful for other health care facilities.

C-10-4 Pressure Table.

C-10-1.1.2 Under hyperbaric conditions utilizing compressed air, the partial pressure of oxygen is increased.

C-10-1.1.3.4.2 Combustible fabrics have tiny air spaces which become filled with oxygen when exposed to oxygen-enriched environments. Once removed to atmospheric air

(e.g., room air outside the chamber), the fabric will burn, if ignited, almost as rapidly as if it were still in the oxygen environment. This hazard will remain until the oxygen trapped in the air spaces in the fabric has had time to diffuse out and be replaced by air.

C-10-1.1.3.5 Oil-based or volatile cosmetics (facial creams, body oils, hair sprays and the like) constitute a source of fuel which is highly flammable in an oxygen-enriched atmosphere.

C-10-1.1.4 Sources of Ignition.

C-10-1.1.4.1 Sources of ignition which might be encountered in a hyperbaric chamber include, but are not necessarily limited to: defective electrical equipment, including failure of high voltage components of radiological or monitoring equipment; heated surfaces in broken vacuum tubes or broken lamps used for general illumination, spot illumination or illumination of diagnostic instruments; the hot-wire cautery or high-frequency electrocautery; open or arcing switches, including motor switches; bare defibrillator paddles; overheated motors; electrical thermostats.

C-10-1.1.4.2 Sources of ignition which should not be encountered in a hyperbaric facility, but which might be introduced by inept practice, include: lighted matches or tobacco; static sparks from improper use of personal attire; electrical wiring not complying with 10-2.7 of Chapter 10; cigarette lighters; and any oil contaminated materials which present a spontaneous heating hazard.

C-10-1.1.4.3 In oxygen-enriched atmospheres, the minimum energy necessary to ignite flammable or combustible materials is reduced below the energy required in atmospheres of ambient air in most instances.

C-10-1.2 Mechanical Hazards.

C-10-1.2.1 General.

C-10-1.2.1.1 A large amount of potential energy is stored in even a small volume of compressed gas. In hyperbaric chambers of moderate or large size, the potential energy of the chamber's compressed atmosphere, if released suddenly, can produce devastating destruction to adjacent structures and personnel, as well as to structures and personnel remote from the site of the chamber. Such sudden release could result from failure of the vessel structure, its parts or its piping.

C-10-1.2.1.2 A particular hazard can be created if individuals attempt to drill, cut or weld the vessel in a manner contrary to ASME *Pressure Vessel Codes*.

C-10-1.2.2 The restriction on escape, and the impedance to efforts at rescue and fire fighting posed by the chamber, create a significant hazard to life in case of fire or other emergency.

C-10-1.2.2.1 A particular hazard exists to chamber personnel in the event of a fire within the structure housing the chamber. Inability to escape from the chamber and loss of services of the chamber operator would pose serious threats to life of all occupants of the chamber.

C-10-1.2.2.2 All personnel involved in hyperbaric chamber operation and therapy, including patients and family, must be made aware of the risks and hazards involved. Fire prevention is essential. Extinguishment of a fire within a Class B chamber is impossible. Extinguishment of a fire within a Class A chamber is only possible utilizing equipment already installed in such a chamber, and then often only by the efforts of the occupants of such a chamber or the chamber operator.

C-10-1.2.3 The necessity for restricting viewing ports to small size limits the vision of chamber operators and other observers, reducing their effectiveness as safety monitors.

C-10-1.2.4 Containers and enclosures may be subjected to collapse or rupture in consequence to the changing pressures of the hyperbaric chamber. Items containing entrained gas include, but are not necessarily limited to: ampoules; partially filled syringes; stoppered or capped bottles; cuffed endotracheal tubes; pneumatic cushions employed for breathing masks or aids in positioning patients. The rupture of such containers having combustible or flammable liquids would also constitute a severe fire or explosion hazard.

C-10-1.2.4.1 The sudden collapse of containers from high external pressures will result in adiabatic heating of the contents. Therefore the collapse of a container of flammable liquid would constitute a severe fire or explosion hazard both from heating as well as spill of the liquid. (See 10-3.1.5.2, and C-10-1.1.3.2.)

C-10-1.2.5 Other mechanical hazards relate to the malfunction, disruption or inoperativity of many standard items when placed in service under pressurized atmospheres. Hazards which might be encountered in this regard are: implosion of illuminating lamps and vacuum tubes; overloading of fans driving gas at higher density; and inaccurate operation of standard flowmeters, pressure gauges and pressure reducing regulators.

C-10-1.2.5.1 Illuminating lamps or vacuum tubes which implode, or overloaded fans, are sources of ignition.

C-10-1.3 Physiological and Medical Hazards.

C-10-1.3.1 Medical hazards which may be encountered routinely include compression problems, nitrogen narcosis, oxygen toxicity, and the direct effects of sudden pressure changes.

C-10-1.3.1.1 Inability to equalize pressure differentials between nasopharynx (nose) and nasal sinuses or middle ear can result in excruciating pain and may cause rupture of the ear drum or hemorrhage into the ear cavity or nasal sinus.

C-10-1.3.1.2 The breathing of air (78 percent nitrogen) under significant pressures (as by chamber personnel breathing chamber atmosphere) can result in nitrogen narcosis which resembles alcoholic inebriation. The degree of narcosis is directly related to the amount of pressurization and, up to a certain point, the duration of pressurization. Nitrogen narcosis results in impairment of mental

functions, loss of manual dexterity and interference with alertness and ability to think clearly and act quickly and intelligently in an emergency.

C-10-1.3.1.3 Oxygen toxicity may develop from breathing of oxygen at partial pressures above 0.21 atmosphere absolute for a significant length of time. Oxygen toxicity can affect the lungs (pain in the chest, rapid shallow breathing, coughing), nervous system (impaired consciousness and convulsions) and/or other tissue and organs, or combinations thereof.

C-10-1.3.1.4 Direct effects of reduction in pressure may include inability to equalize pressures between the nasopharynx and sinuses or middle ear; expansion of gas pockets in the gastrointestinal tract; and expansion of trapped gas in the lungs.

C-10-1.3.1.5 The presence of personnel within the cramped confines of the hyperbaric chamber in close proximity to grounded metallic structures on all sides creates a definite shock hazard if accidental contact is made with a live electrical conductor or a defective piece of electrical equipment. Such accidental contact also could be a source of ignition of flammable or combustible materials. (See C-10-1.1.4.)

C-10-1.3.2 Medical hazards which are not ordinarily encountered during hyperbaric oxygen therapy, but which may arise during malfunction, fire or other emergency conditions include electric shock and fouling of the atmosphere of the chamber with oxygen, nitrous oxide, carbon dioxide, carbon monoxide, pyrolysis products from overheated materials or the toxic products of combustion from any fire.

C-10-1.3.2.1 Increased concentrations of carbon dioxide within the chamber, as might result from malfunction of the systems responsible for monitoring or removal thereof, can be toxic under increased pressures.

C-10-1.3.2.2 The development of combustion products or gases evolved from heated nonmetals within the closed space of the hyperbaric chamber can be extremely toxic to life because of the confining nature of the chamber and the increased hazards of breathing such products under elevated pressure.

NOTE: Extreme pressure rises have accompanied catastrophic fires in confined atmospheres. These pressures have driven hot, toxic gases into the lungs of victims as well as exceeding the structural limits of the vessel, in at least one case.

C-10-1.3.3 Physiological hazards include exposure to high noise levels and decompression sickness. Rapid release of pressurized gases may produce shock waves and loss of visibility.

C-10-1.3.3.1 During hyperbaric therapy, and especially during compression, the noise level within the chamber becomes quite high. Such a level can be hazardous because it is distracting, interferes with communication, and may produce headache or other problems in susceptible individuals.

C-10-1.3.3.2 Decompression sickness (bends, caisson worker's disease) results from the elution into the blood stream or extravascular tissues of bubbles of inert gas (mainly nitrogen) which becomes dissolved in the blood and tissue fluids while breathing air at elevated pressures for a significant period of time.

NOTE: Rapid decompression of the chamber may occur if the pressure relief valve is damaged from exposure to a fire external to the chamber or from the venting of hot products of combustion from within the chamber.

C-10-1.3.3.3 The use of decompression procedures will prevent immediate escape from the Class A chamber by occupants during emergency situations.

NOTE: These procedures are not followed if chamber occupants are exposed to a "no-decompression exposure" [compression to less than 2 atmospheres absolute (ATA) air], or when compressed to 2 ATA or higher pressures by and breathing 100 percent oxygen.

C-10-1.3.3.4 The sudden release of gas whether by rupture of a container or operation of a device such as used in fire fighting will produce noise, possible shock waves, reduced or obscured visibility and temperature changes. The initial effect may be to cool the air, but resulting pressure rises will cause adiabatic heating.

C-10-1.3.4 In summary, the hazards of fire and related problems in hyperbaric systems are real. By the very nature of the hyperbaric atmosphere, increased partial pressures of oxygen are present routinely. Flammability and combustibility of materials are increased. Ignition energy is lowered. Both immediate escape and ready entry for rescue are impeded. Finally, attendants within the chamber, through effects of the elevated noise level and nitrogen pressure, may be unable to respond to emergencies quickly and accurately.

C-10-2 Suggested Procedures to Follow in Event of Fire in Class A Chambers.

NOTE: The procedures contained in Appendix C-10-2 are adopted from those employed by the United States Air Force. These procedures are published herein only as a guide for those who are preparing procedures for their own hyperbaric facilities. Their publication herein is not to be construed as implying that they become a literal part of the standard procedure in any hyperbaric facility.

C-10-2.1 Fire Inside Chamber.

Inside Observer.

- (a) Advise outside.
- (b) Don breathing air mask.
- (c) Activate fire suppression system and/or hand held hoses.

Console Operator.

- (a) Maintain chamber depth.
- (b) Activate the fire suppression system, if needed.
- (c) Ensure breathing gas is compressed air.
- (d) Notify the Fire Department by activating Fire Alarm Station or telephone.

- (e) Note time of fire and record progress of events.

Hyperbaric Chamber (System) Technician (Outside).

- (a) Stand by with a fire extinguisher.
(b) Assist in unloading chamber occupants.

Physician/Safety Monitor (Outside).

- (a) Direct operations and assist crew members wherever necessary.
(b) Terminate procedure as soon as possible.

Other Personnel.

- (a) Stand by to evacuate chamber personnel.

C-10-2.2 Fire Outside Chamber.

Console Operator.

- (a) Notify the inside observer to stand by for emergency return to normal atmospheric pressure.
(b) Notify Fire Department by activating Fire Alarm Station or telephone.
(c) Change chamber breathing gas to compressed air.
(d) Don fire mask.
(e) Note time of fire and record progress of events.

Hyperbaric Chamber (System) Technician (Outside).

- (a) Assure that compressor intake is drawing outside air.
(b) Man fire extinguisher.
(c) Assist chamber operator to don fire mask.

Physician/Safety Monitor (Outside).

- (a) Direct operations.
(b) Determine whether procedure should be terminated.

Other Personnel.

- (a) Stand by to evacuate chamber personnel.

C-10-3 Suggested Procedures to Follow in Event of Fire in Class B Chambers.

C-10-3.1 For fires within facility not involving the chamber:

- (a) Turn off oxygen source
(b) Decompress chamber
(c) Remove patient and evacuate to safe area.

C-10-3.2 For fire within chamber:

- (a) Turn off oxygen source
(b) Decompress chamber
(c) Remove patient
(d) Sound fire alarm of facility
(e) Evacuate area
(f) Attempt to suppress fire, or
close door and await arrival of fire service personnel.

Table C-10-4 Pressure Table

Abso- lute	Mercury mmHg	PSIA	PSIG	Equivalent Depth in Ft Seawater	mmHg Oxygen Pressure of Compressed Air	mmHg Oxygen Pressure of Oxygen- Enriched Air (23.5%)
1	760	14.7	0	0	160	179
1.5	1140	22	7.35	16.5	240	268
2.0	1520	29.4	14.7	33	320	357
2.5	1900	36.7	22.0	49.7	400	447
3.0	2280	44.1	29.4	66.2	480	536
3.5	2660	51.4	36.7	82.9	560	625
4.0	3040	58.8	44.1	99.2	640	714
5.0	3800	73.5	58.8	132.4	800	893

NOTE 1: The oxygen percentage in the chamber environment, not the oxygen partial pressure, is of principal concern, as concentrations above 23.5 percent oxygen increase the rate of flame spread. Thirty percent oxygen in nitrogen at 1 ATA (228 mmHg pO₂), increases burning rate. However, 6 percent oxygen in nitrogen will not support combustion, regardless of oxygen partial pressure (at 5 ATA, 6 percent oxygen gives 228 mmHg pO₂.)

NOTE 2: The Technical Committee recommends that one unit of pressure measurement be employed. Since a variety of different units are now in use, and since chamber operators have not settled upon one single unit, the above table includes the five units most commonly employed in chamber practice.

Appendix C-11 Additional Explanatory Information to Chapter 11, Hypobaric Facilities

C-11-1 Nature of Hazards.

C-11-2 Fire Response.

C-11-3 Pressure Table.

C-11-1 Nature of Hazards.

C-11-1.1 General.

C-11-1.1.1 There are several hazards involved in the design, construction, operation and maintenance of hypobaric facilities. Some equipment may prove to be extremely hazardous in oxygen-enriched atmospheres compared with similar use in air. Under small scale test conditions, some materials that are self-extinguishing in air, for example, have horizontal burning rates of more than 20 inches per second in oxygen at atmospheric pressure.

C-11-1.1.2 Material Control. All items brought into a hypobaric chamber should comply with acceptance criteria. Waivers should be granted in accordance with clearly defined criteria that include both ignitability and propagation rates and, furthermore, are subject to periodic review. It should also be an accepted fact that despite great care, some materials in a hypobaric chamber will be flammable and a fire once started may quickly become catastrophic.

C-11-1.1.3 Ventilation in a hypobaric chamber is significantly different than in normal atmospheres. For example, if a hypobaric chamber atmosphere is cycled through a purifier to remove only excess carbon dioxide or water vapor, flammable gas levels could build up to excessive levels as in any closed breathing circuit.

C-11-1.1.4 The quantity of oxygen in the atmosphere of

a hypobaric chamber can be related to the number of pounds of fuel that would burn, the number of BTUs released in such a reaction, and the pressure rise. Typically, for four pounds of oxygen one pound of a hydrocarbon fuel is consumed, liberating approximately 20,000 BTUs per pound.

C-11-1.2 Fire and Explosion.

C-11-1.2.1 The occurrence of a fire requires the presence of a combustible material, an oxidizer, and a source of energy to provide ignition.

C-11-1.2.2 Under hypobaric conditions the oxygen content of the atmosphere may be increased from 21 percent to as much as 100 percent. Both the increased partial pressure of oxygen and the reduction in diluent inert or nonoxidizing gas contribute to an increased fire hazard. (See Figure C-11-1.2.2.)

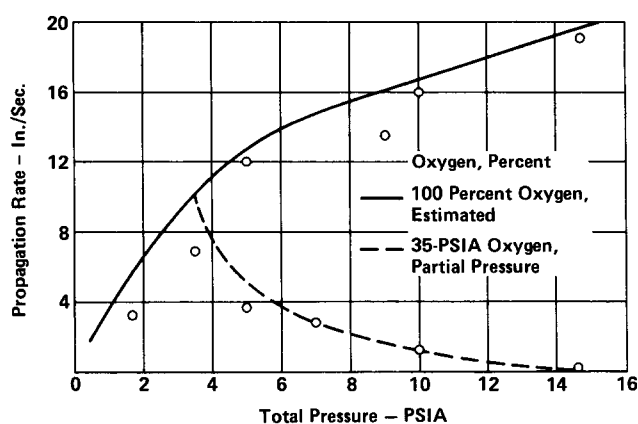


Figure C-11-1.2.2 Horizontal Flame Propagation Rate on Open Polyurethane Foam.

C-11-1.2.2.1 Material self-extinguishing in air at atmospheric pressure may burn vigorously in an oxygen-enriched atmosphere. The specific rates, or ability to continue burning once an igniter is removed, depends on the composition of the material and the geometry of the system. Examples include wool, leather, polyvinyl chloride, silicone rubber, neoprene, epoxy adhesives, and many fire-retardant compounds. The resulting higher flame temperature from materials burning in oxygen also plays a significant role, as it enables things that are harder to burn to enter into combustion, such as metals which have high heats of combustion. There is also a slight reduction in ignition energy. Thus, the following effects are produced in an oxygen-enriched hypobaric atmosphere:

- Reduced inert gas.
- Increased partial pressure of oxygen giving increased available oxygen.
- Slightly reduced ignition energy.
- Increased burning rates.
- Higher flame temperature and lower flash point than at 14.7 psia.

C-11-1.2.2.2 There is a change in "flash point" and "fire point" as pressure is reduced. Published data obtained in air at 14.7 psia are therefore not reliable for hypobaric atmospheres nor is there a *clear-cut* way to estimate the change.

C-11-1.2.2.3 The flammability of petroleum products and other compounds containing carbon and hydrogen is well known. Hazards of liquids and gases that are flammable in air are apparent in hypobaric chambers. Some guidelines to their use in oxygen are documented in Chapter 3, Use of Inhalation Anesthetics. (See also *NFPA 53M, Manual on Fire Hazards in Oxygen-Enriched Atmospheres* and *NFPA 325M, Fire Hazard Properties of Flammable Liquids, Gases and Volatile Solids*.) Lubricants, cleaning agents and sterilization agents (such as ethylene oxide) are also in this category. They should be avoided unless data are available to verify their safety in the chamber.

C-11-1.2.3 Garments used by occupants of a hypobaric chamber produce a special hazard. All conventional fabrics used as clothing are highly combustible under oxygen-enriched conditions, except while saturated with water. Dependence must not be placed on fire-retardant treatments for service in oxygen-enriched atmospheres. Bedding, including mattresses, sheets, pillows, and blankets, is combustible. All conventional waterproof fabrics are combustible, including gloves. All bandages and dressings, including wooden splints, canvas, and much conventional medical equipment are combustible. Other combustible products include name tags, check lists, notebooks, towels, sponges, and dry food products.

C-11-1.2.3.1 Choice of construction materials is based on many factors including availability, ease of cleaning, toxic properties, and cost, to name a few. Approved materials for use elsewhere in an institution normally are the basis for selection in hypobaric facilities. For Class D chambers this is normally adequate. However, Class E and Class F chambers raise the difficult question of oxygen compatibility. As this document is a standard, not a handbook, complete guidelines or design tips are not appropriate. Flammable liquids and gases are covered in the preceding section. The criteria in selecting solids, both metals and nonmetals, are not so easily dealt with. (See 11-3.1.6.4, 11-3.1.7 and 11-3.3.)

C-11-1.2.3.2 Metal screens, woven wire shields on cables, and braided wire coverings on electrical or pneumatic tubing can present unusual fire hazards. Whether aluminum, stainless steel or other alloys containing iron, titanium, nickel, chromium, or silver, etc., a fire started by an electric arc can produce considerable heat and is difficult to extinguish.

C-11-1.2.4 Sources of Ignition.

C-11-1.2.4.1 Sources of ignition which might be encountered in a hypobaric chamber include, but are not necessarily limited to: defective electrical equipment (including failure of high-voltage equipment), heated surfaces in broken vacuum tubes or broken lamps used for general illumination, open or arcing switches (including motor switches), overheated motors, electrical thermostats, and communications equipment.

C-11-1.2.4.2 Sources of ignition which should not be encountered in a hypobaric facility, but which might be introduced by inept practice, include: lighted matches or tobacco; static sparks from improper use of personal attire; electrical wiring not complying with 11-2.7, including convenience outlets and brushes on motor rotors; photo-

graphic flash equipment; cigarette lighters; and any animal or vegetable oil contaminated materials which present a spontaneous heating hazard.

C-11-1.2.4.3 In oxygen-enriched atmospheres as defined in Section 2-2, the minimum energy necessary to ignite flammable or combustible materials is generally reduced below the energy required in atmospheres of ambient air in most instances.

NOTE: Items previously sterilized and packaged within biological barriers can be charged with significant levels of static energy. Upon opening such packages the neutralization of the static charge can release sufficient energy to cause ignition. The situation is worse if the inside atmosphere is dried by the use of a package of desiccant, and if packaged in a sterilized atmosphere containing ethylene oxide, an explosion could result as the static electricity is released as a spark. The force of the explosion will probably be at a low level but the resulting flame could ignite adjacent material including the arm of the person opening the package.

C-11-1.3 Mechanical Hazards.

C-11-1.3.1 A vacuum vessel is subject to implosion and/or sudden inlet of surrounding atmosphere. As a result, inlets into the chamber must be protected from harming exterior personnel and chamber occupants by the vacuum action, and structures surrounding the chamber must be vented to allow pressure equalization. Inlet valves should be protected.

C-11-1.3.2 A particular hazard can be created if individuals attempt to drill, cut or weld the vessel in a manner contrary to ASME PVHO-1, *Safety Standard for Pressure Vessels for Human Occupancy*.

C-11-1.3.3 The restriction on escape, and the impedence to efforts at rescue and fire fighting posed by the chamber, create a significant hazard to life in case of fire or other emergency.

C-11-1.3.3.1 A particular hazard to chamber personnel exists in the event of a fire within the structure housing the chamber. Inability to escape from the chamber and loss of services of the chamber operator would pose serious threats to life of all occupants of the chamber.

C-11-1.3.3.2 All occupants of hypobaric chambers should be aware that accidental fires are extremely dangerous and may be avoided by exercising due care in restricting burnables, reducing oxygen concentration and eliminating ignition sources.

C-11-1.3.4 Viewing ports, if of small size, limit the vision of chamber operators and other observers, reducing their effectiveness as safety monitors.

C-11-1.3.5 Containers, including aerosol cans, and enclosures may be subjected to rupture or collapse in consequence of the changing pressures in the hypobaric chamber. Items containing entrained gas include, but are not necessarily limited to: ampoules, partially filled syringes; stoppered or capped bottles; cuffed endotracheal catheters; pneumatic cushions employed for breathing masks or as aids in positioning patients. The rupture of such containers having combustible or flammable liquids would also constitute a severe fire or explosion hazard and they should be excluded from the chamber.

C-11-1.3.5.1 Containers sealed in a hypobaric environment may implode and containers sealed at atmospheric

pressure may explode when pressure is elevated or reduced, respectively. The fracture of a container of flammable liquid would constitute a severe fire or explosion hazard from the spill and vaporization of the liquid. (See 11-3.1.5.2, 11-3.4.1 and Appendix C-11-1.2.2.3).

C-11-1.3.5.2 The pressure rise due to fire may cause the chamber interior to reach high pressures.

C-11-1.3.5.3 The hot gases vented in an emergency should be ducted to atmosphere. Care must be exercised in the location of such a vent, in that flame propagation will be enhanced by the flow of gases.

C-11-1.3.6 Other mechanical hazards relate to the malfunction, disruption or inoperativity of many standard items when placed in service under evacuated atmospheres. Hazards which might be encountered in this regard are: explosion of containers that are normally hermetically sealed at atmospheric pressure such as condensers, batteries, tin cans and the like; overheating of devices that require convection to remove heat such as motors, lamps, transistors and the like. Corona effects (ionization flashover) are more likely to occur in vacuum than at pressure resulting in arcs, destruction of electrical apparatus and possible fire in an oxygen-enriched atmosphere.

C-11-1.3.6.1 Sealed electrical equipment or convectively cooled apparatus may be a source of ignition.

C-11-1.4 Physiological and Medical Hazards.

C-11-1.4.1 Medical hazards which may be encountered routinely include compression problems and the direct effects of sudden pressure changes, such as dysbarism, anoxia, hypoxia, etc.

C-11-1.4.1.1 Inability to equalize pressure differentials between nasopharynx (nose) and nasal sinuses or middle ear can result in excruciating pain and may cause rupture of the ear drum or hemorrhage into the ear cavity or nasal sinus.

C-11-1.4.1.2 Direct effects of reduction in pressure may include inability to equalize pressures between the nasopharynx and sinuses or middle ear; expansion of gas pockets in the gastrointestinal tract; and expansion of trapped gas in the lungs.

C-11-1.4.1.3 The presence of personnel within the cramped confines of the hypobaric chamber in close proximity to grounded metallic structures on all sides creates a definite shock hazard if contact is made with a live electrical conductor or a defective piece of electrical equipment. Such contact also could be a source of ignition of flammable or combustible materials. (See Appendix C-11-1.2.4.)

C-11-1.4.2 Medical hazards which are not ordinarily encountered during use of hypobaric facilities, but which may arise during malfunction, fire or other emergency conditions include electric shock, and fouling of the atmosphere of the chamber with carbon dioxide, carbon monoxide pyrolysis products from overheated materials, or the toxic products of combustion from any fire.

C-11-1.4.2.1 Increased concentrations of carbon dioxide within the chamber, as might result from malfunction of

the systems responsible for monitoring or removal thereof, can be toxic under decreased pressures.

C-11-1.4.2.2 The development of combustion products or gases evolved from heated substances, particularly organic materials, within the closed space of the hypobaric chamber can be extremely toxic to life because of the confining nature of the chamber and the increased hazards of breathing such products under reduced pressure.

NOTE: Extreme pressure rises have accompanied catastrophic fires in confined atmospheres. These pressures have driven hot, toxic gases into the lungs of victims as well as exceeding the structural limits of the vessel.

C-11-1.4.3 Physiological hazards include exposure to high noise levels and decompression sickness. Rapid release of pressurized gases may produce shock waves and loss of visibility.

C-11-1.4.3.1 During rapid changes in pressure, the noise level within the chamber becomes quite high. Such a level can be hazardous because it is distracting, interferes with communication and, if prolonged, may be injurious, produce headaches, or cause other problems to susceptible individuals.

C-11-1.4.3.2 Decompression sickness (bends) results from the formation of bubbles in the blood stream or extravascular tissues from the dissolved inert gas (mainly nitrogen). The bubbles may form when the chamber pressure is reduced below atmospheric.

C-11-1.4.3.3 Decompression sickness can result if any personnel are exposed to a hypobaric atmosphere without prior denitrogenation. (See 11-3.2.)

NOTE: There is a potential for nitrogen in leakage in any closed oxygen system.

C-11-1.4.3.4 The sudden release of gas, whether by rupture of a container, a medical gas or breathing air piping system, or operation of a device such as used in fire fighting, will produce noise, possibly shock waves, reduced or obscured visibility and temperature changes.

C-11-2 Suggested Fire Response Procedures.

The occurrence of a fire within a hypobaric chamber presents a different problem than in the case of hyperbaric chamber during pressurization. A depressurized hypobaric chamber can be repressurized within minutes without endangering personnel within the chamber, utilizing the emergency "Dump" valve (see 11-2.2.5). Response may differ, however, if there is a fire in the vicinity of the chamber, and if products of combustion may be drawn into the chamber during rapid repressurization. Therefore, *two distinct fire response procedures are required.*

All personnel shall memorize the steps to be taken in these or similar procedures.

NOTE: This part of the Appendix is included for guidance only in the drafting of fire response procedures appropriate to the specific facility. (See 11-3.1.4.4.)

C-11-2.1 Fire in the Chamber.

C-11-2.1.1 Response of Chamber Operator and Personnel Outside Chamber.

(a) Notify chamber occupants that "Dump" repressuri-

zation will be accomplished by shouting "Dump" over intercom.

(b) Operate 'Dump' valve.

(c) Sound institutional fire alarm.

(d) Notify fire department.

(e) Open chamber access door and assist in removal of occupants.

(f) Initiate fire fighting procedures as indicated and feasible.

C-11-2.1.2 Response of Chamber Personnel.

(a) Notify chamber operator of fire.

(b) Don emergency breathing apparatus if feasible.

(c) Be prepared for Dump procedure.

(d) Initiate fire fighting procedures if feasible (see 11-2.6.7) and evacuate chamber.

C-11-2.2 Fire in Vicinity of Chamber.

C-11-2.2.1 Response of Chamber Operator and Personnel Outside the Chamber.

(a) Sound the institutional fire alarm.

(b) Notify chamber occupants of the fire and request that they don breathing masks (see 11-2.4.2).

(c) Chamber operator remains at chamber controls and directs others to initiate fire fighting procedures.

(d) Notify fire department.

(e) Once the occupants have indicated that all have donned breathing apparatus, raise the chamber pressure at a rate commensurate with circumstances.

NOTE: The emergency operation of the Dump valve may draw dangerous products of combustion into the chamber. It may also serve to fan the flames and intensify the fire.

(f) Assist chamber occupants to leave the chamber.

C-11-2.2.2 Response of Chamber Occupants.

(a) Don breathing apparatus when apprised to do so.

(b) Notify chamber operator after all occupants have donned breathing apparatus.

(c) Remain calm and prepare to leave chamber after repressurization.

C-11-3 Pressure Table.

Total Pressures, Altitude and Oxygen Partial Pressure or Concentration in Hypobaric Chambers

Atmo- spheres	Total Absolute Pressure		Altitude Above Sea Level	Partial Pressure of Oxygen in Class D Chamber	Concentration of Oxygen in Class E Chamber if Partial Pressure is 160 mmHg
	mmHg	psia		mmHg	Percent by vol.
1	760	14.7	sea level	160	20.9
4/5	608	11.7	6,000	128	26.5*
2/3	506	9.8	11,000	106	31.3*
3/5	456	8.8	13,500	96	35.0*
1/2	380	7.3	18,000	80	42.8*
2/5	304	5.9	23,000	64	52.6*
1/3	253	4.9	27,500	52	62.7*
1/5	152	2.9	38,500	32	100.0*

*Oxygen-enriched atmosphere.

Appendix D Health Care Emergency Preparedness

A Plan for Emergency Expansion of Facilities and Disaster Preparedness for Health Care Facilities

This Appendix is not a part of the requirements of this NFPA document. . .but is included for information purposes only.

D-1 Introduction.

D-1-1 Purpose. The purpose of this Appendix is to provide the information necessary for the preparation of a disaster plan for a health care facility.

D-1-2 Scope. This Appendix covers types of disasters that need be anticipated, factors to be considered in responding to a disaster, a sample of a typical disaster plan, guidance on implementing a disaster plan, and the obligations of the governing body and staff of the health care facility. While this Appendix primarily addresses hospitals, many parts are readily usable in upgrading emergency preparedness of nursing and residential-custodial care facilities.

D-1-3 Applicability.

D-1-3.1 External Disasters. This Appendix is applicable to any health care facility that is intended to provide first aid or long-term medical treatment to the victims of a disaster in the community at large. Such facilities include, but are not limited to: hospitals, clinics, convalescent or nursing homes, and first aid stations. Such facilities may be formally designated by a government authority as a disaster treatment center, or may reasonably be assumed by the layman as being a disaster treatment center because of appearance, tradition, or location.

D-1-3.2 Internal Disasters. This Appendix is applicable to any facility used for medical or other treatment or care of persons suffering from physical or mental illness, disease or infirmity. Such facilities include hospitals, clinics, and convalescent or nursing homes. Such facilities would not normally include doctors' or dentists' offices, medical laboratories, or school nurseries, unless such facilities are used for treatment of external disaster victims (see D-1-3.1).

D-1-4 Life Safety Code. This Appendix is intended to assist the governing body and staff of a health care facility in meeting the requirements of NFPA 101, *Life Safety Code*. The *Life Safety Code* establishes the basic mechanical or architectural requirements (such as exits, fire alarms, and smoke partitions) for fire safety in all occupancies, including health care facilities. It also requires that adequate plans for drills, evacuation, etc., be made (see NFPA 101, *Life Safety Code*). This Appendix will assist in making such plans but is not limited solely to the requirements of the *Life Safety Code*.

D-1-5 Organization of this Appendix. Since no single model of a disaster plan is feasible for every health care facility, this Appendix is intended to provide guidance in the preparation and implementation of an individual plan. Because of the diversity of health care facilities it cannot state mandatory requirements that would be appropriate in

every case. Accordingly, it is presented as an appendix to this standard.

D-1-6 Responsibility of the Governing Body. It is the responsibility of the governing body of the health care facility to provide its staff, patients, and visitors with plans necessary to respond to a disaster. Further, a government authority may impose upon the governing body the responsibility for participating in a community disaster plan. In order to discharge those obligations, the governing body may elect to delegate to its medical staff, consultants, architects, engineers and others the authority for writing and implementing a disaster plan.

D-1-7 Authority Having Jurisdiction. In time of disaster all persons are subject to certain constraints not present during normal circumstances. During peacetime such restrictions are exercised by civil authority, such as a fire department, police department, public health department, or Emergency Medical Service Councils. During wartime, or declaration of martial rule, it would be exercised by a civil defense or military authority. It is imperative that all disaster plans written by a health care facility be reviewed and coordinated with such authorities so as to prevent confusion or unnecessary hardship.

D-1-8 Interpretations. The National Fire Protection Association does not approve, inspect, or certify any installation, procedure, equipment, or material. With respect to this Appendix, and to disaster planning, its role is limited solely to an advisory capacity. The acceptability of a particular disaster plan is solely a matter between the health care facility and the authority having jurisdiction. However, to assist in the determination of such acceptability, the National Fire Protection Association has established interpretation procedures. These procedures are outlined in NFPA "Regulations Governing Committee Projects."

D-2 Types of Disasters.

D-2-1 Definition of Disaster. Within the context of this Appendix, a disaster is defined as any situation which seriously overtaxes or threatens to seriously overtax the routine capabilities of a health care facility. Such a situation creates the need for emergency expansion of facilities, as well as operation of this expanded facility in an unfamiliar environment. Under this definition, the recognition of a disaster situation will vary greatly from one facility to another and from time to time in any given facility. Such recognition and concomitant activation of the Health Care Disaster Plan is dependent upon facility type, geographic location, bed capacity, bed occupancy at a given time, staff size, staff experience with disaster situations, and other factors. For example, the routine workload of the Emergency Department of a large metropolitan general hospital would constitute a disaster, requiring activation of the Health Care Disaster Plan, were this same workload to be suddenly applied to a small community hospital.

D-2-2 Causes of Disaster. Disasters have a variety of causes, all of which must be considered in effective emergency preparedness planning. Among the most common are natural disasters such as earthquakes, hurricanes, tornados, and floods; mass food poisoning; industrial accidents involving explosion or environmental release of

toxic chemicals; transportation accidents involving crashes of trains, planes, or automobiles with resulting mass casualties; civil disturbances; building fires; extensive or prolonged utility failure; collapse of buildings or other occupied structures; and toxic smogs in urban areas. The ultimate disaster, nuclear warfare, must be given extensive consideration in disaster planning. Conventional bombing in warfare is another possibility which cannot be overlooked. Arson attempts and bomb threats have been made on health care facilities and must therefore be considered, as must the potential admission to the facility of Very Important Persons. While the last does not involve mass casualties or the potential of mass casualties, the degree of disruption of normal routine will be sufficient to qualify it as a disaster-like situation.

D-2-3 Location of the Disaster vs. Impact on a Health Care Facility. The location of the disaster will create different degrees of impact upon a health care facility's ability to respond effectively. For the purposes of this Appendix, disasters may be categorized as either internal or external.

An internal disaster is an event which causes or threatens to cause physical damage and injury to the hospital personnel or patients within the facility. Examples of internal disasters are fire (including arson), explosion, radiation accident or telephoned bomb threat.

An external disaster is an event which requires expansion of facilities to receive and care for a large number of casualties resulting from a disaster which produces no damage or injury to the health care facility and staff. This is the most common type of disaster and, in a relative sense, the easiest for a health care facility to handle since facility and staff remain intact. Examples of external disasters are transportation accidents with mass casualties, mass food poisoning in the community, nuclear accidents/incidents, and natural disasters such as a tornado occurring at a distance from the facility itself. Obviously, the most serious disaster which a health care facility might face is the combined internal-external disaster, such as an earthquake or nuclear warfare, in which the facility's physical plant and its staff have been degraded at the same time that it faces a mass influx of casualties resulting from the same disaster.

D-3 Basic Considerations in Health Care Disaster Planning.

D-3-1 Differences Between Standard Operating Procedure and Disaster Operating Procedure. Under routine procedures, the individual patient receives the highest quality of medical care which the health care facility is capable of providing. In the disaster situation the philosophy changes to that of providing the best available medical care for the greatest number of patients. Austerity of treatment and triage play progressively greater roles as the magnitude of the disaster increases. In a general sense, triage occurs routinely in any hospital Emergency Department, in that the seriously injured or ill patient is usually treated before the patient with less serious injury or illness. However, in the extreme disaster situation the most seriously ill or injured patient is not necessarily treated first and perhaps is not treated at all. If the injury or illness is of such magnitude as to prove fatal despite treatment, the available treatment will be given preferentially to the

serious injury or illness of lesser severity in which such treatment will prove life saving.

A "difference" that is conjured up by inexperienced planners is the false contrasting of daily vs. disaster modes of functioning. On the contrary, proper plans have people use the same skills (and preferably in or near the same places) under all circumstances. Planners must be alert to avoid the pitfalls offered by the temptation to cast personnel in dissonant roles, thus wasting valuable skills and tending toward conditions of chaos.

D-3-2 Flexibility. The key to effective emergency preparedness planning is flexibility, which is attained by contingency planning (i.e., consideration of all likely possibilities and development of options for action which are maximally effective under each such possibility). Thus, the first step in disaster planning is to review the various types of disasters which can occur, emphasizing the types of disasters which are most likely to affect a given facility. For example, a California hospital might give special emphasis to earthquakes, whereas a Gulf Coast hospital might give special emphasis to hurricanes. The second step in disaster planning is the assessment of resources (facilities, material, and personnel) including resources on hand, resources required to effectively cope with disaster, and potential remaining resources following degradation due to internal disaster. The final step is then the meshing of disaster type and magnitude (number of casualties) with the potentially available medical resources in each given case into options for action.

D-3-3 Coordination. Having developed a flexible plan, it is essential that this plan be coordinated both internally and externally.

D-3-3.1 Internal Coordination. Internal coordination is necessary to assure that each professional staff member and employee of the health care facility is aware of his individual role under the Health Care Disaster Plan and to assure that all available resources are most efficiently and effectively utilized. Each supervisor at each level of organization within the health care facility must assure that the staff and employees under him are aware of their individual roles and responsibilities during a disaster, stressing the flexibility of such roles and responsibilities.

D-3-3.2 External Coordination. Since no health care facility is completely self-sufficient, external coordination is essential if a hospital is to effectively function under disaster conditions. Such external coordination is best accomplished through a community Emergency Medical Service Council composed of representatives of the local fire department, law enforcement agencies, civil defense office, military units, search and rescue groups, ambulance services, volunteer agencies (Red Cross, Salvation Army, etc.); local professional medical associations, local hospital and nursing home associations, and local hospitals and nursing homes. Ideally, regional disaster councils should also be established, these to be composed of representatives from constituent local councils.

Often, through the work of such local and regional councils in planning patient distribution in the event of disaster, the necessity for health care facilities to activate their individual disaster plans can be averted. For example,