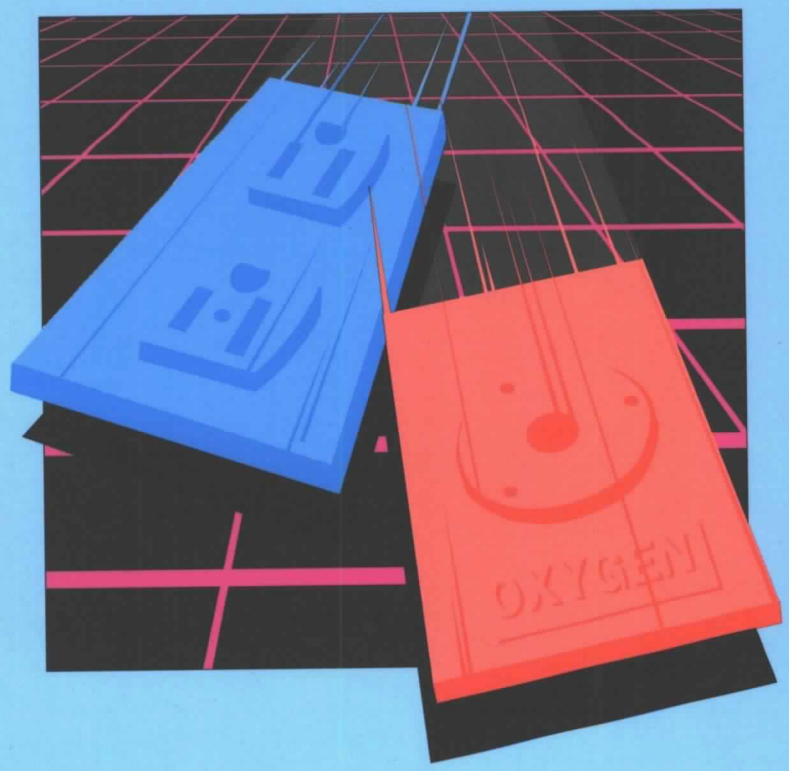
STANDARD FOR

Health Care Facilities

NFPA 99 1993 Edition



ANSI/NFPA 99 An American National Standard February 12, 1993

National Fire Protection Association

NFPA®

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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.

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Errata

NFPA 99

Health Care Facilities

1993 Edition

Reference: 4-3.1.2.2, 4-4.1.2.1(j), 4-4.1.3.1, 4-5.1.3.10, and 4-9.1.1.7(a)

The Committee on Health Care Facilities notes the following errors in the 1993 edition of NFPA 99, *Standard for Health Care Facilities.*

1. *In 4-3.1.2.2, in the title, change* "57 m^3" *to* "85 m^3."

2. *In 4-4.1.2.1(j), change reference from* "4-4.1.2.1(c)" *to* "4-4.1.2.1(d)."

3. *In 4-4.1.3.1, change* "riser valve" *to* "riser." *Add* "4-4.1.2.2(f)" *before* "4-4.1.3.2 or 4-4.1.3.3."

4. *In 4-5.1.3.10, in Table for carbon dioxide, change* "±500 ppm" *to* "≤500 ppm."

5. *In 4-9.1.1.7(a), in sentence 1, change reference from* "4-10.1.2.1" *to* "4-10.1.2.6."

Issue date: April 21, 1993

NFPA 99

Standard for

Health Care Facilities

1993 Edition

This edition of NFPA 99, *Standard for Health Care Facilities*, was prepared by the Technical Committee on Health Care Facilities and acted on by the National Fire Protection Association, Inc. at its Fall Meeting held November 16-18, 1992, in Dallas, TX. It was issued by the Standards Council on January 15, 1993, with an effective date of February 12, 1993, and supersedes all previous editions.

The 1993 edition of this document has been approved by the American National Standards Institute.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

Origin and Development of NFPA 99

The idea for this document grew as the number of documents under the original NFPA 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. These documents were:

NFPA 3M, *Manual on Health Care Emergency Preparedness,*

NFPA 56A, *Standard on the Use of Inhalation Anesthetics,*

NFPA 56B, *Standard on Respiratory Therapy,*

NFPA 56C, *Standard on Laboratories in Health Related Institutions,*

NFPA 56D, *Standard on Hyperbaric Facilities,*

NFPA 56E, *Standard on Hypobaric Facilities,*

NFPA 56G, *Standard on Inhalation Anesthetics in Ambulatory Care Facilities,*

NFPA 56HM, *Manual on Home Use of Respiratory Therapy,*

NFPA 56K, *Recommended Practice on Medical-Surgical Vacuum Systems in Hospitals,*

NFPA 76A, *Standard on Essential Electrical Systems for Health Care Facilities,*

NFPA 76B, *Standard on Safe Use of Electricity in Patient Care Areas of Health Care Facilities,*

NFPA 76C, *Recommended Practice on Safe Use of High Frequency Electricity in Health Care Facilities.*

For a history on each of these documents, see "Origin and Development of NFPA 99" in the beginning of the 1984 edition of NFPA 99.

What was then 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. Combining all the individual documents into one document would place all of them on the same revision cycle.

(2) It would place in one unit many documents that referenced 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, and 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*. 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 the 1984 edition of NFPA 99, in addition to technical changes, 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) were placed in Chapter 2; (2) all previous standards were designated as chapters in the text; (3) all previous recommended practices and manuals were designated as appendixes; (4) all explanatory material on specific paragraphs in chapters was placed in Appendix A; (5) all references were grouped into Chapter 12 and Appendix B; and (6) all additional informatory material from previous individual standards was placed in Appendix C. The document was presented for adoption as a standard as a result of public comments.

For the 1987 edition of NFPA 99, the third and final step in the process of combining the previous individual documents took place — that of integrating the content of these individual documents into a cohesive document. In addition, there were again technical changes made. (*See Section 1-6, "Organization of This Document."*) The 1987 edition also saw the incorporation of NFPA 56F, *Standard on Nonflammable Medical Piped Gas Systems*, into NFPA 99.

For the 1990 edition of NFPA 99, some structural changes were made and some modifiers were added to make it easier to determine where requirements are applicable. Technical changes made included the following:

(1) Correlation with changes made in the 1988 edition of NFPA *101®*, *Life Safety Code®*;

(2) Changes in Chapter 4 on requirements for compressed medical air systems, on the use of gas powered medical devices operating at 200 psig, and piped gas systems in general;

(3) Changes in Chapters 7 and 9 in leakage current limits for patient care electrical appliances to correlate more closely with an international document that includes these criteria;

(4) Changes in Chapter 12 to make it clear that patient care areas and wet locations are mutually exclusive, and

(5) Further guidance in disaster planning to take into consideration the problem of the effects of a disaster on staff (Annex 1).

For this 1993 edition of NFPA 99 there were further efforts to make the document more "user friendly" (e.g., placing all "recommended" guidance either in notes or in the Appendix). Significant technical changes included the following:

(1) Adding requirements in Chapter 12 and recommendations in Annex 2 to further prevent or minimize fires in operating rooms.

(2) Making major changes to requirements in Chapter 4 for installing, testing, and maintaining nonflammable medical piped gas systems, including:

(a) defining the new term "medical air compressor,"

(b) revising the term "medical compressed air,"

(c) modifying master alarm and area alarm requirements,

(d) extensively revising installation, testing, inspecting, and verification criteria for piping systems.

(3) Adding new sections on dental compressed air and dental vacuum requirements in Chapter 4.

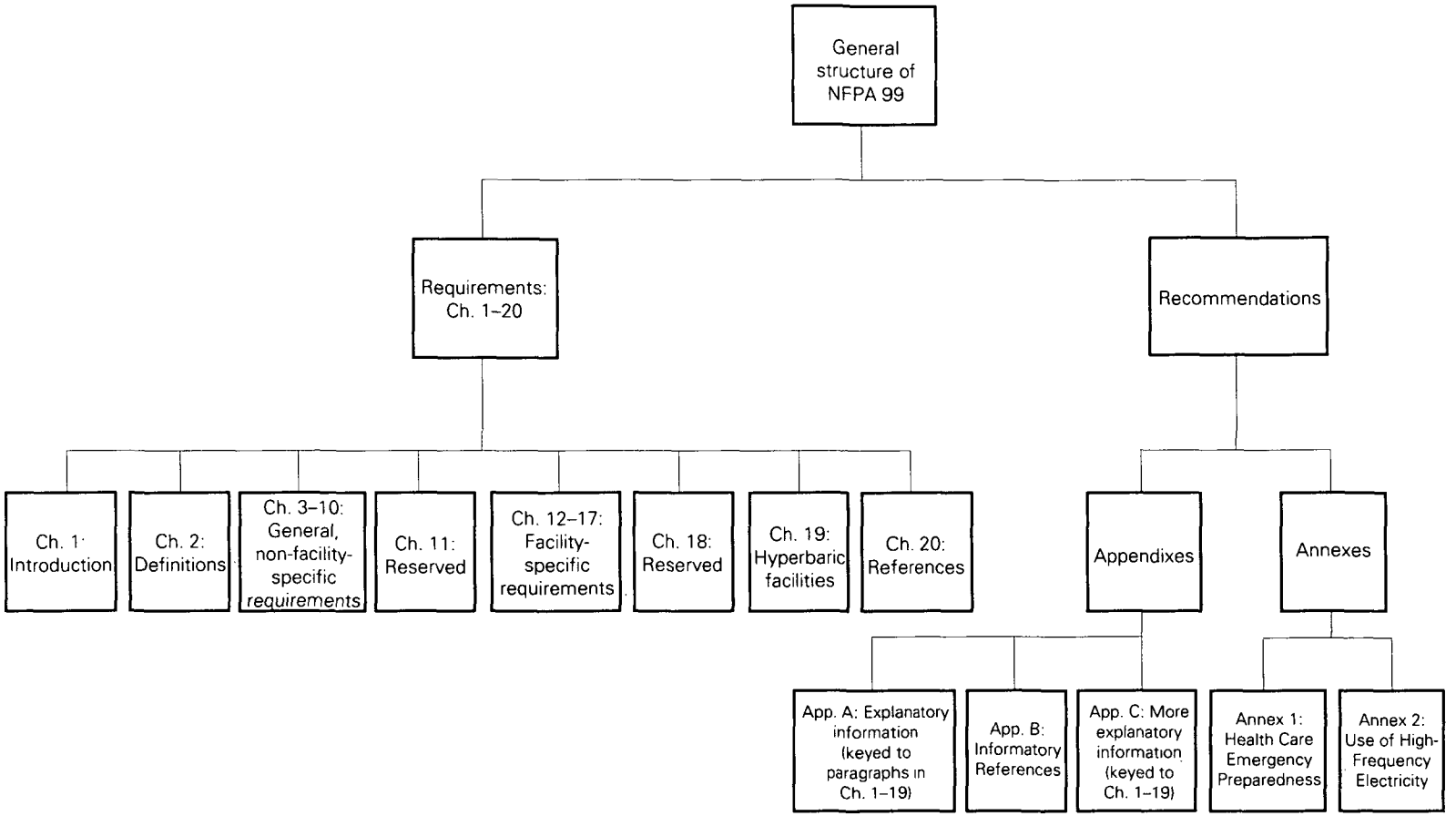
(4) Further changing leakage current limits of patient-care-related electrical appliances to correlate more closely with an international document on the subject.

(5) Revising laboratory requirements to correlate more closely with NFPA 45, *Standard for Laboratories Using Chemicals*.

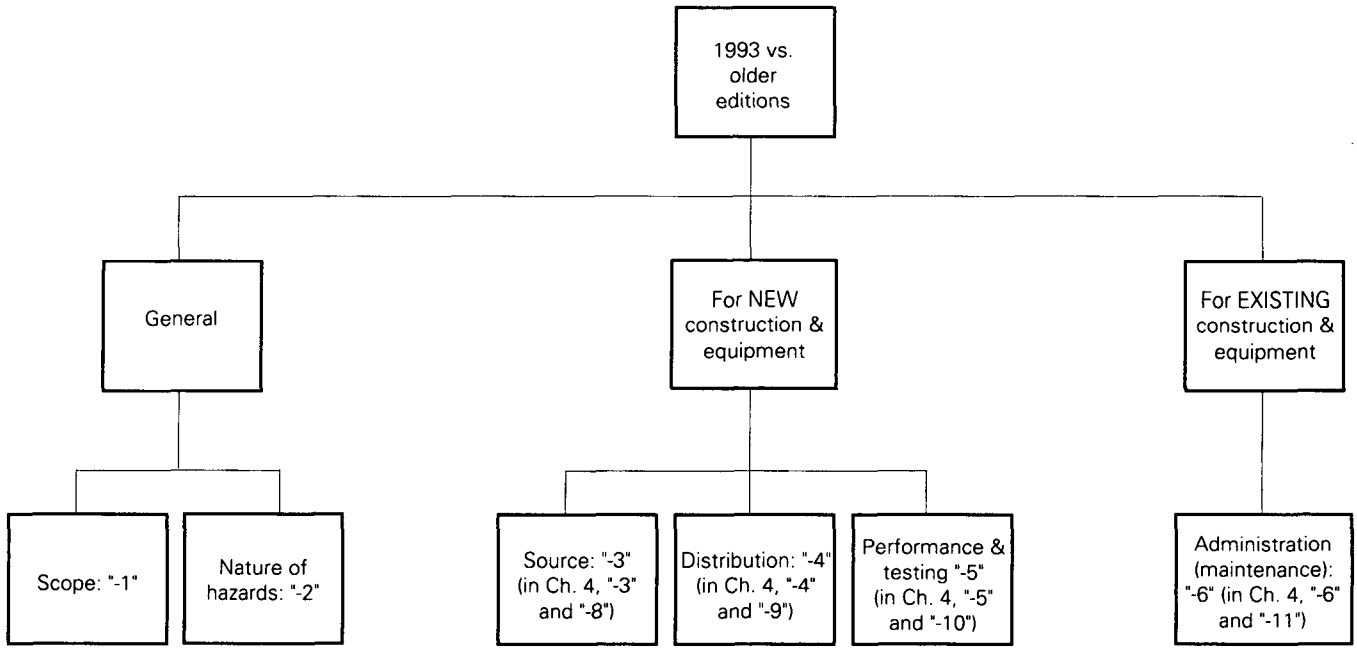
(6) Changing essential electrical system requirements in ambulatory health care clinics and medical/dental offices.

(7) Extensively revising hyperbaric chamber requirements (Chapter 19).

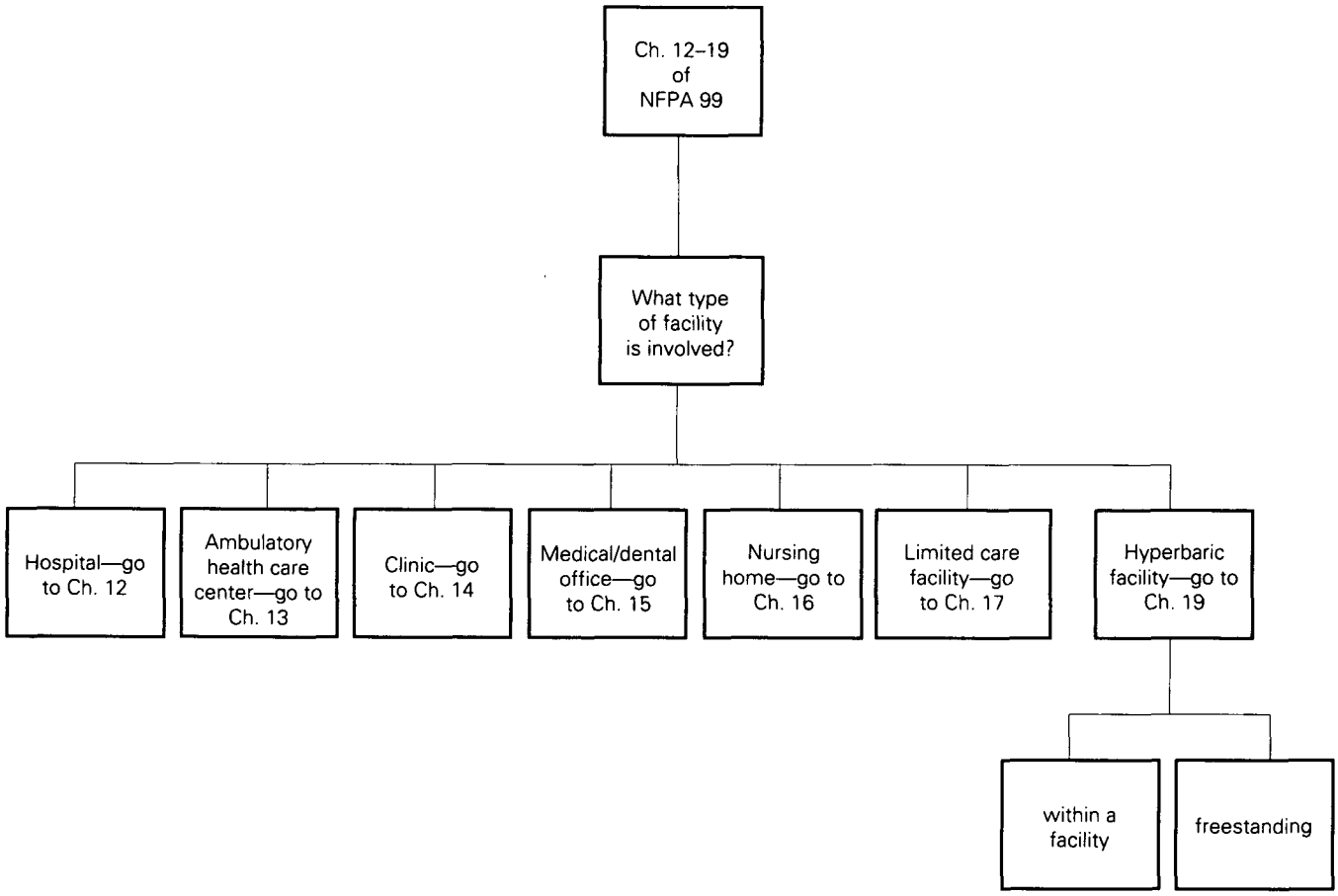
To further help users of the document, several flow charts have been created (*see following pages*). These present the general structure of NFPA 99, the difference between "new" and "existing" requirements, and examples of how to find requirements for a particular facility.



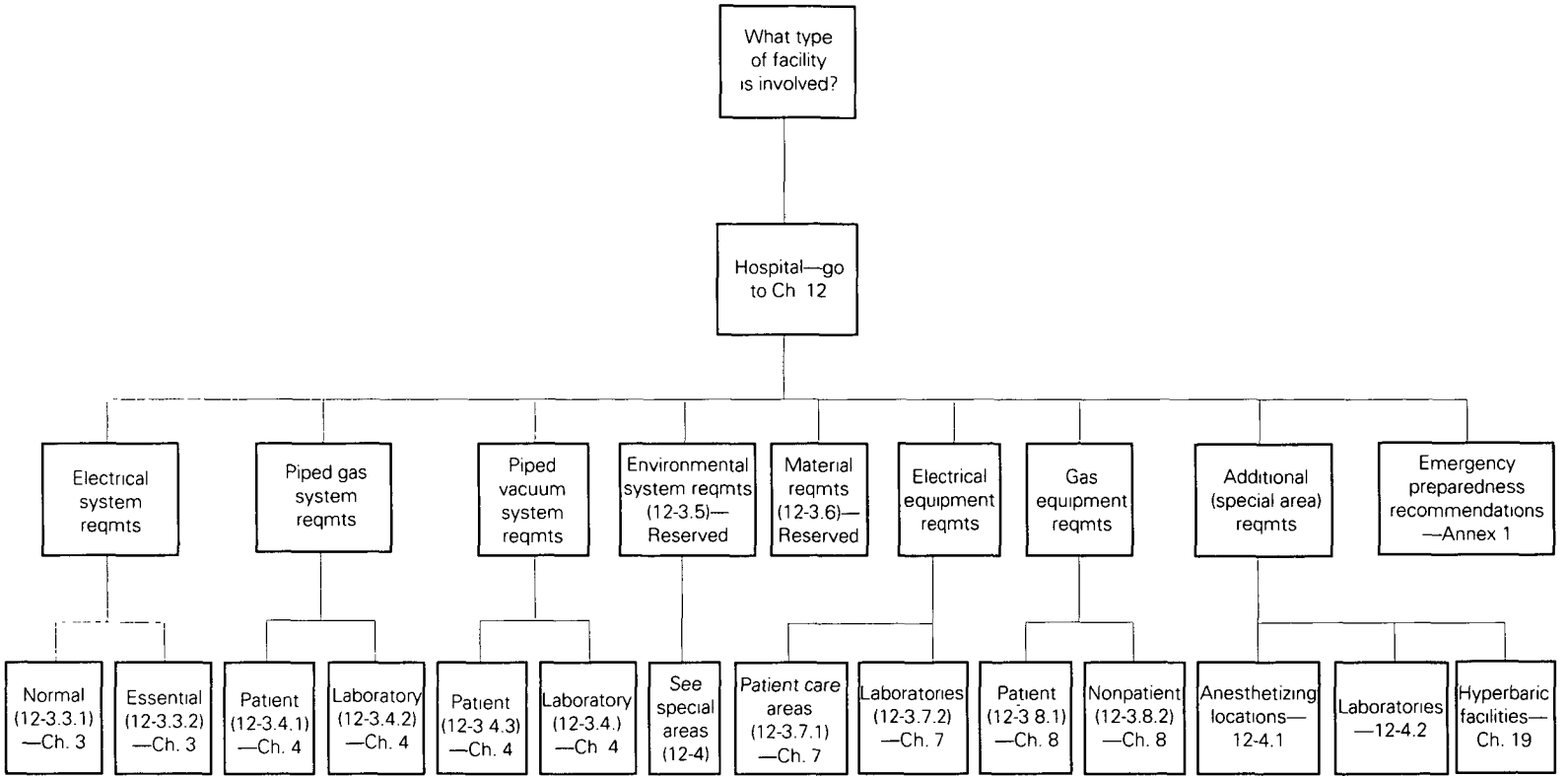
How NFPA 99 Is Organized



Existing vs. New Requirements in Ch. 3-11 of NFPA 99-1993



Finding a Requirement in a Health Care Facility



Example of How to Find a Requirement in a Hospital

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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.

Committee Scope: This Committee shall have primary responsibility for developing documents which contain criteria for safeguarding patients and health care personnel in the delivery of health care services within health care facilities: (a) from fire, explosion, electrical and related hazards resulting either from the use of anesthetic agents, medical gas equipment, electrical apparatus and high frequency electricity, or from internal or external incidents that disrupt normal patient care; (b) from fire and explosion hazards associated with laboratory practices; (c) in connection with the use of hyperbaric and hypobaric facilities for medical purposes; (d) through performance, maintenance and testing criteria for electrical systems, both normal and essential; and (e) through performance, maintenance and testing and installation criteria: (1) for vacuum systems for medical or surgical purposes, and (2) for medical gas systems.

Contents

NOTICE

Following release by the NFPA Standards Council of this 1993 edition of NFPA 99, *Standard for Health Care Facilities*, the following appeal was filed with the NFPA Board of Directors:

The appeal requests that text on waste anesthetic gas disposal (WAGD) systems (paragraph 4-8.1.2) be placed in Chapter 5 of NFPA 99.

NFPA will announce the disposition of this appeal when it has been determined. Anyone wishing to receive automatically a copy of the disposition of the appeal should notify in writing the Secretary, Standards Council, NFPA, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 99

Standard for Health Care Facilities

1993 Edition

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 20 and Appendix B.

Further explanatory information on Chapters 1 through 19 can be found in Appendix C.

Sections of Chapter 3 identified by a dagger (†) include text extracted from NFPA 110, *Standard for Emergency and Standby Power Systems*, 1993 edition. Requests for interpretations or revisions of the extracted text will be referred to the Technical Committee on Emergency Power Supplies. Requests for interpretations or revisions of the extracted figures will be referred to the Technical Committee on Electrical Equipment in Chemical Atmospheres. Sections of Appendixes A and C identified by a dagger (†) include text extracted from NFPA 30, *Flammable and Combustible Liquids Code*, 1990 edition. Requests for interpretations or revisions of the extracted text will be referred to the Technical Committee on General Storage of Flammable Liquids.

Chapter 1 Introduction

1-1 Scope. The scope of this document is to establish criteria to minimize the hazards of fire, explosion, and electricity in health care facilities. These criteria include performance, maintenance, testing, and safe practices for facilities, material, equipment, and appliances and include other hazards associated with the primary hazards.

1-2 Application. This document shall apply to all health care facilities. Construction and equipment requirements shall be applied only to new construction and new equipment, except as modified in individual chapters.

Chapters 12 through 18 specify the conditions under which the requirements of Chapters 3 through 11 shall apply in Chapters 12 through 18.

1-3 Intended Use. This document is intended for use by those persons involved in the design, construction, inspection, and operation of health care facilities and in the design, manufacture, and testing of appliances and equipment used in patient care areas of health care facilities.

1-4 Discretionary Powers of Authority Having Jurisdiction. The authority having jurisdiction for the enforcement of this document shall be permitted to grant exceptions to its requirements.

Nothing in this document is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety to those prescribed by this document, providing (a) technical documentation is submitted to the authority having jurisdiction to demonstrate equivalency and (b) the system, method, or device is approved for the intended purpose.

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 document. 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 document. Refer to Section 16 of the NFPA *Regulations Governing Committee Projects* for complete details.

1-6 Organization of This Document.

1-6.1 Beginning with the 1987 edition, the organization of NFPA 99 reflected an attempt to make the document completely integrated and cohesive. Having been originally developed from 12 previously independent documents, the 1987 edition of NFPA 99 restructured all the existing text in the following way:

Chapter 1 is an introductory chapter.

Chapter 2 lists all definitions.

Chapters 3 through 11 contain requirements but do not state where they are applicable.

Chapters 12 through 18 are "facility" chapters listing requirements from Chapters 3 through 11 that are applicable to specific facilities. These chapters also contain any additional requirements specific to that facility.

Chapter 19 contains safety requirements for hyperbaric facilities (whether freestanding or part of a larger facility).

Chapter 20 lists required references made in Chapters 1 through 19.

Appendix A contains nonmandatory information keyed to the text of Chapters 1 through 19 (e.g., A-5-4.2 is explanatory information on 5-4.2).

Appendix B lists informatory references.

Appendix C contains more explanatory information on Chapters 1 through 19, though not keyed to specific text (numbering is such that the first number after the letter C indicates the chapter to which material is related, e.g., Appendix C-7 contains information related to Chapter 7).

Finally, two annexes contain guidance on the following subjects: disaster planning (Annex 1) and the use of high-frequency electricity (Annex 2).

As a result of this restructuring, a reader interested in learning, for example, what the electrical system requirements are for a hospital would begin by first turning to Chapter 12 ("Hospital Requirements"), then to 12-3.3 ("Electrical System Requirements"). Similarly, electrical system requirements for a nursing home would be found by first turning to Chapter 16 ("Nursing Home Requirements"), then to 16-3.3 ("Electrical System Requirements").

1-6.2 Each general chapter (3 through 11)[1] has been organized into the following sections:[1]

-1 Scope
-2 Nature of Hazards
-3 Source

[1]Chapter 4 contains requirements in two parts. The first portion covers piped gas system requirements; the second portion covers piped vacuum systems.

-4 Distribution
-5 Performance Criteria and Testing
-6 Administration

The major topics considered in each facility chapter (12 through 18) under "General Requirements" (e.g., 12-3, 13-3, etc.) are arranged in the following order (for consistency with the order of the general chapters):

.3 Electrical Systems
.4 Gas and Vacuum Systems
.5 Environmental Systems
.6 Materials
.7 Electrical Equipment
.8 Gas Equipment

1-6.3 The 1987 edition completed the original goal of combining the 12 previously individual documents under the jurisdiction of the former Correlating Committee on Health Care Facilities, now Technical Committee on Health Care Facilities. Cross-referencing to the previous individual documents was possible but would have been complicated because of the major difference between the structure of the previous individual documents and the structure of the 1987 edition of NFPA 99.

1-7 Metric Units. While it is common practice for medical appliances to have metric units on their dials, gauges, and controls, many components of systems within the scope of this document, which are manufactured and used in the U.S., employ nonmetric dimensions. Since these dimensions (such as nominal pipe sizes) are not established by the National Fire Protection Association, the Technical Committee on Health Care Facilities cannot independently change them. Accordingly, this document uses dimensions that are presently in common use by the building trades in the U.S. Conversion factors to metric units are included in Appendix C-4.5.

1-8 Effective Date. The effective date of application of any provision of this document is not determined by the National Fire Protection Association. All questions related to applicability shall be directed to the authority having jurisdiction.

1-9 Preface. This document's genesis was a series of explosions in operating rooms during surgery in the 1930s. The problem was traced to static discharges of sufficient energy to ignite the flammable anesthetic agents being used. A series of recommendations to mitigate the hazard were then promulgated. In addition, a Committee on Hospitals was established with responsibility to periodically review and revise recommendations.

Since then, the concerns of this Committee have grown to encompass many other fire and fire-related hazards related to the delivery of health care services. The Committee was also allowed to enlarge its scope to include all health care facilities.

The major concerns of the Committee are those hazards associated with operating a health care facility, treating patients, and operating laboratories. This includes the electrical system (both normal and emergency power), gas systems (both positive and negative pressure), medical equipment (both electrical and gas powered), environmental conditions peculiar to health care facilities operation, and the management of a facility in the event of disasters (e.g., fire, chemical spill) that disrupt normal patient care.

The Committee and its Subcommittees originally developed separate documents as hazards were identified. NFPA 99 is the result of a proposal to combine, organize, and integrate into one document all the material contained in the individual documents. The intent was, and still is, to provide as useful a document as possible to its many and varied users.

Chapter 2 Definitions

[Secretary's Note: The letters in parentheses at the end of each definition refer to the Technical Committee Standing Subcommittee responsible for defining the term. The key to identifying responsibility is as follows:

(AS): Subcommittee on Anesthesia Services
(DIS): Subcommittee on Disaster Planning
(EE): Subcommittee on Electrical Equipment
(ES): Subcommittee on Electrical Systems
(GE): Subcommittee on Gas Equipment
(HFE): Subcommittee on Use of High Frequency Electricity
(HHF): Subcommittee on Hyperbaric and Hypobaric Facilities
(LAB): Subcommittee on Laboratories
(MGS): Subcommittee on Nonflammable Piped Gas Systems
(VSE): Subcommittee on Vacuum Systems and Equipment
(TC): Technical Committee on Health Care Facilities.]

For the purposes of this document, 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*). (VSE)

Adiabatic Heating. The temperature rise of a gas caused only by its compression. (HHF)

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. (GE)

Air, Oil-Free, Dry (Air for Testing). Air complying, as a minimum, with Grade D in CGA, Inc., Pamphlet G-7.1, *Commodity Specification for Air*, and having a maximum dew point of -20°F (-28.9°C) at line pressure. (MGS)

Alarm System, Area. A warning system that provides visible and audible signals for the monitoring of medical gas and vacuum systems serving a specific area, consisting of alarm panel(s) and associated actuating device(s).

Alarm System, Local. A warning system that provides visible and audible signals for the monitoring functions of medical gas and vacuum system source equipment at the equipment site.

Alarm System, Master. A warning system that provides visible and audible signals for the monitoring of medical gas and vacuum sources and systems, consisting of alarm panel(s) and associated actuating device(s).

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. (ES)

Ambulatory Health Care Center. A building or part thereof used to provide services or treatment to four or more patients at the same time and meeting either (1) or (2) below.

(1) Those facilities that provide, on an outpatient basis, treatment for patients that would render them incapable of taking action for self-preservation under emergency conditions without assistance from others, such as hemodialysis units or freestanding emergency medical units.

(2) Those facilities that provide, on an outpatient basis, surgical treatment requiring general anesthesia. (EE)

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

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

Anesthetizing Location. Any area of the facility that 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*). (AS)

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

Antistatic. That class of materials that includes conductive materials and, also, those materials that throughout their stated life meet the requirements of 12-4.1.3.8(f)(3) and (4). (AS)

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. (EE)

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

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

Area of Administration. Any point within a room within 15 ft (4.3 m) of oxygen equipment or an enclosure containing or intended to contain an oxygen-enriched atmosphere. (GE)

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 a hyperbaric facility. When used as a measure of pressure, atmosphere is expressed as a fraction of standard air pressure [14.7 psi (101.4 kPa)]. (*See NFPA 99B, Appendix C-3, Pressure Table, Column 1.*) (HHF)

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

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

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

Atmosphere of Increased Burning Rate.* 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.,

$$\frac{23.45}{\sqrt{T.P._{atmos}}}$$

where $T.P._{atmos}$ = total pressure in atmospheres.

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. (ES)

Bends. Decompression sickness; caisson worker's disease. (*See Appendix C-19.1.3.3.2.*) (HHF)

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

Branch Line. (*See Piping.*)

Bulk Systems:

Bulk Nitrous Oxide System. An assembly of equipment as described in the definition of bulk oxygen system that has a storage capacity of more than 3200 lb (1452 kg) [approximately 28,000 cu ft (793 m^3) (NTP)] of nitrous oxide. (MGS)

Bulk Oxygen System. An assembly of equipment such as oxygen storage containers, pressure regulators, pressure relief devices, vaporizers, manifolds, and interconnecting piping that has a storage capacity of more than 20,000 cu ft (566 m^3) of oxygen (NTP) including unconnected reserves on hand at the site. The bulk oxygen system terminates at the point where oxygen at service pressure first enters the supply line.

NOTE: The oxygen containers may be stationary or movable, and the oxygen may be stored as gas or liquid. (MGS)

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

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

Clinic. A health care facility where patients are seen on an ambulatory basis, but where surgery involving general anesthesia is not performed. (TC)

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

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

Combustible Liquid. See definition of Liquid and Appendix C-10.2.1. (LAB)

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

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 phosphorus 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. (AS)

Conductive. Not only those materials, such as metals, that are commonly considered electrically conductive, but also that class of materials that, 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. (AS)

Container. A low-pressure, vacuum-insulated vessel containing gases in liquid form. (GE)

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 that are connected to alternate power sources by one or more transfer switches during interruption of normal power source. (ES)

Critical Care Area. (*See Patient Care Area.*)

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 custodial care facilities arranged for connection to the alternate power source to restore service to certain critical receptacles, task illumination, and equipment. (ES)

Cylinder. A supply tank containing high-pressure gases or gas mixtures at pressures that may be in excess of 2000 psig (13.8 kPa gauge). (GE)

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

Dental Compressed Air.* For purposes of this standard, dental compressed air is:

(a) Air, supplied from cylinders, that complies at a minimum with Grade D in CGA Pamphlet G-7.1, *Commodity Specification for Air*, or;

(b) Locally compressed indoor or outdoor atmospheric air, to which no contaminants in the form of particulate matter, odor, oil vapor, or other gases have been added by a compressor system. The air delivered shall:

(1) Have a maximum relative humidity of 40 percent at line pressure and temperature.

(2) Be filtered to 5 microns or less with 98 percent efficiency or better.

NOTE: Local atmospheric air may not be equal in purity or dryness to the commodity specification Grade D in (a).

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

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 while the other is outside the body and is accessible for inadvertent or intentional contact with grounded objects or energized, ground-referenced sources.

NOTE: Electrodes, such as those used for pacing the heart, and catheters filled with conductive fluids are examples of direct electrical pathways to the heart. (EE)

Double-Insulated Appliances. Appliances having an insulation system comprising both basic insulation necessary for the functioning of the appliance and for basic protection against electric shock and 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. (EE)

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

Electrode. An electrically conductive connection to a patient. Some electrodes of interest are: (EE)

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

Bipolar Electrode. An electrode consisting of adjacent contacts (e.g., the two legs of a forceps) such that the high-frequency current passes between the pair of contacts generating the surgical effect. (HFE)

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." (HFE)

Emergency System. A system of circuits and equipment 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. (ES)

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

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

Essential Electrical System. A system comprised of alternate sources of power and all connected distribution systems and ancillary equipment, designed to ensure 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. (ES)

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

Failure. An incident that 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. (EE)

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. (ES)

Feeder. All circuit conductors between the service equipment or the source of a separately derived system and the final branch-circuit overcurrent device. (ES)

Flame Resistant. The property of a material that passes the small-scale test in NFPA 701, *Standard Methods of Fire Tests for Flame-Resistant Textiles and Films.* (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.

Flammable. An adjective describing easy ignition, intense burning, and rapid rate of flame spread 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. (AS)

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

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-10.2.1. (LAB)

Flash Point. The minimum temperature at which a liquid gives off vapor in sufficient concentration to form an ignitible mixture with air near the surface of the liquid within the vessel, as specified by appropriate test procedures and apparatus. (*See Appendix C-10.2.2.*) (LAB)

Flow-Control Valve. A valve, usually a needle valve, that precisely controls flow of gas. (GE)

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

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

Frequency. The number of oscillations, per unit time, of a particular current or voltage waveform. The unit of frequency is the hertz.

NOTE 1: Formerly the unit of frequency was cycles per second, a terminology no longer preferred.

NOTE 2: The waveform may consist of components having many different frequencies, in which case it is called a complex or nonsinusoidal waveform. (EE)

Fume Hood. An enclosure designed to draw air inward by means of mechanical ventilation. This definition does not include canopy hoods or recirculation laminar-flow biological-safety cabinets that are not designed for use with flammable materials. (LAB)

NOTE: Laboratory fume hoods prevent toxic, flammable, or noxious vapors from entering the laboratory, present a physical barrier from chemical reactions, and serve to contain accidental spills.

General Care Area. (*See Patient Care Area.*)

Governing Body. The person or persons who have the overall legal responsibility for the operation of a health care facility. (*See the Accreditation Manual for Hospitals, Joint Commission on Accreditation of Healthcare Organizations, Chicago, 1989.*) (AS)

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. (ES)

Grounding. See grounding system.

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

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

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: (ES)

Fault Hazard Current. The hazard current of a given isolated power system with all devices connected except the line isolation monitor. (ES)

Monitor Hazard Current. The hazard current of the line isolation monitor alone. (ES)

Total Hazard Current. The hazard current of a given isolated system with all devices, including the line isolation monitor, connected. (ES)

Hazardous Area in a Flammable Anesthetizing Location.* The space extending 152 cm (5 ft) above the floor in a flammable anesthetizing location. (*See 12-4.1.3 and Appendix A-2-2.*) (AS)

Hazardous Area in Laboratories. The area inside fume hoods or enclosures where tests or procedures are being conducted under the conditions listed in 10-7.4.1. (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 the Fire Hazards of Materials*: Health — 2, 3, or 4; Flammability — 2, 3, or 4; Reactivity — 2, 3, or 4. (*See Appendixes A-2-2 and C-10.2.3.*) (LAB)

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

Health Care Facilities. Buildings or portions of buildings in which medical, dental, psychiatric, nursing, obstetrical, or surgical care are provided. Health care facilities include, but are not limited to, hospitals, nursing homes, limited care facilities, clinics, medical and dental offices, and ambulatory care centers, whether permanent or movable. (TC)

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

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

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. (ES)

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

Hyperbaric. 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. 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. (ES)

Impedance. Impedance is the ratio of the voltage drop across a circuit element to the current flowing through the same circuit element. The unit of impedance is the ohm. (EE)

NOTE: The circuit element may consist of any combination of resistance, capacitance, or inductance.

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

Intrinsically Safe. As applied to equipment and wiring, equipment and wiring that are incapable of releasing sufficient electrical energy under normal or abnormal conditions to cause ignition of a specific hazardous atmospheric mixture.

NOTE: Abnormal conditions may include accidental damage to any part of the equipment or wiring; insulation or other failure of electrical components; application of overvoltage; adjustment and maintenance operations; and other similar conditions. (HHF)

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

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.*) (ES)

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

Laboratory. A building, space, room, or group of rooms 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 Work Area. A room or space for testing, analysis, research, instruction, or similar activities that involve the use of chemicals.

NOTE: 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, that is conveyed from exposed metal parts of an appliance to ground or to other accessible parts of an appliance. (EE)

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 that is automatically connected to alternate power sources during interruption of the normal power source. (ES)

Limited Care Facility. A building or part thereof used on a 24-hour basis for the housing of four or more persons who are incapable of self-preservation because of age, physical limitation due to accident or illness, or mental limitations such as mental retardation/developmental disability, mental illness, or chemical dependency. (TC)

Limited-Combustible Material. A material (as defined in NFPA 220, *Standard on Types of Building Construction*) not complying with the definition of noncombustible material that, in the form in which it is used, has a potential heat value not exceeding 3500 Btu/lb (8141 kJ/kg) and complies with one of the following paragraphs (a) or (b). Materials subject to increase in combustibility or flame-spread rating beyond the limits herein established through the effects of age, moisture, or other atmospheric condition shall be considered combustible. (*See NFPA 259, Standard Test Method for Potential Heat of Building Materials.*)

(a) Materials having a structural base of noncombustible material, with a surfacing not exceeding a thickness of 1/8 in. (3.2 mm) and having a flame-spread rating not greater than 50.

(b) Materials, in the form and thickness used, other than as described in (a), having neither a flame-spread rating greater than 25 nor evidence of continued progressive combustion and of such composition that surfaces that would be exposed by cutting through the material on any plane would have neither a flame-spread rating greater than 25 nor evidence of continued progressive combustion. (MGS)

Line Isolation Monitor. A test instrument designed to continually check the balanced and unbalanced impedance from each line of an isolated circuit to ground and equipped with a built-in test circuit to exercise the alarm without adding to the leakage current hazard. (ES)

Liquid. Any material that has a fluidity greater than that of 300 penetration asphalt when tested in accordance with ASTM D5, *Test for Penetration of Bituminous Materials*. When not otherwise identified, the term *liquid* shall include both flammable and combustible liquids. (*See Appendix C-10.2.1.*) (LAB)

mA. Milliampere.

Manifold. A device for connecting the outlets of one or more gas cylinders to the central piping system for that specific gas. (MGS)

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

Medical Air Compressor. A compressor that is designed to exclude oil from the air stream and compression chamber, and that does not under normal operating conditions or any single fault add any toxic or flammable contaminants to the compressed air.

Medical Compressed Air. For purposes of this standard, medical compressed air is air that (a) is supplied from cylinders, bulk containers, medical air compressors, or has been reconstituted from oxygen USP and nitrogen NF, and (b) complies with the following:

1.	Medical Air USP	
2.	Total hydrocarbons	
	liquid	nondetectable
	gaseous	< 25 ppm
3.	Pressure dew point at 50 psig	< 39°F (4°C)
4.	Permanent particulates	5 milligrams per cu. meter at normal atmospheric pressure of particulate at 1 micron size or greater

NOTE 1: For fire and safety purposes, air supplied from on-site compressor and air-treatment systems should comply at a minimum with the limiting characteristics in the above definition at the design conditions.

The quality of local atmospheric air should be determined to assist in establishing the optimum compressor and air-treatment system performance.

Hydrocarbon contamination of compressor supply systems for medical compressed air and the carryover into the pipeline distribution system could be detrimental to the safety of the end user and to the integrity of the system, and could be a potential fire hazard. Mixing of medical compressed air with oxygen is a common clinical practice, and the hazards of fire are increased if the air is thus contaminated. No quantitative data is readily available concerning specific levels or mixtures that could create this hazard. Therefore, the limit for liquid hydrocarbons is established on the basis of empirical data.

NOTE 2: The dew point at line pressure outlined recognizes that some medical compressed air piping systems may be routed outside buildings. This requirement calls attention to the fact that where colder ambient temperatures are experienced, the system design precludes freezing of the air line.

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 station inlets at locations where patient suction may be required. (VSE)

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. (AS)

mV. Millivolt.

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

Negative Pressure. Pressure less than atmospheric. (GE)

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

Nitrogen Narcosis. A condition resembling alcoholic inebriation, which results from breathing nitrogen in the air under significant pressure. (*See C-19.1.3.1.2.*) (HHF)

Nitrogen, Oil-Free, Dry (Nitrogen for Testing and System Operation). Nitrogen complying, at a minimum, with Grade D in CGA, Inc. Pamphlet G-10.1, *Commodity Specification for Nitrogen*. (MGS)

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. (AS)

Noncombustible (Hyperbaric). Within the context of Chapter 19, "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 NFPA 99B, *Standard for Hypobaric Facilities*, an adjective describing a substance that will not burn in 95 ± 5 percent oxygen at pressures of 760 mm Hg. (HHF)

Noncombustible Material. A material (as defined in NFPA 220, *Standard on Types of Building Construction*) that, in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat. Materials reported as noncombustible, when tested in accordance with the *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, ASTM E136, shall be considered noncombustible materials. (MGS)

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 that, 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. (AS)

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

Nonflammable Medical Gas System. A system of piped oxygen, nitrous oxide, compressed air, or other nonflammable medical gases. (*See Chapter 4, "Gas and Vacuum Systems," Sections 4-3 through 4-6.*) (MGS)

Nursing Home. A building or part thereof used for the housing and nursing care, on a 24-hour basis, of four or more persons who, because of mental or physical incapacity, may be unable to provide for their own needs and safety without the assistance of another person. Nursing home, wherever used in this document, shall include nursing and convalescent homes, skilled nursing facilities, intermediate care facilities, and infirmaries in homes for the aged. (EE)

Operating Supply. The portion of the supply system that normally supplies the piping systems. The operating supply consists of a primary supply or a primary and secondary supply. (MGS)

Primary Supply. That portion of the equipment that is actually supplying the system. (MGS)

Secondary Supply. When existing, a supply that automatically supplies the system when the primary supply becomes exhausted. This is a normal operating procedure of the equipment. (MGS)

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

Oxygen. An element that, at atmospheric temperatures and pressures, exists as a colorless, odorless, tasteless gas. (AS)

NOTE: Its outstanding property is its ability to sustain life and to support combustion. Although oxygen is nonflammable, materials that burn in air will burn much more vigorously and create higher temperatures in oxygen or in oxygen-enriched atmospheres.

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

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.

NOTE: If spilled, the liquid can cause frostbite on contact with skin. (GE)

Oxygen Delivery Equipment. Any device used to transport and deliver an oxygen-enriched atmosphere to a patient. If an enclosure such as a mask, hood, incubator, canopy, or tent is used to contain the oxygen-enriched atmosphere, then that enclosure is considered to be oxygen delivery equipment. (GE)

Oxygen-Enriched Atmosphere. For the purpose of this standard, and only for the purpose of this standard, an atmosphere in which the concentration of oxygen exceeds 23.5 percent by volume.

Oxygen Index. The minimum concentration of oxygen, expressed as percent by volume, in a mixture of oxygen and nitrogen that will just support combustion of a material under conditions of ASTM D2863, *Method for Measuring the Minimum Oxygen Concentration to Support Candle-like Combustion of Plastics (Oxygen Index)*. (HHF)

Oxygen Toxicity (Hyperbaric). Physical impairment resulting from breathing gaseous mixtures containing oxygen-enriched atmospheres at elevated partial 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-19.1.3.1.3*) (HHF)

Patient Bed Location. The location of a patient sleeping bed, or the bed or procedure table of a critical care area.

Patient Care Area. Any portion of a health care facility wherein patients are intended to be examined or treated. (EE)

NOTE: Business offices, corridors, lounges, day rooms, dining rooms, or similar areas typically are not classified as patient care 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.

NOTE: In such areas, patients may be connected to electromedical devices (such as heating pads, electrocardiographs, drainage pumps, monitors, otoscopes, ophthalmoscopes, intravenous lines, etc.).

(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.

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

Patient Care Vicinity. A space, within a location intended for the examination and treatment of patients, extending 6 ft (1.8 m) beyond the normal location of the bed, chair, table, treadmill, or other device that supports the patient during examination and treatment. A patient care vicinity extends vertically to 7 ft 6 in. (2.3 m) above the floor.

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

Patient Lead. Any deliberate electrical connection that may carry current between an appliance and a patient. It is not intended to include adventitious or casual contacts such as a push button, bed surface, lamp, hand-held appliance, etc. (EE)

NOTE 1: 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).

NOTE 2: Also see definition of isolated patient lead.

Piped Distribution System. A system that consists of a central supply system (manifold, bulk, or compressors) with control equipment and piping extending to points in the facility where nonflammable medical gases are required, with suitable station outlet valves at each use point. (MGS)

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

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

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

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

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

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

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

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 gauge) (215 psia). (GE)

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.) (HHF)

NOTE: 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 mm Hg.

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

Pressure, Working. A pressure not exceeding 200 psig (11.6 kg/cm^2). (GE)

NOTE: A pipeline working pressure of 50 to 55 psig (2.9 to 3.2 kg/cm^2) is conventional because medical gas equipment is generally designed and calibrated for use at this pressure.

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)

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

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

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-10-2.3.3 for definitions of Reactivity 3 and Reactivity 4.*) (LAB)

Reference Grounding Point. A terminal bus that 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. (EE)

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 a patient by the inhalation of concentrations of nitrous oxide insufficient to produce loss of consciousness (conscious sedation). (AS)

Remote.* A use point and/or the gas system storage shall be considered remote if it cannot be accessed directly by walking from the front door of the treatment facility through to the use point or storage area without walking out through another exit. A remote use point shall be considered a separate single treatment facility. (MGS)

Reserve Supply. Where existing, that portion of the supply equipment that automatically supplies the system in the event of failure of the operating supply. The reserve supply only functions in an emergency and not as a normal operating procedure. (MGS)

Safety Can. An approved container, of not more than 5 gal (18.9 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)

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 1 atmosphere (29.92 in. of Hg). (VSE)

Selected Receptacles. A minimal number of receptacles selected by the governing body of a facility as necessary to provide essential patient care and facility services during loss of normal power. (ES)

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)

Single Treatment Facility.* A diagnostic or treatment complex under a single management comprising a number of use points but confined to a single contiguous grouping of use points, i.e., do not involve widely separated locations or separate distinct practices. For the purposes of this standard, a single treatment facility will be on a single level or one in which a person travels to a second level totally from within the confines of the treatment area. One-, two-, or three-level complexes in which entry to other use points is achieved through an outer foyer or hall entry shall not be considered single treatment facilities. (MGS)

Site of Intentional Expulsion. All points within 1 ft (0.3 m) of a point at which an oxygen-enriched atmosphere is intentionally vented to the atmosphere. For example: for a patient receiving oxygen via a nasal cannula or face mask, the site of expulsion normally surrounds the mask or cannula; for a patient receiving oxygen while enclosed in a canopy or incubator, the site of intentional expulsion normally surrounds the openings to the canopy or incubator; for a patient receiving oxygen while on a ventilator, the site of intentional expulsion normally surrounds the venting port on the ventilator.

NOTE: This definition addresses the site of intended expulsion. Actual expulsion may occur at other sites remote from the intended site due to disconnections, leaks, or rupture of gas conduits and connections. Vigilance on the part of the patient care team is essential to ensure system integrity. (GE)

Station Inlet. An inlet point in a piped vacuum distribution system at which the user makes connections and disconnections. (VAC)

Station Outlet. An outlet point in a piped medical gas distribution system at which the user makes connections and disconnections. (MGS)

Storage Cabinet.* A cabinet for the storage of flammable and combustible liquids constructed in accordance with Section 4-3 of NFPA 30, *Flammable and Combustible Liquids Code*. (LAB)

Storage Location for Flammable Inhalation Anesthetics. Any room within a consuming facility 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 the location. (AS)

Surface-Mounted Medical Gas Rail Systems.* A surface-mounted gas delivery system intended to provide ready access for two or more gases through a common delivery system to provide multiple gas station outlet locations within a single patient room or critical care area. (MGS)

Task Illumination. Provisions for the minimum lighting required to carry out necessary tasks in the areas described in Chapter 3, including safe access to supplies and equipment and access to exits. (ES)

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

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. (AS)

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)

Use Point. A room, or area within a room, where medical gases are dispensed to a single patient for medical purposes. A use point is permitted to be comprised of a number of station outlets of different gases. (MGS)

Wet Location. A patient care area that is normally subject to wet conditions while patients are present. This includes standing fluids on the floor or drenching of the work area, either of which condition is intimate to the patient or staff. Routine housekeeping procedures and incidental spillage of liquids do not define a wet location.

Chapter 3 Electrical Systems

NOTE 1: The application of requirements contained in this chapter for specific types of health care facilities can be found in Chapters 12 through 18.

NOTE 2: Sections of Chapter 3 identified by a dagger (†) include text extracted from NFPA 110, *Standard for Emergency and Standby Power Systems*, 1993 edition. Requests for interpretations or revisions of the extracted text will be referred to the Technical Committee on Emergency Power Supplies.

3-1* Scope.

3-1.1 This chapter covers the performance, maintenance, and testing of electrical systems (both normal and essential) used within health care facilities.

3-1.2 Specific requirements for wiring and installation on equipment are covered in NFPA 70, *National Electrical Code*.

3-1.3 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.

3-1.4 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.

3-1.5 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.

3-1.6 Requirements for the installation of stationary engines and gas turbines are covered in NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*.

3-2* 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-3-2.*)

3-2.1 Fire and Explosions. Electrical systems may be subject to the occurrence of electrical fires. Grounding systems, overcurrent protective devices, and other subjects discussed in this standard 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.

3-2.2 Shock.

3-2.2.1 General. (*See A-3-2.*)

3-2.2.2* Control. 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-3-2.2.2.

3-2.3 Thermal. (Reserved)

3-2.4 Interruption of Power.

3-2.4.1 General. Medical and nursing sciences are becoming progressively more dependent on 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 on 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 on 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 ensure 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.

3-2.4.2 Need to Maintain Power. Interruption of the supply of electric power in a facility may be a hazard. Implementation of the requirements of this chapter serves to maintain the required level of continuity and quality of electrical power for patient care electrical appliances.

3-2.5 RF Interference. (Reserved)

(*See Annex 2, "The Safe Use of High-Frequency Electricity in Health Care Facilities," at the end of this document for recommendations.*)

3-3 Sources.

3-3.1 Normal (AC). 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.

3-3.1.1 Power/Utility Company. (Reserved)

3-3.1.2 On-Site Generator Set. (Reserved)

3-3.2 Alternative.

3-3.2.1 On-Site Generator Set.

3-3.2.1.1* Design Considerations. Dual sources of normal power shall be considered. Such dual sources of normal power shall not constitute an alternate source of power as described in this chapter.

NOTE: 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.

Distribution system arrangements shall be designed to minimize interruptions to the electrical systems due to internal failures by the 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 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.

(g) Bypass arrangements to permit testing and maintenance of system components that could not otherwise be maintained without disruption of important hospital functions.

(h) Effects of any harmonic currents on neutral conductors and equipment.

3-3.2.1.2 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.

3-3.2.1.3 The alternate source of power shall be a generator(s) driven by some form of prime mover(s) and located on the premises.

Exception: 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.

3-3.2.1.4 General. Generator sets installed as an alternate source of power for essential electrical systems shall be designed to meet the requirements of such service.

(a) Type I and Type II essential electrical system power sources shall be classified as Type 10, Class X, Level 1 generator sets per NFPA 110, *Standard for Emergency and Standby Power Systems*.

(b) Type III essential electrical system power sources shall be classified as Type 10, Class X, Level 2 generator sets per NFPA 110, *Standard for Emergency and Standby Power Systems*.

3-3.2.1.5 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 that operates the essential electrical system shall be permitted to be part of the system supplying the entire electrical system for the purposes of (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 3 years.

3-3.2.1.6† 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. [110: 5-2.1]

3-3.2.1.7† Capacity and Rating. The generator set(s) shall have sufficient capacity and proper rating to meet the maximum demand of the essential electrical system at any one time. [110: 3-4.1]

3-3.2.1.8 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.

3-3.2.1.9† 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). [110: 3-5.5.2(d), 5-7.6]

3-3.2.1.10† Ventilating Air. Provision shall be made to provide adequate air for cooling and to replenish engine combustion air. [110: 5-7.2, 5-7.4]

3-3.2.1.11*† Cranking Batteries. Internal combustion engine starting batteries shall have sufficient capacity to provide 60 seconds of continuous cranking. [110: 3-5.4]

3-3.2.1.12† 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. [110: 3-5.4]

3-3.2.1.13† 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. [110: 3-1]

Exception: The use of fuels 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.

3-3.2.1.14† Requirements for Safety Devices. [110: 3-5.5.2]

(a) *Internal Combustion Engines.* Internal combustion engines serving generator sets shall be equipped with:

(1) A sensor device plus visual warning device to indicate a water-jacket temperature below those required in 3-3.2.1.9.

(2) Sensor devices plus visual prealarm warning device to indicate:

(i) High engine temperature (above manufacturer's recommended safe operating temperature range).

(ii) Low lubricating oil pressure (below manufacturer's recommended safe operating range).

(3) An automatic engine shutdown device plus visual device to indicate that a shutdown took place for:

(i) Overcrank (failed to start).

(ii) Overspeed.

(iii) Low lubricating oil pressure.

(iv) Excessive engine temperature.

(4) 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 (2) and (3) is to use two sensors for each alarm condition set at different operating points.

(b) *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.

(c) *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 3-hour operating supply.

3-3.2.1.15† 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 3-3.2.1.9).

(3) Excessive water temperature.

(4) Low fuel — when the main fuel storage tank contains less than a 3-hour operating supply.

(5) Overcrank (failed to start).

(6) Overspeed.

Where a regular work station will 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 3-3.2.1.15(a) and (b) occur, but need not display these conditions individually. [110: 3-5.5.2]

3-3.2.2 Battery. Battery systems shall meet all requirements of Article 700 of NFPA 70, *National Electrical Code*.

3-3.2.3 Separate Utility. (Reserved)

3-4 Distribution.

3-4.1 General.

3-4.1.1 Electrical Installation. Installation shall be in accordance with NFPA 70, *National Electrical Code*.

3-4.1.2 All Patient Care Areas. (*See Chapter 2 for definition of patient care area.*)

3-4.1.2.1* Wiring, Regular Voltage.

(a)* *Circuits.* Branch circuits serving a given patient bed location shall be fed from not more than one normal branch circuit distribution panel. When required, branch circuits serving a given patient bed location shall be permitted to be fed from more than one emergency branch circuit distribution panel.

Critical care areas shall be served by circuits from (1) critical branch panel(s) served from a single automatic transfer switch, and (2) a minimum of one circuit served by the normal power distribution system or by a system originating from a second critical branch transfer switch.

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.

(b) *Grounding.*

(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.

(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 that does not use a separate grounding conductor shall be permitted to continue in use provided that it meets the performance requirements in 3-5.2.1, "Grounding System in Patient Care Areas."

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.

(c)* *Grounding Interconnects.* 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 that of the essential electrical system shall be interconnected.

(d) *Circuit Protection.*

(1) Circuit breakers, fuses, and ground fault protection of equipment shall be coordinated so that power interruption in that part of the circuit that precedes the interrupting device closest to a fault shall not occur.

(2) If used, ground-fault circuit interrupters (GFCIs) shall be approved for the purpose.

NOTE: Listed Class A ground-fault circuit interrupters trip when a fault current to ground is 6 mA or more.

(e) *Wiring in Anesthetizing Locations.*

(1) All Anesthetizing Locations.

(i) Wiring. Installed wiring shall be in metal raceway or shall be as required in NFPA 70, *National Electrical Code*, Sections 517-60 through 517-63.

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

(iii) Grounding to Raceways. Each device connected to the distribution system shall be effectively grounded to the metal raceway at the device.

(iv) Installation. Methods of installation shall conform to Articles 250 and 517 of NFPA 70, *National Electrical Code.*

(v) General Purpose. A general-purpose lighting circuit connected to the normal grounded service shall be installed in each operating room.

Exception: Where connected to any alternate source permitted in NFPA 70, Section 700-12, that is separate from the source serving the emergency system.

(2) Flammable Anesthetizing Locations. Electric wiring 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.

3-4.1.2.2 Wiring, Low-Voltage.

(a) Fixed systems of 30 V (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.

(b) 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 12-4.1.3.*)

3-4.1.2.3 Switches.

(a) *Anesthetizing Locations.*

(1) Switches controlling ungrounded circuits within or partially within an inhalation anesthetizing location shall have a disconnecting pole for each conductor.

(2) 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.*

3-4.1.2.4 Receptacles.

(a)* *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.

(b) *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.

(1) Receptacles for Patient Bed Locations in General Care Areas: Each patient bed location shall be provided with a minimum of four receptacles.

(2) Receptacles for Patient Bed Locations in Critical Care Areas: Each patient bed location shall be provided with a minimum of six receptacles.

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.

(c) *Polarity of Receptacles.* Each receptacle shall be wired in accordance with NFPA 70, *National Electrical Code*, to ensure correct polarity.

(d) *Anesthetizing Location Receptacles.* Receptacles for use in nonflammable anesthetizing locations and nonhazardous areas of flammable anesthetizing locations shall be listed for the use.

In nonflammable anesthetizing locations of new and existing construction having receptacles on isolated and grounded power, all receptacles shall be identified as to whether they are on isolated or grounded power.

(e) *Receptacles and Amperage.* 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 receptacles shall be of the two-pole, three-wire design with the third contact connecting to the (green or green with yellow stripe) grounding wire of the electric system.

(f) *Other Services Receptacles.* 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.

(g) *Hazardous Area Receptacles.* Receptacles 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 the "on" position.

NOTE: It should be recognized that any interruption of the circuit, even of circuits as low as 8 volts, either by any switch or by loose or defective connections anywhere in the circuit, may produce a spark sufficient to ignite a flammable anesthetic agent.

(h) *Plugs and Receptacles.* Nonexplosionproof plugs shall not engage, or 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 that can also mate with the nonexplosionproof receptacles in nonhazardous areas.

3-4.1.2.5 Special Grounding.

(a) *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.

(b) *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 care vicinity.

(c) *Special Grounding in Patient Care Areas.* In addition to the grounding required to meet the performance requirements of 3-5.2.1, additional grounding shall be permitted where special circumstances so dictate. (*See A-3-2, "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 3-5.2.1 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.

3-4.1.2.6 Wet Locations.

(a) Wet location patient care areas shall be provided with special protection against electric shock. This special protection shall be provided by a power distribution system that 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.

NOTE: Moisture may reduce the contact resistance of the body, and electrical insulation is more subject to failure.

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 3-4.1.2.6(a) are not required when 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:

(1) when first installed,

(2) where there is evidence of damage,

(3) after any repairs, or

(4) at intervals not exceeding 6 months.

(b) 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 3-4.3.

(c) Where power interruption under first fault condition (line-to-ground fault) is tolerable, the use of a ground-fault circuit interrupter (GFCI) shall be permitted as the protective means that monitors the actual ground fault current and interrupts the power when that current exceeds 6 mA.

3-4.1.2.7 Isolated Power. An isolated power system is not required to be installed in any patient care area except as specified in 12-4.1, "Anesthetizing Locations." The system shall be permitted to be installed, however, and when installed, shall conform to the performance requirements specified in 3-4.3.

3-4.1.3 Laboratories. 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 installation is to be at least 3.15 in. (8 cm) above the countertop.

3-4.1.4 Other Nonpatient Areas. (Reserved)

3-4.1.5 Ground-Fault Protection. When ground-fault protection is provided for operation of the service or feeder disconnecting means, an additional step of ground-fault protection shall be provided in the next level of feeder downstream toward the load. Ground-fault protection for operation of the service and feeder disconnecting means shall be fully selective such that the *downstream* device and not the *upstream* device shall open for downstream ground faults. The additional step of ground-fault protection shall not be required where the service or feeder disconnecting means does not serve patient care areas or equipment intended to support life, such as clinical air compressors and vacuum pumps. When equipment ground-fault protection is first installed, each level shall be performance tested to ensure compliance with the above.

3-4.2 Essential System.

NOTE: It 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 that 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 hygenic procedures are performed, only remote corridor lighting for purposes of egress would be sufficient. Emergency power for equipment would not be necessary. As with oral surgery locations, a surgical clinic requiring use of life support or emergency devices such as suction machines, ventilators, cauterizers, or defibrillators would require both emergency light and power.

3-4.2.1 General.

3-4.2.1.1† Electrical characteristics of the transfer switches shall be suitable for the operation of all functions and equipment they are intended to supply. [110: 4-1.1]

3-4.2.1.2† Switch Rating. The rating of the transfer switches shall be adequate for switching all classes of loads to be served and for withstanding the effects of available fault currents without contact welding. [110: 4-2.1]

3-4.2.1.3 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.

3-4.2.1.4† Automatic Transfer Switch Features. [110: 4-2.4]

(a) *General.* Automatic transfer switches shall be electrically operated and mechanically held. The transfer switch shall transfer and retransfer the load automatically.

Exception: It shall be permitted to program the transfer switch (i) for a manually initiated retransfer to the normal source, or (ii) for an automatic intentional "off" delay, or (iii) for an in-phase monitor relay or similar automatic delay method, 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 fails and the normal source is available.

(b) *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.

(c)* *Voltage Sensing.* Voltage sensing devices shall be provided to monitor all ungrounded lines of the normal source of power.

(d) *Time Delay on Starting of Alternate Power Source.* A time delay device shall 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.

(e) *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.

(f)* *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 3-4.2.1.4(a).

(g)* *Test Switch.* A test switch shall be provided on each automatic transfer switch that will simulate a normal power source failure to the switch.

(h)* *Indication of Switch Position.* Two pilot lights, properly identified, shall be provided to indicate the transfer switch position.

(i) *Manual Control of Switch.* A means for the safe manual operation of the automatic transfer switch shall be provided.

(j) *Time Delay on Engine Shutdown.* A time delay of 5 minutes minimum to allow engine cooldown shall be provided for unloaded running of the alternate power source generator set prior to shutdown.

Exception: Time delay need not be provided on small (15 kW or less) aircooled prime movers or if included with the engine control panel. [110: 4-2.4.8]

(k)* *Motor Load Transfer.* Provisions shall be included to reduce excessive currents resulting from motor load transfer if such currents may damage essential electrical system equipment or cause nuisance tripping of essential electrical system overcurrent protective devices. [110:4-2.4.12]

(l) *Isolation of Neutral Conductors.* Provisions shall be included for ensuring proper continuity, transfer, and isolation of the normal and the alternate power source neutral conductors whenever they are separately grounded, if needed, to achieve proper ground-fault sensing. [*See NFPA 70, National Electrical Code, Section 230-95(b).*] [110: 4-2.4.13]

3-4.2.1.5 Nonautomatic Transfer Device Classification. Nonautomatic transfer devices shall be approved for emergency electrical service (*see NFPA 70, National Electrical Code, Section 700-3*).

3-4.2.1.6† Nonautomatic Transfer Device Features. [110: 4-2.5]

(a) *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.

(b) *Interlocking.* Reliable mechanical interlocking, or an approved alternate method, shall be inherent in the design in order to prevent the unintended interconnection of the normal and alternate sources of power, or of any two separate sources of power.

(c) *Indication of Switch Position.* Pilot lights, properly identified, shall be provided to indicate the switch position.

3-4.2.1.7† Bypass-Isolation Switches. [110: 4-4.1] Bypass-isolation switches shall be permitted for bypassing and isolating the transfer switch. If installed, they shall be in accordance with the following:

(a) *Bypass-Isolation Switch Rating.* The bypass-isolation switch shall have a continuous current rating and withstand current rating compatible with that of the associated transfer switch.

(b) *Bypass-Isolation Switch Classification.* Each bypass-isolation switch shall be listed for emergency electrical service as a completely factory-assembled and tested apparatus. (*See NFPA 70, National Electrical Code, Section 700-3.*)

(c)* *Operation.* With the transfer switch isolated or disconnected or both, means shall be provided so the bypass-isolation switch can function as an independent nonautomatic transfer switch and allow the load to be connected to either power source. Reconnection of the transfer switch shall be possible with a load interruption no greater than the maximum time in seconds by the type of essential electrical system.

3-4.2.2 Essential Electrical Distribution Requirements — Type I Systems.

3-4.2.2.1* General. Type I essential electrical systems 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 facility 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-3.1*).

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 Type I 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 facility with a maximum demand on the essential electrical system of 150 kVA (120 kW).

NOTE: In 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 tradeoffs among reliability, transfer switch and generator load characteristics, maintainability, and cost.

3-4.2.2.2 Emergency System.

(a) *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 3-4.2.2.2(b) and (c).

(b) *Life Safety Branch.* The life safety branch of the emergency system shall supply power for the following lighting, receptacles, and equipment:

(1) Illumination of means of egress as required in NFPA *101, Life Safety Code.*

(2) Exit signs and exit direction signs required in NFPA *101, Life Safety Code.*

(3) Alarm and alerting systems including:

(i) Fire alarms.

(ii) Alarms required for systems used for the piping of nonflammable medical gases as specified in Chapter 4, "Gas and Vacuum Systems."

(4)* Hospital communication systems, where used for issuing instruction during emergency conditions.

(5) Task illumination, battery charger for emergency battery-powered lighting unit(s), and selected receptacles at the generator set location.

(6) Elevator cab lighting, control, communication, and signal systems.

No function other than those listed above in items (1) through (6) shall be connected to the life safety branch.

Exception: The auxiliary functions of fire alarm combination systems complying with NFPA 72 shall be permitted to be connected to the life safety branch.

(c)* *Critical Branch.* The critical branch of the emergency system shall supply power for task illumination, fixed equipment, selected receptacles, and selected power circuits serving the following areas and functions related to patient care. It shall be permitted to subdivide the critical branch into two or more branches.

(1) Critical care areas that utilize anesthetizing gases — task illumination, selected receptacles, and fixed equipment.

(2) The isolated power systems in special environments.

(3) Patient care areas — task illumination and selected receptacles in:

(i) Infant nurseries.

(ii) Medication preparation areas.

(iii) Pharmacy dispensing areas.

(iv) Selected acute nursing areas.

(v) Psychiatric bed areas (omit receptacles).

(vi) Ward treatment rooms.

(vii) Nurses' stations (unless adequately lighted by corridor luminaires).

(4) Additional specialized patient care task illumination and receptacles, where needed.

(5) Nurse call systems.

(6) Blood, bone, and tissue banks.

(7)* Telephone equipment rooms and closets.

(8) Task illumination, selected receptacles, and selected power circuits for:

(i) General care beds (at least one duplex receptacle per patient bedroom).

(ii) Angiographic labs.

(iii) Cardiac catheterization labs.

(iv) Coronary care units.

(v) Hemodialysis rooms or areas.

(vi) Emergency room treatment areas (selected).

(vii) Human physiology labs.

(viii) Intensive care units.

(ix) Postoperative recovery rooms (selected).

(9) Additional task illumination, receptacles, and selected power circuits needed for effective facility operation. Single-phase fractional horsepower exhaust fan motors that 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 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.

3-4.2.2.3 Equipment System.

(a) *General.* The equipment system shall be connected to equipment described in 3-4.2.2.3(c) and (d).

(b) *Connection to Alternate Power Source.* The equipment system shall be installed and connected to the alternate power source, such that equipment described in 3-4.2.2.3(c) 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 3-4.2.2.3(d) by either delayed-automatic or manual operation.

(c) *Equipment for Delayed-Automatic Connection.* The following equipment shall be arranged for delayed-automatic connection to the alternate power source:

NOTE: The equipment in 3-4.2.2.3(c)(1) through (3) may be arranged for sequential delayed-automatic action to the alternate power source to prevent overloading the generator where engineering studies indicate that it is necessary.

(1) Central suction systems serving medical and surgical functions, including controls. It shall be permitted to place such suction systems on the critical branch.

(2) Sump pumps and other equipment required to operate for the safety of major apparatus, including associated control systems and alarms.

(3) Compressed air systems serving medical and surgical functions, including controls.

(4) Smoke control and stair pressurization systems.

(5) Kitchen hood supply and/or exhaust systems, if required to operate during a fire in or under the hood.

(d) *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 [*also see Appendix A-3-4.2.3.3(c)*]:

(1) Heating equipment to provide heating for operating, delivery, labor, recovery, intensive care, coronary care, nurseries, infection/isolation rooms, emergency treatment spaces, 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:

(a) The outside design temperature is higher than +20°F (−6.7°C), or

(b) The outside design temperature is lower than +20°F (−6.7°C) and a selected room(s) is provided for the needs of all confined patients [then only such room(s) need be heated], or

(c) The facility is served by a dual source of normal power as described in 3-3.2.1.1.

NOTE: The outside design temperature is based on the 97½ percent design value as shown in Chapter 24 of the *ASHRAE Handbook of Fundamentals* (1985).

(2) 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 3-4.2.2.2(b)(6).*]

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 are confined between floors.

(3) Supply, return, and exhaust ventilating systems for surgical and obstetrical delivery suites, intensive care, coronary care, nurseries, infection/isolation rooms, emergency treatment spaces, and exhaust fans for laboratory fume hoods, nuclear medicine areas where radioactive material is used, ethylene oxide evacuation, and anesthesia evacuation.

(4) Hyperbaric facilities.

(5) Hypobaric facilities.

(6) Automatically operated doors.

(7) Autoclaving equipment shall be permitted to be arranged for either automatic or manual connection to the alternate source.

(8) Other selected equipment shall be permitted to be served by the equipment system.

NOTE 1: Consideration should be given to selected equipment in kitchens, laundries, and radiology rooms and to selected central refrigeration.

NOTE 2: It is desirable that, where heavy interruption currents can be anticipated, the transfer load can 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.

3-4.2.2.4 Wiring Requirements.

(a) *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.*)

(b) *Receptacles.*

(1) The number of receptacles on a single branch circuit for areas described in 3-4.2.2.2(c)(8) 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.

(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.

NOTE: If color is used to identify these receptacles, the same color should be used throughout the facility.

(c) *Switches.* Switches installed in the lighting circuits connected to the essential electrical system shall comply with Article 700, Section E, of NFPA 70, *National Electrical Code.*

(d) *Mechanical Protection of the Emergency System.* The wiring of the emergency system shall be mechanically protected by raceways, as defined in NFPA 70, *National Electrical Code.*

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 Chapters 7 or 8 of NFPA 70, National Electrical Code.

3-4.2.3 Essential Electrical Distribution Requirements — Type II Systems.

3-4.2.3.1 General. Type II essential electrical systems 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 facility with a maximum demand on the essential electrical system of 150 kVA (120 kW). (*Also see Appendix A-3-4.2.2.1.*)

NOTE: In 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 tradeoffs among reliability, transfer switch and generator load characteristics, maintainability, and cost.

3-4.2.3.2 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 systems, including:

(1) Fire alarms.

(2) Alarms required for systems used for the piping of nonflammable medical gases as specified in Chapter 4, "Gas and Vacuum 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, communication, and signal systems.

No function other than those listed above in items (a) through (g) shall be connected to the emergency system.

3-4.2.3.3 Critical System.

(a) *General.* The critical system shall be so installed and connected to the alternate power source that equipment listed in 3-4.2.3.3(b) 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 3-4.2.3.3(c) by either delayed-automatic or manual operation.

(b) *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:

(1) Patient care areas — task illumination and selected receptacles in:

(i) Medication preparation areas.

(ii) Pharmacy dispensing areas.

(iii) Nurses' stations (unless adequately lighted by corridor luminaires).

(2) Sump pumps and other equipment required to operate for the safety of major apparatus and associated control systems and alarms.

(3) Smoke control and stair pressurization systems.

(4) Kitchen hood supply and/or exhaust systems, if required to operate during a fire in or under the hood.

(c)* *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:

(1) 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:

(i) The outside design temperature is higher than +20°F (−6.7°C), or

(ii) The outside design temperature is lower than +20°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

(iii) The facility is served by a dual source of normal power as described in 3-3.2.1.1.

NOTE: The outside design temperature is based on the 97½ percent design value as shown in Chapter 24 of the *ASHRAE Handbook of Fundamentals* (1985).

(2) 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 3-4.2.3.2(g).*]

(d) *Optional Connections to the Critical System.* Additional illumination, receptacles, and equipment shall be permitted to be connected only to the critical system.

3-4.2.3.4 Wiring Requirements.

(a) *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.

(b) *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.

NOTE: If color is used to identify these receptacles, the same color should be used throughout the facility.

3-4.2.4 Essential Electrical Distribution Requirements — Type III Systems.

3-4.2.4.1 General. Type III essential electrical systems are comprised of 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.

3-4.2.4.2 Connection to the Essential Electrical System. The system shall supply power for task illumination that is related to the safety of life and that is necessary for the safe cessation of procedures in progress.

3-4.2.4.3 Connections to Alternate Source of Power. 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.

3-4.2.4.4 Wiring Requirements.

(a) *General.* The design, arrangement, and installation of the system shall be in accordance with NFPA 70, *National Electrical Code*.

(b) *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.

NOTE: If color is used to identify these receptacles, the same color should be used throughout the facility.

3-4.3* Isolated Power Systems.

3-4.3.1 Isolation Transformer.

3-4.3.1.1 The isolation transformer shall be approved for the purpose.

3-4.3.1.2 The primary winding shall be connected to a power source so that it is not energized with more than 600 V (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.

3-4.3.1.3 Wiring of isolated power systems shall be in accordance with Article 517-62 of NFPA 70, *National Electrical Code*.

3-4.3.2 Impedance of Isolated Wiring.

3-4.3.2.1 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 shall include receptacles but is not required to include lighting fixtures or components of fixtures. This value shall be determined by energizing the system and connecting a low-impedance ac milliammeter (0 to 1 mA scale) between the reference grounding point and either conductor in sequence. This test shall be permitted to be performed with the line isolation monitor (*see 3-4.3.3*) 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 should be determined that no phase conductor is at ground potential.

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 and using insulation with a dielectric constant less than 3.5 and insulation resistance constant greater than 6100 megohmmeters (20,000 megohm-ft) 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 6100 megohmmeters (20,000 megohm-ft) at 60°F (16°C) reduces the monitor hazard current.

NOTE 4: To correct milliammeter reading to line impedance:

$$\text{Line impedance (in ohms)} = \frac{V \times 1000}{I}$$

where V = isolated power system voltage and I = milliammeter reading made during impedance test.

3-4.3.2.2 An approved capacitance suppressor shall be permitted to 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 1 megohm prior to the connection of the suppression equipment. Capacitance suppressors shall be installed so as to prevent inadvertent disconnecton during normal use.

3-4.3.3 Line Isolation Monitor.

3-4.3.3.1 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, which 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.

3-4.3.3.2 The monitor shall be designed such that a green signal lamp, conspicuously visible to persons in the anesthetizing location, remains lighted when the system is adequately isolated from ground; and an 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 mA under normal line voltage conditions. The line isolation monitor shall not alarm for a fault hazard current of less than 3.7 mA.

NOTE: A 120-V (nominal) 60-Hz ac system of moderate ampacity is assumed for the description of the specification of the line isolation monitor in 3-4.3.3.1. If other systems are considered, modifications are required, e.g., for other voltages or frequencies, and installed impedance; sensitivity (alarm) levels remain the same, however.

3-4.3.3.3 The line isolation monitor shall have sufficient internal impedance such that when properly connected to the isolated system, the maximum internal current that will flow through the line isolation monitor, when any point of the isolated system is grounded, shall be 1 mA.

Exception: The line isolation monitor is permitted to 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.

3-4.3.3.4 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 mA) 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 such that it is conspicuously visible to persons in the anesthetizing location.

3-4.3.3.5 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.

3-4.3.3.6 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 the appropriate magnitude to produce a meter reading corresponding to the rated total hazard current at the nominal line voltage, or to a lesser alarm hazard current if the line isolation monitor is so rated. 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.

3-4.3.3.7 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 1000 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 mV when the gain is 10^4. The 1000 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).

3-4.3.4 Identification of Conductors for Isolated (Ungrounded) Systems. The isolated conductors shall be identified in accordance with 517-160(a)(5) of NFPA 70, *National Electrical Code*.

3-5 Performance Criteria and Testing.

3-5.1 Source (Up to and Including Transfer Switch).

3-5.1.1 Normal. (Reserved)

3-5.1.2 Essential.

3-5.1.2.1 Alternate Power Source Requirements.

(a) *Type I Systems.* The branches of the emergency system shall be installed and connected to the alternate power source specified in 3-3.2.1.2 and 3-3.2.1.3 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.

(b) *Type II Systems.* The emergency system shall be installed and connected to the alternate source of power specified in 3-3.2.1.2 and 3-3.2.1.3 so that all functions specified herein for the emergency system will be automatically restored to operation within 10 seconds after interruption of the normal source.

(c) *Type III Systems.*

(1) The emergency system shall have an alternate source of power separate and independent from the normal source that will be effective for a minimum of $1\frac{1}{2}$ hours after loss of the normal source.

NOTE: Consideration should be given to medical procedures that may necessitate emergency power being supplied for more than $1\frac{1}{2}$ hours.

(2) The emergency 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.

3-5.1.2.2 Transfer Switch Operation Requirements.

(a) *Type I System.*

(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.

(2) Failure of the normal source shall automatically start the alternate source generator after a short delay [*see 3-4.2.1.4(d)*]. 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.

(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 3-4.2.1.4(e)*] or nonautomatically and in such a sequential manner as not to overload the generator.

(4) When the normal power source is restored, and after a time delay [*see 3-4.2.1.4(f)*], the automatic transfer switches shall disconnect the alternate source of power and connect the loads to the normal power source. The alternate power source generator set shall continue to run unloaded for a preset time delay [*see 3-4.2.1.4(j)*].

(5) If the emergency power source fails and the normal power source has been restored, retransfer to the normal source of power shall be immediate, bypassing the retransfer delay timer.

(6) If the emergency power source fails during a test, provisions shall be made to immediately retransfer to the normal source.

(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.

(b) *Type II System.*

(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.

(2) Failure of the normal source shall automatically start the alternate source generator, after a short delay [*see 3-4.2.1.4(d)*]. 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.

(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 3-4.2.1.4(e)*] or nonautomatically and in such a sequential manner as not to overload the generator.

(4) When the normal power source is restored, and after a time delay [*see 3-4.2.1.4(f)*], the automatic transfer switches shall disconnect the alternate source of power and connect the loads to the normal power source. The alternate power source generator set shall continue to run unloaded for a preset time delay [*see 3-4.2.1.4(j)*].

(5) If the emergency power source fails and the normal power source has been restored, retransfer to the normal source of power shall be immediate, bypassing the retransfer delay timer.

(6) If the emergency power source fails during a test, provisions shall be made to immediately retransfer to the normal source.

(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.

(c) *Type III Systems with Engine Generator Sets.*

(1) The operation of the equipment shall be arranged such that the load will be served by the normal source except when the normal source is interrupted, or when the voltage drops 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.

(2) When the normal source is restored, and after a time delay [*see 3-4.2.1.4(f)*], the automatic transfer switch shall disconnect the alternate source of power and connect the loads to the normal power source.

(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.

(d) *Type III Systems with Battery Systems.*

(1) Failure of the normal source shall automatically transfer the load to the battery system.

(2) Retransfer to the normal source shall be automatic upon restoration of the normal source.

3-5.2 Distribution.

3-5.2.1 Grounding System in Patient Care Areas.

3-5.2.1.1* 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.

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 or periodically tested.

(b) Whenever the electrical system has been altered or replaced, that portion of the system shall be tested.

NOTE: The grounding system (reference ground and conduit) is to be tested as an integral system. Lifting of grounds from receptacles and fixed equipment is not required or recommended for the performance of this test.

3-5.2.1.2 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, that is electrically remote from receptacles, e.g., 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.

3-5.2.1.3* 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 care 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.

3-5.2.1.4 Impedance Measurements. The impedance measurement shall be made with an accuracy of ± 20 percent.

(a) *New Construction.* The impedance measurement shall be made between the reference point and the grounding contact of each receptacle in the patient care vicinity. The impedance measurement shall be the ratio of the 60-Hz or at dc voltage developed between a point under test and a reference point to 60-Hz or at dc current applied to the point under test.

(b) *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 care 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.

3-5.2.1.5 Test Equipment. Electrical safety test instruments shall be tested periodically, but not less than annually, for acceptable performance.

(a) Voltage measurements specified in 3-5.2.1.3 shall be made with an instrument having an input resistance of 1000 ohms ± 10 percent at frequencies of 1000 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.

3-5.2.1.6 Criteria for Acceptability.

(a) *New Construction.*

(1) Voltage limit shall be 20 mV.

(2) Impedance limit shall be 0.1 ohm.

Exception: For quiet ground systems, the limit shall be 0.2 ohm.

3-5.2.2 Receptacles in Patient Care Areas.

3-5.2.2.1 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 g (4 oz).

3-5.2.3 Ground Fault Circuit Interrupters (GFCIs) in Patient Care Areas.

3-5.2.3.1 Testing. If GFCIs are used, a device or component that causes 6 mA 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.

3-5.2.4 Isolated Power Systems.

3-5.2.4.1 Patient Care Areas. If installed, the isolated power system shall be tested in accordance with 3-5.2.4.2.

3-5.2.4.2 Line Isolation Monitor Tests. The proper functioning of each line isolation monitor (LIM) circuit shall be ensured 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 × V ohms, where V = measured line voltage. The visual and audible alarms (*see 3-4.3.3.2*) shall be activated.

(b) The LIM circuit shall be tested at intervals of not more than 1 month by actuating the LIM test switch (*see 3-4.3.3.6*). 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 6 months, the LIM circuit shall be tested in accordance with paragraph (a) above and only when the circuit is not otherwise in use.

3-6 Administration of Electrical System.

3-6.1 Source.

NOTE: Administration is in conjunction with 3-6.2, "Distribution."

3-6.2 Distribution.

3-6.2.1 Responsibilities of Governing Body.

NOTE: See 12-2, 13-2, etc., for responsibilities within specific facilities.

3-6.2.2 Policies. (Reserved)

3-6.2.3 Maintenance and Testing of Normal Electrical System.

3-6.2.3.1 Testing Interval for Receptacles in Patient Care Areas. Testing shall be performed no less frequently than as listed below.

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.

3-6.2.3.2 Criteria for Acceptability of Existing Grounding Systems.

(a) The voltage limit shall be:

(1) 500 mV for general care 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 indicate a deteriorating condition and should be investigated.

(b) The impedance limit shall be 0.2 ohm.

3-6.2.3.3 Testing Interval for GFCIs in Patient Care Areas. Testing shall be performed no less frequently than every 12 months.

3-6.2.4 Maintenance and Testing of Essential Electrical System.

3-6.2.4.1 Maintenance and Testing of Alternate Power Source and Transfer Switches.

(a) *Maintenance of 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 3-3.2.1.8, 3-5.1.2.1(a), 3-5.1.2.1(b), and 3-5.1.2.1(c)(2).

(b) *Inspection and Testing.*

(1)* Test Interval and Load. Generator sets serving emergency and equipment systems shall be inspected weekly and shall be exercised under at least 50 percent rated load at operating temperatures for at least 30 minutes at intervals of not more than 30 days.

NOTE: Records of changes to the essential electrical system should be maintained so that the actual demand likely to be produced by the connected load will be within the available capacity.

(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 system loads.

(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.

3-6.2.4.2 Maintenance and Testing of Circuitry.

(a) *Circuit Breakers.* Main and feeder circuit breakers shall be exercised annually.

NOTE: Main and feeder circuit breakers should be periodically tested under simulated overload trip conditions to ensure reliability (*see Appendix C-3.2*).

(b) *Insulation Resistance.* The resistance readings of main feeder insulation shall be taken prior to acceptance and whenever damage is suspected.

3-6.2.4.3 Maintenance of Batteries. Storage batteries used in connection with essential electrical systems shall be inspected at intervals of not more than 7 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*).

3-6.2.5 Recordkeeping.

3-6.2.5.1* Normal Electrical Distribution System. A record shall be maintained of the tests required by this chapter 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 chapter.

3-6.2.5.2 Essential Electrical Distribution System. 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-3 for general maintenance guide.*)

3-6.2.5.3 Isolated Power System (Where Installed). A permanent record shall be kept of the results of each of the tests.

3-6.2.6 Information and Warning Signs. (Reserved)

Chapter 4 Gas and Vacuum Systems

NOTE 1: The application of requirements contained in this chapter for specific types of health care facilities can be found in Chapters 12 through 18.

NOTE 2: Gases covered include, but are not limited to, oxygen, nitrogen, nitrous oxide, air, carbon dioxide, natural gas, ethylene oxide, hydrogen, helium, and acetylene.

NOTE 3: Sections 4-3 through 4-6 cover requirements for pressurized centrally piped gas systems; Sections 4-7 through 4-11 cover requirements for centrally piped vacuum systems.

4-1 Scope.

4-1.1 This chapter covers the performance, maintenance, installation, and testing of (1) nonflammable medical gas systems with operating pressures below 300 psig (2068 kPa), (2) flammable and nonflammable laboratory gas systems, and (3) vacuum systems used within health care facilities.

NOTE: Operation of piped medical gas systems at pressures in excess of 200 psig (1380 kPa) involves certain restrictions because of the limitations in materials. (*See 4-4.1.2.1.*)

4-1.2 Wherever the term medical gas occurs in this chapter, the provisions shall apply to all patient gas systems. Wherever the name of a specific gas occurs, the provision applies only to that gas.

4-1.3 This chapter does not apply to portable compressed gas systems.

4-1.4 This chapter applies only to permanently installed, fixed medical-surgical vacuum systems where such systems are intended for patient drainage, aspiration, and suction and, under the conditions set forth in 4-8.2.1, for medical laboratory use. This chapter does not apply to water aspirator systems that dispose of drainage directly into sanitary sewers. This chapter does not cover suction apparatus or appliances attached to the vacuum system terminals (inlets).

4-2 Nature of Hazards.

4-2.1 Gas Systems.

NOTE: See Section 8-2.

4-2.2 Vacuum Systems. There are potential fire and explosion hazards associated with medical gas central piping systems and 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 conditions that should be properly addressed. While the potential for these problems exists, the Subcommittee on Vacuum Systems and Equipment 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 Sections 4-3 through 4-6.

NOTE: Sections 4-3 through 4-6 cover requirements for pressurized centrally piped gas systems; Sections 4-7 through 4-11 cover requirements for centrally piped vacuum systems.

4-3 Gas System Sources.

4-3.1 Patient Gas Supply — Type I.

NOTE: For bulk oxygen systems, see NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites.*

4-3.1.1 Cylinder and Container Management.

4-3.1.1.1 Cylinders or supply containers shall be constructed, tested, and maintained in accordance with the U.S. Department of Transportation specifications and regulations.

NOTE: Regulations of the U.S. Department of Transportation (formerly U.S. 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.

4-3.1.1.2 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 CGA Pamphlet C-4, *Standard Method of Marking Portable Compressed Gas Containers to Identify the Material Contained.*

4-3.1.1.3 Contents of cylinders and containers shall be identified by reading the labels prior to use. Labels shall not be defaced, altered, or removed.

4-3.1.2 Storage Requirements (Location, Construction, Arrangement).

4-3.1.2.1 Nonflammable Gases (Any Quantity; In-Storage, Connected, or Both).

NOTE: This includes oxidizing gases.

(a) 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°C). Care shall be exercised when handling cylinders that have been exposed to freezing temperatures or containers that contain cryogenic liquids to prevent injury to the skin.

(b) Enclosures shall be provided for supply systems cylinder storage or manifold locations for oxidizing agents

such as oxygen and nitrous oxide. Such enclosures shall be constructed of an assembly of building materials with a fire-resistive rating of at least 1 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 that 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 4-3.1.2.4(d)*].

(c) Provisions shall be made for racks or fastenings to protect cylinders from accidental damage or dislocation.

(d) 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.

(e) Storage locations for oxygen and nitrous oxide shall be kept free of flammable materials [*see also 4-3.1.2.1(g)*].

(f) Cylinders containing compressed gases and containers for volatile liquids shall be kept away from radiators, steam piping, and like sources of heat.

(g) Combustible materials, such as paper, cardboard, plastics, and fabrics shall not be stored or kept near supply system cylinders or manifolds containing oxygen or nitrous oxide. Racks for cylinder storage shall be permitted to be of wooden construction. Wrappers shall be removed prior to storage.

Exception: Shipping crates or storage cartons for cylinders.

(h) When cylinder valve protection caps are supplied, they shall be secured tightly in place unless the cylinder is connected for use.

(i) Containers shall not be stored in a tightly closed space such as a closet [*see 8-2.1.2.3(c)*].

(j) *Location of Supply Systems.*

(1) Except as permitted by 4-3.1.2.1(j)(2), supply systems for medical gases or mixtures of these gases having total capacities (connected and in storage) not exceeding the quantities specified in 4-3.1.2.2(a) and (b) shall be located outdoors in an enclosure used only for this purpose or in a room or enclosure used only for this purpose situated within a building used for other purposes.

(2) Locations for supply systems shall not be used for storage purposes other than for containers of nonflammable gases. Storage of full or empty containers shall be permitted. Other nonflammable medical gas supply systems or storage locations shall be permitted to be in the same location with oxygen or nitrous oxide or both. However, care shall be taken to provide adequate ventilation to dissipate such other gases in order to prevent the development of oxygen-deficient atmospheres in the event of functioning of cylinder or manifold pressure-relief devices.

(3) Medical air compressors and vacuum pumps shall be located separately from cylinder gas systems or cylinder storage enclosures. Medical air compressors shall be installed in a designated mechanical equipment area, adequately ventilated and with required services.

(k) *Construction and Arrangement of Supply System Locations.*

(1) Walls, floors, ceilings, roofs, doors, interior finish, shelves, racks, and supports of and in the locations cited in 4-3.1.2.1(j)(1) shall be constructed of noncombustible or limited-combustible materials.

(2) Locations for supply systems for oxygen, nitrous oxide, or mixtures of these gases shall not communicate with anesthetizing locations or storage locations for flammable anesthetizing agents.

(3) Enclosures for supply systems shall be provided with doors or gates that can be locked.

(4) Ordinary electrical wall fixtures in supply rooms shall be installed in fixed locations not less than 5 ft (1.5 m) above the floor to avoid physical damage.

(5) When enclosures (interior or exterior) for supply systems are located near sources of heat, such as furnaces, incinerators, or boiler rooms, they shall be of construction that protects cylinders from reaching temperatures exceeding 130°F (54°C). Open electrical conductors and transformers shall not be located in close proximity to enclosures. Such enclosures shall not be located adjacent to storage tanks for flammable or combustible liquids.

(6) Smoking shall be prohibited in supply system enclosures.

(7) Heating shall be by steam, hot water, or other indirect means. Cylinder temperatures shall not exceed 130°F (54°C).

4-3.1.2.2 Additional Storage Requirements for Nonflammable Gases *Greater* than 3000 cu ft (85 m^3).

(a) Oxygen supply systems or storage locations having a total capacity of more than 20,000 cu ft (566 m^3) (NTP), including unconnected reserves on hand at the site, shall comply with NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites.*

(b) Nitrous oxide supply systems or storage locations having a total capacity of 3200 lb (1452 kg) [28,000 cu ft (793 m^3) (NTP)] or more, including unconnected reserves on hand at the site, shall comply with CGA Pamphlet G-8.1, *Standard for the Installation of Nitrous Oxide Systems at Consumer Sites.*

(c) The walls, floors, and ceilings of locations for supply systems of more than 3000 cu ft (85 m^3) total capacity (connected and in storage) separating the supply system location from other occupancies in a building shall have a fire-resistance rating of at least 1 hour. This shall also apply to a common wall or walls of a supply system location attached to a building having other occupancy.

(d) Locations for supply systems of more than 3000 cu ft (85 m^3) total capacity (connected and in storage) shall be vented to the outside by a dedicated mechanical ventilation system or by natural venting. If natural venting is used, the vent opening or openings shall be a minimum of 72 sq in. (0.05 m^2) in total free area.

4-3.1.2.3 Additional Storage Requirements for Nonflammable Gases *Less* than 3000 cu ft (85 m^3). Doors to such locations shall be provided with louvered openings having a minimum of 72 sq in. (0.05 m^2) in total free area. Where the location of the supply system door opens onto an exit access corridor, (a) the requirements of 4-3.1.2.2(c) and 4-3.1.2.2(d) shall be complied with; or (b) the door shall have louver opening(s) with a minimum of 72 sq in. (0.05 m^2) in total free area, and with fire damper(s) of appropriate rating; or (c) the wall of the location shall be provided with a louver opening(s) with a minimum of 72 sq in. (0.05 m^2) in total free area, and with fire damper(s) of appropriate rating.

4-3.1.2.4 Flammable Inhalation Anesthetic Agents (Any Quantity; In-Storage, Connected, or Both).

(a) 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 shall be permitted to 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 reentry into the building.

(b) Exhaust fans shall have nonsparking blades. The fan motor shall be connected into the equipment system (either automatic or delayed restoration) (*see Chapter 3, "Electrical Systems"*). 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, Division 2, Group C locations. A visual signal that 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.

(c) Approved fire dampers shall be installed in openings through the required fire partition in accordance with the requirements of NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*.

(d) Enclosures shall not be used for purposes other than storage of flammable inhalation anesthetic agents.

(e) Flooring shall comply with 12-4.1.3.8(b)(1).

(f) Electric wiring and equipment in storage locations for flammable inhalation 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, Division 1, Group C hazardous areas (*see 3-5.2.1 for grounding requirements*).

(g) The provisions of 12-4.1.3.2 for ungrounded electric distribution systems do not apply to storage locations for flammable agents.

(h) Storage locations for flammable anesthetics shall meet the construction requirements stated in 4-3.1.2.1(b) and (c), and shall be ventilated as provided in 4-3.1.2.4(a).

(i) Flammable inhalation anesthetizing agents shall be stored only in such locations. Flammable inhalation anesthetizing agents shall not be stored in anesthetizing locations, except for cylinders of flammable anesthetic agents connected to a gas anesthesia apparatus.

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

(k) Storage locations for flammable inhalation agents shall be kept free of cylinders of nitrous oxide, compressed air, oxygen, and mixtures of oxygen.

(l) Sources of illumination and ventilation equipment in storage locations for flammable inhalation anesthetic agents, wherever located, and especially in storage locations that 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.

4-3.1.3 Material — Oxygen Compatibility.

4-3.1.3.1 Oxygen system components, including, but not limited to, containers, valves, valve seats, lubricants, fittings, gaskets, and interconnecting equipment including hoses, shall have adequate compatibility with oxygen under the conditions of temperature and pressure to which the components may be exposed in the containment and use of oxygen. Easily ignitible materials shall be avoided unless they are parts of equipment or systems that are approved, listed, or proved suitable by tests or by past experience.

NOTE 1: Compatibility involves both combustibility and ease of ignition. Materials that burn in air will burn violently in pure oxygen at normal pressure and explosively in pressurized oxygen. Also, many materials that do not burn in air will do so in pure oxygen, particularly under pressure. Metals for containers and piping must be carefully selected, depending on service conditions. The various steels are acceptable for many applications, but some service conditions may call for other materials (usually copper or its alloys) because of their greater resistance to ignition and lower rate of combustion.

NOTE 2: Similarly, materials that can be ignited in air have lower ignition energies in oxygen. Many such materials may be ignited by friction at a valve seat or stem packing or by adiabatic compression produced when oxygen at high pressure is rapidly introduced into a system initially at low pressure.

4-3.1.3.2 The provisions of 4-3.1.3.1 also apply to nitrous oxide, oxygen-nitrous oxide mixtures, and to other medical gas mixtures containing more than 23.5 percent oxygen.

4-3.1.4 Gas Central Supply Systems. The central supply system shall be a system of cylinders and necessary supply equipment assembled as described in either 4-3.1.5 or 4-3.1.6, or a bulk supply system (*see 4-3.1.7*), which may be of the permanently installed type or the trailer type. The medical compressed air source, in addition to the preceding, is permitted to be two or more compressors that

deliver medical compressed air and that comply with 4-3.1.2.2(b), 4-3.1.9, and 4-3.1.2.1(j)(2).

4-3.1.5 Cylinder Systems without Reserve Supply. *(See Figure 4-3.1.5 and Appendixes C-4.1 and C-4.2.)*

4-3.1.5.1 A cylinder manifold shall have two banks (or units) of cylinders that alternately supply the piping system, each bank having a pressure regulator and cylinders connected to a common header. Each bank shall contain a minimum of two cylinders or at least an average day's supply unless normal delivery schedules require a greater supply. When the content of the primary bank is unable to supply the system, the secondary bank shall automatically operate to supply the system. An actuating switch shall be connected to the master signal panels to indicate when, or just before, the changeover to the secondary bank occurs.

4-3.1.5.2 A check valve shall be installed between each cylinder lead and the manifold header to prevent the loss of gas from the manifolded cylinders in the event the pressure relief device on an individual cylinder functions or a cylinder lead (pigtail) fails. The check valve shall be of a material suitable for the gases and pressures involved.

4-3.1.6 Cylinder Supply Systems with Reserve Supply. *(See Figure 4-3.1.6 and Appendixes C-4.1 and C-4.2.)*

4-3.1.6.1 A cylinder supply system with reserve supply shall consist of:

(a) A primary supply, which supplies the piping system.

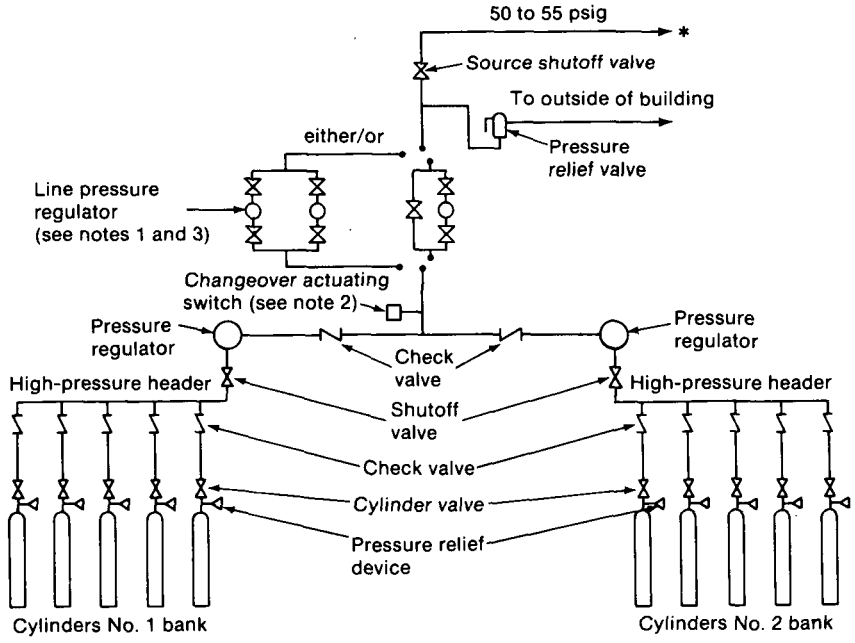
(b) A secondary supply, which shall operate automatically when the primary supply is unable to supply the system. An actuating switch shall be connected to the master signal panels to indicate when, or just before, the changeover to the secondary bank occurs.

(c) A reserve supply, which shall operate automatically in the event that both the primary and secondary supplies are unable to supply the system. An actuating switch shall be connected to the master signal panels to indicate when, or just before, the reserve begins to supply the piping system.

4-3.1.6.2 The reserve supply shall consist of three or more manifolded high-pressure cylinders connected as required under 4-3.1.8.2, and either shall be equipped with check valves as required in 4-3.1.5.2 or shall be provided with an actuating switch that shall operate the master signals when the reserve supply drops to one day's supply. *(See Appendixes C-4.1 and C-4.2.)*

4-3.1.6.3 A cryogenic liquid storage vessel shall be installed either as indicated in Figure 4-3.1.6, or as indicated in Figure 4-3.1.5 with the addition of a reserve supply connected as shown in Figure 4-3.1.6. *(See Appendixes C-4.1 and C-4.2.)*

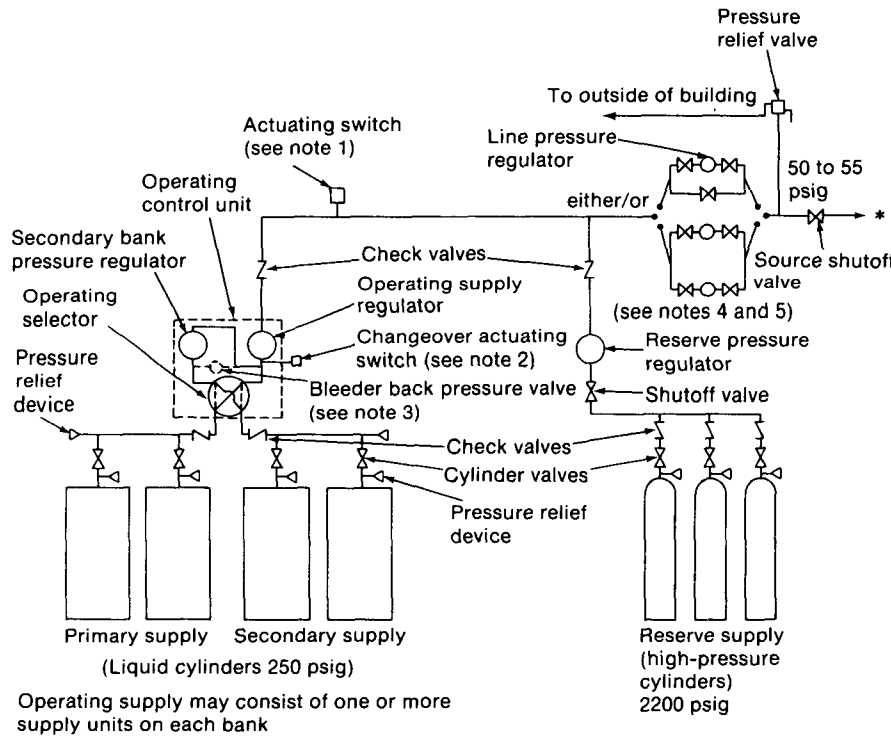
4-3.1.6.4 When cryogenic liquid storage vessels are designed to prevent the loss of the gas produced by the evaporation of the cryogenic liquid in the secondary supply, they shall be designed so that the gas produced shall pass through the line pressure regulator before entering the piped distribution system.



For SI Units: 1 psig = 6.895 kPa gauge.
*Piping system continued on Figure 4-4.1.

NOTE 1: See 4-3.1.8.5.
NOTE 2: See 4-4.1.1.2(b).
NOTE 3: See 4-3.1.8.7.

Figure 4-3.1.5 Typical cylinder supply system without reserve supply (schematic). Supply systems with different arrangements of valves and regulators are permissible if they provide equivalent safeguards. (Type I Gas Systems)



For SI Units: 1 psig = 6.895 kPa gauge.
*Supply piping system continued on Figure 4-4.1.
NOTE 1: See 4-4.1.1.2(c).
NOTE 2: See 4-4.1.1.2(b).
NOTE 3: See 4-3.1.6.4.
NOTE 4: See 4-3.1.8.3.
NOTE 5: See 4-3.1.8.7.

Figure 4-3.1.6 Typical cylinder supply system with reserve supply (schematic). Supply systems with different arrangements of valves and regulators are permissible if they provide equivalent safeguards. (Type I Gas Systems)

4-3.1.6.5 Cryogenic liquid storage vessels shall be constructed to withstand high pressure [2200 psig (15.2 MPa gauge)] or shall be provided with suitable pressure relief devices upstream of the control unit.

4-3.1.6.6 Cylinder supply systems designed in accordance with 4-3.1.6 do not require check valves between each cylinder lead and the manifold header on the primary and secondary supplies.

4-3.1.7* Bulk Medical Gas Systems. (*See Figure 4-3.1.7 and Appendixes C-4.1 and C-4.2.*)

4-3.1.7.1 The bulk system shall consist of two sources of supply, one of which shall be a reserve supply for use only in an emergency. An actuating switch shall be connected to the master signal panels to indicate when, or just before, the reserve begins to supply the system. There are two types of bulk supply systems:

(a) The alternating type with two or more units alternately supplying the piping system. When the primary supply is unable to supply the bulk system, the secondary supply automatically becomes the primary supply and a new secondary supply, not the reserve supply, is connected when or before this changeover takes place. An actuating switch shall be connected to the master signal panels to indicate when, or just before, the changeover occurs.

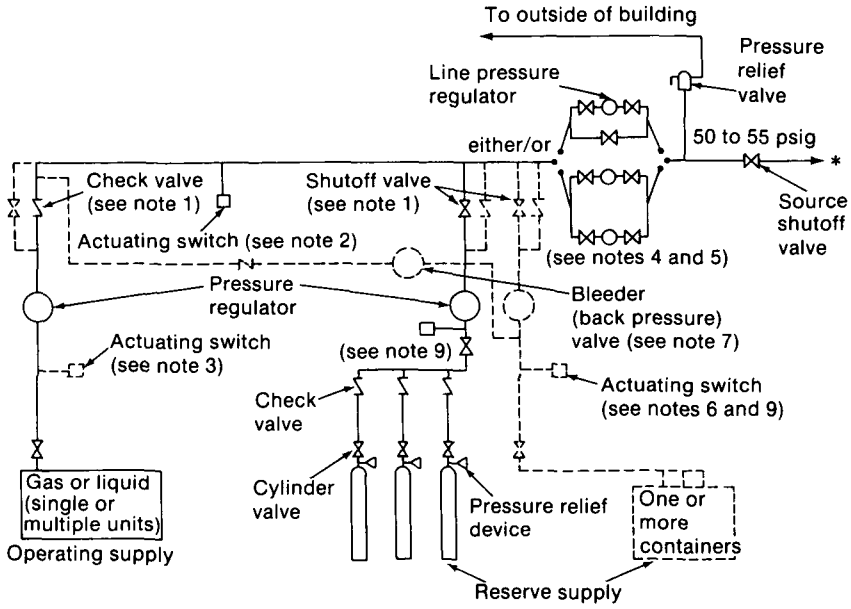
(b) The continuous type with one or more units continuously supplying the piping system while another unit remains as the reserve supply and operates only in case of an emergency.

4-3.1.7.2 The secondary supply and the reserve supply referred to in 4-3.1.7.1 shall each contain at least an average day's supply and shall consist of:

(a) Three or more manifolded high-pressure cylinders connected as required under 4-3.1.5.1 and 4-3.1.8.2; or

(b) High-pressure cylinders without check valves provided an actuating switch, which shall operate the master alarm signal when the reserve supply is down to one day's average supply, is installed; or

(c) A cryogenic liquid storage unit used as the reserve for a bulk supply system provided with an actuating switch that shall operate the master alarm signal when the contents of the reserve are reduced to one day's average supply, and another actuating switch that shall operate the master alarm signal if the gas pressure available in the reserve unit is reduced below the pressure required to function properly. It shall also be designed to prevent the loss of gas produced by the evaporation of the cryogenic liquid in the reserve and so that the gas produced shall pass through a line pressure regulator before entering the piped distribution system.



For SI Units: 1 psig = 6.895 kPa gauge.
*Piping system continued on Figure 4-4.1.
NOTE 1: See 4-3.1.8.4.
NOTE 2: See 4-4.1.1.2(c).
NOTE 3: See 4-4.1.1.2(b).
NOTE 4: See 4-3.1.8.3.
NOTE 5: See 4-3.1.8.7.
NOTE 6: See 4-4.1.1.2(d).
NOTE 7: See 4-3.1.7.2(c).
NOTE 8: Dotted lines are alternates.
NOTE 9: See 4-4.1.1.2(e).

Figure 4-3.1.7 Typical bulk supply system (schematic). Bulk supply systems with different arrangements of valves, regulators, and gas supply units are permissible if they provide equivalent safeguards. The reserve supply shown in dotted lines indicates the arrangements outlined in 4-3.1.7.2(b) or (c). (Type I Gas Systems)

4-3.1.8 General Requirements for Gas Central Supply Systems.

4-3.1.8.1 Cylinders. Cylinders shall be designed, constructed, tested, and maintained in accordance with 4-3.1.1.1. Cylinders in service shall be adequately secured. Cylinders in storage shall be secured and located to prevent them from falling or being knocked over.

4-3.1.8.2 Manifolds. Manifolds shall be of substantial construction and of a design and materials suitable for the gases and pressures involved. Mechanical means shall be provided to ensure the connection of cylinders containing the proper gas to the manifold. Cylinder valve outlets and manifold or regulator inlet connections shall comply with the CGA Pamphlet V-1, *Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections* (ANSI B57.1, CGA B96). When any nonflammable medical gases or gas mixtures are to be piped, care shall be taken to ensure noninterchangeability of cylinders or equipment. Manifolds shall be obtained from and installed under the supervision of a manufacturer or supplier familiar with proper practices for their construction and use.

4-3.1.8.3 Pressure Regulation. Pressure-regulating equipment shall be installed in the supply main upstream of the final line-pressure relief valve (*see 4-3.1.8.5*). Where multiple piping systems for the same gas at different operating pressures are required, separate pressure-regulating equipment, relief valves, and source shutoff valves shall be provided for each pressure.

4-3.1.8.4 Shutoff Valves. A manually operated shutoff valve shall be installed upstream of each pressure regulator, and a shutoff valve or a check valve shall be installed downstream.

4-3.1.8.5 Pressure Relief Valves. Each central supply system shall have a pressure relief valve set at 50 percent above normal line pressure, installed downstream of the pressure regulator and upstream of any shutoff valve. This pressure relief valve shall be permitted to be set at a higher pressure, provided another pressure relief valve set at 50 percent above normal line pressure is installed in the main supply line. All pressure relief valves shall close automatically when excess pressure has been released. Pressure relief valves set at 50 percent above normal line pressure shall be vented to the outside if the total capacity of the supply system is in excess of 2000 cu ft (57 m^3) of gas. Pressure relief valves shall be of brass or bronze and specially designed for the gas service involved.

(a) The pressure relief valve downstream of the line pressure regulator in nitrogen systems used to provide power for gas-driven medical tools or instruments, and for other systems that vary from the normal 50- to 55-psig (340- to 380-kPa gauge) line pressure (for example, systems supplying medical gases to hyperbaric chambers), shall be set at 50 percent above line pressure.

4-3.1.8.6 Check Valves. Supply systems complying with 4-3.1.6 or 4-3.1.7 (*see Figures 4-3.1.6 and 4-3.1.7*) shall have a check valve in the primary supply main, upstream of the point of intersection with the secondary or reserve supply main.

4-3.1.8.7 Final Line Regulators. All final line regulators shall be duplexed with isolating valves or placed in a three-valve bypass to permit service to the regulator without completely shutting down the gas piping system. The choice of duplex or three-valve bypass shall be made based on the ability of the source equipment to provide normal line pressure during isolation of the regulator.

4-3.1.8.8 Emergency Oxygen Supply Connection. Where the oxygen supply, cryogenic or other, is located outside of the building served, there shall be incorporated in the piping system an inlet for connecting a temporary auxiliary source of supply for emergency or maintenance situations. The inlet shall be located on the exterior of the building served and shall be physically protected to prevent tampering and unauthorized access. It shall be labeled "Emergency Gaseous Oxygen Inlet." This connection shall be installed downstream of the shutoff valve on the main supply line [*see 4-4.1.2.2(c)*] and be suitably controlled with the necessary valves to allow emergency supply of oxygen and isolation of the piping to the normal source of supply. It shall have one check valve in the main line between the main line shutoff valve and the tee'd connection and one check valve between the tee'd connection and the emergency supply shutoff valve. (*See Figure 4-4.1.*)

(a) The emergency oxygen supply connection piping assembly shall be provided with a pressure relief valve of adequate size to protect the downstream piping system and related equipment from exposure to pressures in excess of 50 percent higher than normal pipeline pressure.

(b) The emergency oxygen supply connection shall have incorporated within it the proper pressure-regulating devices.

(c) The inlet shall be the oxygen connection listed in CGA Pamphlet V-1 (ANSI B57.1), Type 540.

4-3.1.9 Medical Air Compressor Supply Systems. (*See Figure 4-3.1.9.*)

4-3.1.9.1 The medical air compressor shall be an air compressor as defined in Chapter 2. The medical air compressor shall take its source from the outside atmosphere and shall not add contaminants in the form of particulate matter, odor, or other gases. It shall be connected only to the medical air piping distribution system and shall not be used for any other purpose. The medical air compressor shall be designed to prevent the introduction of contaminants or liquid into the pipeline by:

(a) Elimination of oil anywhere in the compressor, or

(b) Separation of the oil-containing section from the compression chamber by an area open to atmosphere, which allows continuous visual inspection of the interconnecting shaft.

NOTE 1: Examples of (a) are liquid ring and permanently sealed bearing compressors.

NOTE 2: Example of (b) is an extended head compressor with an atmospheric vent between the compression chamber and the crankcase.

NOTE 3: The second sentence of 4-3.1.9.1 applies to both the distribution of the air in the piping system and to the use of a compressor as a source.

It is the intent that the medical air piping distribution system support only the intended need for breathable air for such items as IPPB and long-term respiratory assistance needs, anesthesia machines, etc. The system is not intended to be used to provide engineering, maintenance, and equipment needs for general hospital support use. It is the intent that the life safety nature of the medical air be protected by a system dedicated solely for its specific use. The medical air distribution system could also supply air-driven instruments that exhaust into the pharynx. This might be a dental or other surgical device.

As a compressed air supply source, a medical air compressor should not be used to supply air for other purposes because such use could increase service interruptions, reduce service life, and introduce additional opportunities for contamination.

4-3.1.9.2 Except as provided in 4-3.1.9.2(a), the intake to medical air compressors shall be located outdoors above roof level a minimum distance of 10 ft (3 m) from any door, window, other intake, or opening in the building, and a minimum distance of 20 ft (6 m) above the ground. Intakes shall be turned down and screened or otherwise be protected against the entry of vermin or water, with screening that shall be fabricated or composed of a noncorrosive material such as stainless steel or other suitable material. (*See Appendix C-4.2.6.*)

(a) If a source is available that is equal to or better than outside air (air already filtered for use in operating room ventilating systems, for example), it shall be permitted to be used for the medical air compressors. This alternate source of supply air must be available on a continuous 24-hour-per-day, 7-day-per-week basis.

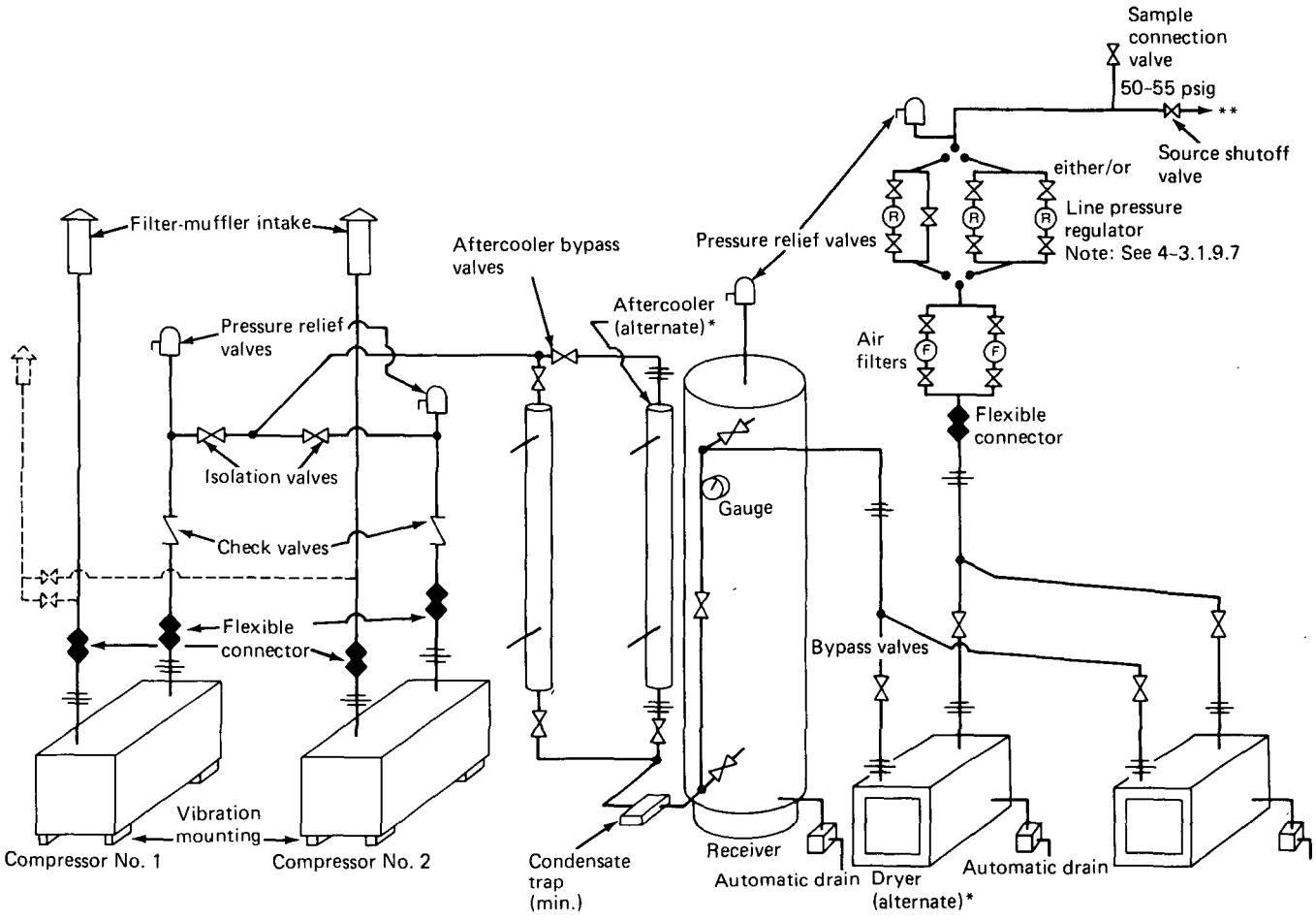
(b) The compressor air intake shall be located where no contamination from engine exhausts, fuel storage vents, vacuum system discharges, particulate matter, or odor of any type is anticipated.

Air intakes for separate compressors shall be permitted to be joined together to one common intake, provided such intake is appropriately sized. Where this is done, open inlet piping to a compressor removed for service shall be isolated by manual or check valve, blind flange, or tube cap to prevent backflow.

4-3.1.9.3 Two or more air compressors shall be used with provisions for operation alternately or simultaneously dependent on demand. When two compressors are used, each unit shall be capable of maintaining the supply of air to the system at peak calculated demand. When more than two compressors are provided, the peak calculated demand shall be met with the largest compressor out of service. An automatic means shall prevent backflow through off-cycle units.

4-3.1.9.4 Each compressor shall be provided with a disconnect switch and motor-starting device with overload protection. Each compressor system shall be provided with automatic alternation of the units dividing usage evenly and an automatic means to activate the additional units when the in-service unit becomes incapable of maintaining adequate pressure.

(a) Manual alternation of larger units shall be permitted if the system is provided with an automatic means to activate the additional units when the in-service unit becomes incapable of maintaining adequate pressure.



For SI Units: 1 psig = 6.895 kPa gauge.
*See 4-3.1.9.7 for details regarding alternate aftercoolers and/or dryers.
**Piping system continued on Figure 4-4.1.
NOTE: Flow schematics that differ may be acceptable as long as they meet intent of standard.

Figure 4-3.1.9 Typical duplex medical air compressor system (schematic). (Type I Gas Systems)

(b) A local audible and visual signal shall be provided to indicate when the reserve or off-duty air compressor is in operation.

NOTE: One method of indicating the reserved air compressor is in use is to activate the alarm from the pressure switch that starts the reserve air compressor.

(c) Required control and alarm functions shall remain energized while any compressor in the system remains electrically on-line.

(d) The power source for medical air compressors shall be the equipment system of the essential electrical system as described in Chapter 3, "Electrical Systems."

4-3.1.9.5 The use of a liquid ring air compressor, as defined in 4-3.1.9.1 under medical air compressor — type (a), shall require separate compressor sensors that shut down that compressor when the water exceeds the design level in the separator, activate a local alarm indicating which compressor is affected, and activate the master alarm (single or multi-signals). In addition, a high water level in the receiver shall activate an alarm that shuts down the liquid ring compressor system and activates the master and local alarms. Service water and seal water shall be as recommended by the manufacturer.

The use of permanently lubricated sealed bearing compressors, as defined in 4-3.1.9.1 under medical air compressor — type (a), shall require monitoring of the air temperature at the immediate outlet of each cylinder with a "high temperature" switch that shuts down the compressor and activates both master and local alarms. If the air compressor has water-cooled heads, a high-water-level switch in the receiver shall activate both master and local alarms and shut down the system. The temperature switch setting shall be recommended by the manufacturer.

The use of a medical air compressor, as defined in 4-3.1.9.1 under medical air compressor — type (b), shall monitor air temperature at the immediate outlet of each

cylinder with a "high temperature" switch that shuts down the compressor and activates both the master and local alarms. If the system includes water-cooled heads, the compressor system shall have a high-water-level switch on the receiver tank that activates both master and local alarms. The compressor shall contain coalescing filters with an "element change indicator" and a charcoal filter with colormetric hydrocarbon indicator.

Ambient temperature range for air-cooled equipment shall be as recommended by the manufacturer.

4-3.1.9.6 The receiver shall be equipped with a safety valve, automatic drain, sight glass, and pressure gauge and shall have the capacity to ensure practical on-off operation. The receiver shall comply with Section VIII ("Unfired Pressure Vessels") of the ASME *Boiler and Pressure Vessel Code*. Piping between compressors and the source shutoff valve shall be in accordance with 4-4.1.2.1(c).

4-3.1.9.7 Compressor systems for medical air shall be equipped with intake filter-mufflers of the dry type, aftercoolers and/or air dryers, line filter(s) appropriate for the intake air conditions and compressor type, and pressure regulators to ensure the delivery of medical compressed air (*see definition of medical compressed air in Section 2-2*).

The medical air receiver shall be provided with a three valve bypass to permit service to this device without shutting down the medical air system.

Dryer systems shall be, at a minimum, duplexed and valved to permit isolation of individual components to allow for maintenance or repair in the event of failure, while still continuing to adequately treat the flow of air. Under normal operation, only one dryer shall be open to airflow with the other dryer valved off. Each dryer system shall be capable of providing dry air at the peak calculated demand of the system. [*See 4-4.1.1.2(f).*]

Aftercoolers, where required, shall be duplexed and provided with individual condensate traps. The receiver shall not be used as an aftercooler or aftercooler trap.

NOTE: The utilization of an air-treatment system is the joint responsibility of the system designer, hospital clinical and engineering staffs, and the authority having jurisdiction. Different types of compressors have characteristics that affect the selection of the type of air-treatment system. Some air-treatment systems impose an additional load upon the compressors that must be accounted for in the sizing of the system (usable capacity). The compressor duty cycle must be chosen in accordance with the manufacturer's recommendation.

When more than two devices are provided, the peak calculated demand shall be met with the largest single unit out of service.

Final line filters shall be duplexed with appropriate valves to permit service to these devices without shutting down the medical air system. Each of the filters shall be sized for 100 percent of the system peak calculated demand at design conditions and shall be rated for a minimum of 98 percent efficiency at 1 micron. These filters shall be equipped with a continuous visual indicator showing the status of the filter element life.

NOTE: The type of air compressor and air condition at the intake will govern the type of filter provided for the air compressor supply system. All filters should be examined quarterly for the presence of liquids or excessive particulates and replaced according to the manufacturer's instructions.

All final line regulators shall be duplexed with isolating valves or placed in a three-valve bypass to permit service to the regulator without completely shutting down the gas piping system. The choice of duplex or three-valve bypass shall be made based on the ability of the source equipment to provide normal line pressure during isolation of the regulator.

4-3.1.9.8* The monitoring of air quality downstream of the dryers and upstream of the piping system, and the monitoring system response, shall be in accordance with Table 4-3.1.9.8.

Exception: Existing piping systems, provided such piping systems do not constitute a distinct hazard to life.

Table 4-3.1.9.8 Analytical Tests

Type of Compressor*	Dew Point Freq'y	Dew Point Alarm	G.H. Freq'y	L.H. Freq'y	CO Freq'y	CO Alarm
Type (a)						
Liquid ring	C	R	NR	NR	C	R
Reciprocating	C	R	NR	NR	C	R
Type (b)						
Reciprocating	C	R	Q**	C***	C	R

See 4-4.1.1.2(g) for performance criteria.
G.H. = gaseous hydrocarbon.
L.H. = liquid hydrocarbon.
*Refer to 2-2 and definition of medical air compressor.
**Pigment indicators.
***Pigment indicators permanently installed downstream of each compressor and inspected daily and documented.
C = continuous line monitoring.
R = required.
CO = carbon monoxide.
Q = quarterly.
NR = not required.

4-3.1.9.9 If required by equipment dynamics or location, antivibration mountings, in accordance with the manufacturer's recommendations, shall be installed under components, and flexible couplings shall interconnect the air compressor units, the receiver, intake lines, and the supply line from the storage receiver.

4-3.1.9.10 Where medical-air piping systems at different operating pressures are required, the piping shall separate after the filters but shall be provided with separate line regulators, dew point monitors, relief valves, and source shutoff valves.

4-3.2 Patient Gas Supply — Type II.

4-3.2.1 Cylinders shall comply with 4-3.1.1. Cylinders in service shall be adequately secured. Cylinders in storage shall be secured or located to prevent falling or being knocked over.

4-3.2.2* Supply system and storage locations shall comply with 4-3.1.2.1(j); 4-3.1.2.1(k) [except 4-3.1.2.1(k)(3)]; 4-3.1.2.2 [except 4-3.1.2.2(d)]; and 4-3.1.2.3.

Enclosures for supply systems shall be provided with doors or gates. If the enclosure is outside and/or remote from the single treatment facility, it shall be kept locked. If the storage area is within the single treatment facility (i.e., is not remote), it shall be permitted to be locked.

4-3.2.3 Dental Air Compressor Supply Systems. (*See Figure 4-3.2.3.6*)

4-3.2.3.1* The dental air compressor system shall provide dental compressed air as defined in Chapter 2. The dental air compressor shall add no contaminants in the form of particulate matter, odor, or other gases.

NOTE: Dental compressed air is primarily used to drive gas-powered dynamic devices. Similar applications are in podiatry and plastic surgery. Examples of these are air to drive turbine-powered drills and air to dry teeth and gums. Some dental hand pieces have an internal self-contained air return system, while other hand pieces may discharge air into the atmosphere. Some may discharge a mixture of air and water.

4-3.2.3.2 Dental compressed air shall be permitted to be used to power air-powered devices for evacuation only if the exhaust of the evacuation device is a closed vent to the outside of the building.

4-3.2.3.3 Equipment shall be obtained from and be installed under the supervision of a manufacturer(s) or supplier(s) familiar with proper practices for its construction and use. Maintenance programs, in accordance with the recommendations of manufacturer(s), shall be established for the dental air compressor supply system as connected in each individual installation.

4-3.2.3.4* The compressor system shall be permitted to be a single, duplex, or multicompressor system.

4-3.2.3.5 Each system installation shall include appropriate disconnect switch(es), motor-starting device(s), and motor overload protection device(s). For single, duplex, or multicompressor systems, a means for activating/deactivating each individual compressor shall be provided. When multiple compressors are used, alternation of units, and a means to activate the additional unit(s) should the in-service unit(s) be incapable of maintaining adequate pressure, shall be provided.

4-3.2.3.6* Compressor systems for dental air shall be equipped with intake filter-muffler(s) of the dry type; receiver(s); shutoff valves; air dryer(s); in-line final particulate filters rated at 5 microns, 98 percent efficiency, with filter status indicator; and downstream pressure regulator(s) to ensure the delivery of compressed air (*see definition of dental compressed air in Section 2-2*). The compressor air intake shall be located where no contamination from vacuum system discharges or particulate matter is anticipated. The compressor air intake shall be taken from a space other than an operatory and other than the room or space in which there is an open or semi-open discharge from a dental vacuum system. (*See Figure 4-3.2.3.6.*) Air intake shall be from outside the building when practical or shall be located within a room where no chemical-based material is stored or used.

4-3.2.3.7 The system shall be equipped with a pressure relief valve, pressure gauge, and receiver automatic drains(s). Receiver(s) shall have the capacity to ensure practical on/off operation of the compressor(s). Receiver(s) shall comply with Section VIII ("Unfired Pressure Vessels") of the ASME *Boiler and Pressure Vessel Code.*

4-3.2.3.8* An appropriate moisture indicator shall be provided. The moisture indicator shall be located downstream of the receiver but upstream of any system pressure regulators.

The moisture indicator shall indicate if the relative humidity of the compressed air exceeds 40 percent at line pressure and temperature.

4-3.2.3.9 Any outlet of a dental compressed air system that allows for a temporary quick-attach connection shall be labeled with the pressure identified as dental compressed air and a warning against using the air for medical air purposes.

Example of label wording:

DENTAL COMPRESSED AIR DO NOT USE FOR MEDICAL AIR PURPOSES

The dental air station outlet shall not be interchangeable with the medical air station outlet.

4-3.2.3.10 When the air compressor is to be used to provide respirable air or otherwise life-supporting air (e.g., to operate a respirator, or anesthesia equipment in oral surgery applications), the air compressor shall in every respect comply with 4-3.1.9.

4-3.3 Laboratory Gas Supply. (Reserved)

4-3.4 Other Gases.

NOTE: Refer to NFPA 54, *National Fuel Gas Code.*

4-4 Gas System Distribution.

4-4.1 Patient Gas Distribution — Type I (Manifold, Piping, Valving/Controls, Outlets/Terminals, Alarms).

4-4.1.1 Gas Warning Systems.

4-4.1.1.1 General. (*See Appendix C-4.2.*)

(a) Alarm signals and pressure gauges shall be located to ensure continuous responsible surveillance. Each signal device and gauge shall be appropriately labeled.

(b) A master alarm system shall be provided to monitor the operation and condition of the source of supply, the reserve (if any), and the pressure in the main line of the medical gas system. (*See Appendixes C-4.1 and C-4.2.*)

(c) An area alarm system shall be provided in anesthetizing and other critical care locations to monitor the pressure in the local supply line.

(d) The power source for warning systems shall be the life safety branch of the emergency system as described in Chapter 3, "Electrical Systems."

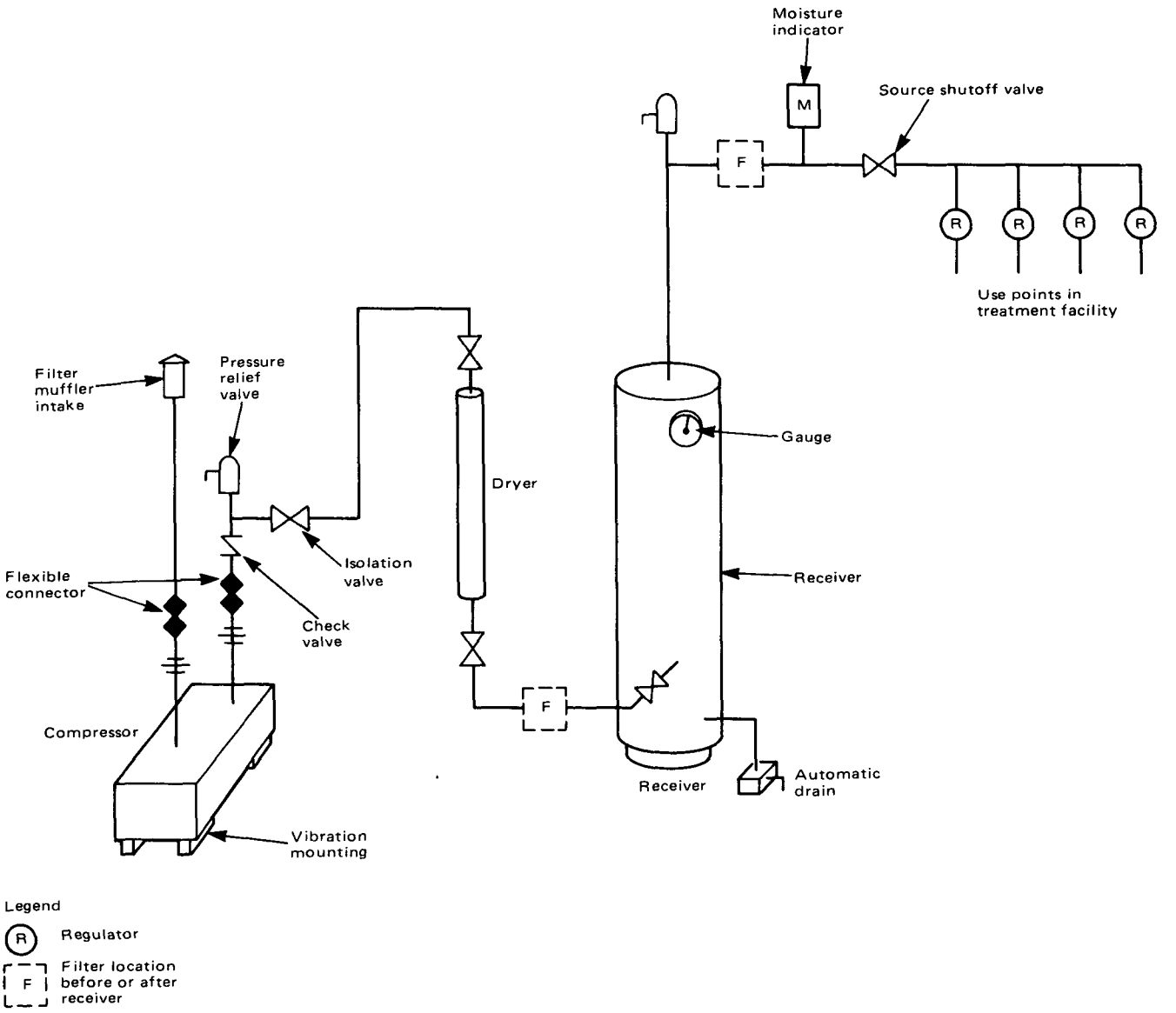


Figure 4-3.2.3.6 Dental air compressor system (typical).

(e) The connection of the master alarm system to a centralized computer (e.g., a building management system) is permitted. The computer shall not constitute one of the master alarm signal panels required in 4-4.1.1.2(a).

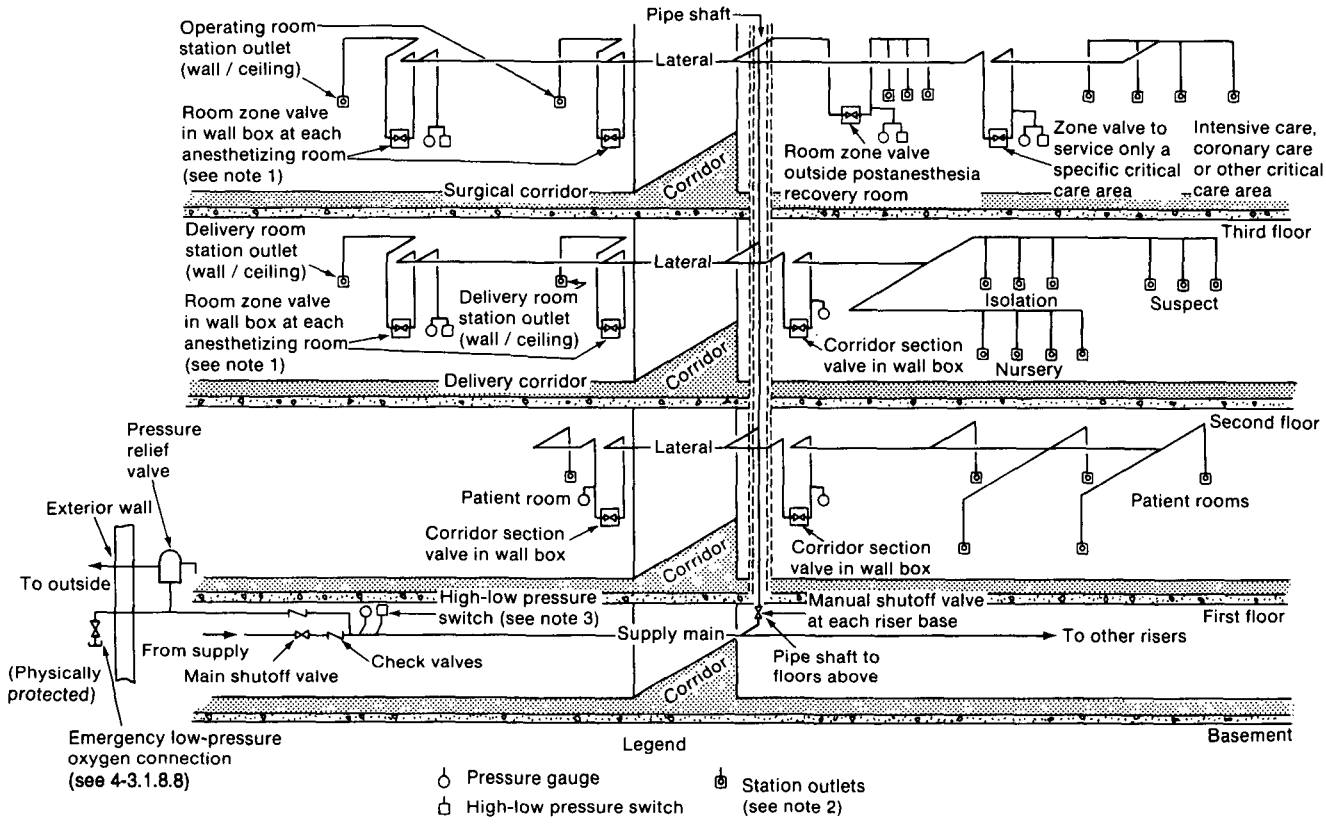
4-4.1.1.2 Master Alarm Systems for Gases.

(a) To ensure continuous responsible observation, the master alarm signal panels shall be located in two separate warning locations, wired in parallel to a single sensor for each condition. Audible and noncancellable visual signals shall be installed in the office or principal working area of the individual responsible for the maintenance of the medical gas system and, to ensure continuous surveillance, at the telephone switchboard, the security office, or at another suitable location. Separate visual signals, as required, shall be provided for each of the conditions described in 4-4.1.1.2(b) through (g).

(b) A signal shall be provided for all medical gas systems when the piping system is supplied by a manifold or an alternating-type bulk system that has as part of its normal operation a changeover from one portion of the operating supply to another portion. An audible and noncancellable visual signal shall indicate when, or just before, this changeover occurs. (*See Appendixes C-4.1 and C-4.2.*)

(c) When a manifold or bulk supply consists of one or more units that continuously supply the piping system while another unit remains as the reserve supply and operates only in case of emergency, audible and noncancellable visual signals shall indicate when, or just before, the reserve supply goes into operation. (*See Appendixes C-4.1 and C-4.2.*)

(d)* When check valves are not provided for each cylinder lead of the reserve supply for a manifold or bulk supply system, an audible and noncancellable visual signal



NOTE 1: See 4-4.1.3.3 and 4-4.1.3.2.
NOTE 2: See 4-4.1.1.2, 4-4.1.1.3, 4-4.1.1.4(b), and 4-4.1.2.2(e).
NOTE 3: See 4-4.1.1.2(f).

Figure 4-4.1 Location of valves, pressure switches, and piping for medical gas systems (schematic). (Type I Gas Systems)

shall indicate when the reserve supply is reduced to one average day's supply. If check valves are provided in each cylinder lead, this signal shall not be used. (*See Appendixes C-4.1 and C-4.2.*)

(e) When a cryogenic liquid storage unit is used as a reserve for a bulk supply system, separate audible and noncancellable visual signals shall indicate when the contents of the reserve are reduced to one day's average supply, and when the gas pressure available in the reserve unit is reduced below the pressure required to function properly.

(f) All medical gas piping systems shall be provided with audible and noncancellable visual signals to indicate if the pressure in the main line increases or decreases from the normal operating pressure. The actuating switch for these warning signals shall be installed in the main line immediately downstream (on the piping distribution side) of the main-line shutoff valve. (*See Appendix C-4.1.*)

(g) All of the individual alarms as required in 4-3.1.9 shall be provided with audible and manually resettable visual signals in accordance with 4-4.1.1.2(a). A manually resettable alarm for each monitored parameter shall be provided at the air compressor control enclosure.

Dew point for medical compressed air shall be monitored and alarmed per 4-3.1.9.8 and 4-4.1.1.2(f) to protect from a line pressure dew point rise to 39°F (3.9°C) from the nominal design of 35°F (1.7°C). Dew point shall be reported as pressure dew point in either degrees Fahrenheit or Celsius.

4-4.1.1.3 Area Alarm Systems for Gases.

(a) Area alarms shall be provided for anesthetizing locations and critical care areas. Warning signals shall be provided for all medical gas piping systems supplying these areas to indicate if the pressure increases or decreases from the normal operating pressure.

(b) The audible and noncancellable visual signal shall be activated by an actuating switch installed in the individual line supplying each such specific area.

(c)* The actuating switch for anesthetizing locations shall be in the specific line supplying the operating or delivery room suites, with the individual room shutoff valve being the only one between the actuating switch and the room outlets.

(d)* The area alarm actuating switch for each vital life support and critical care unit shall be in the specific line serving that area. No shutoff valve shall be installed between the actuating switch and the outlets.

(e) The appropriately labeled warning signal panel for area alarms shall be installed at the nurses' station or other suitable location near the point of use that will provide responsible surveillance.

4-4.1.1.4 Pressure Gauges for Gases.

(a) A pressure gauge shall be installed in the main line adjacent to the actuating switch required in 4-4.1.1.2(f). It shall be appropriately labeled and be readily visible from a standing position. (*See Appendix C-4.2.*)

(b) An appropriately identified pressure gauge, connected to the line being monitored, shall be installed at each area alarm panel location. It shall be appropriately labeled and be readily visible from a standing position. (*See Appendix C-4.2.*)

4-4.1.2 Gas Piping Systems (General).

4-4.1.2.1 Gas Piping. The provisions of this section apply to field-installed piping for the distribution of nonflammable medical piped gases.

NOTE: See 4-4.1.2.1(c) and 4-4.1.5 for additional requirements for tubes used in systems at nonstandard pressures.

(a) Tubes, valves, fittings, station outlets, and other piping components in medical gas systems shall have been cleaned for oxygen service prior to installation.

(b) Piping for nonflammable medical gas systems shall be suitable for oxygen service in accordance with 4-4.1.4.1. Each length of tube shall be permanently labeled and delivered plugged and capped. Fittings, valves, and other devices shall be sealed and marked. The installer shall furnish documentation certifying that all installed piping materials comply with the requirements of this paragraph.

(c) Piping shall be hard-drawn seamless medical gas tube, Type K or L (ASTM B819), and bear one of the following markings: OXY, MED, OXY/MED, ACR/OXY, or ACR/MED. Mains and branches in piping systems shall be not less than 1/2 in. nominal size. Runouts to area alarm panels shall be permitted to be 1/4 in. nominal size.

Exception: For systems operated at pressures between 200 and 300 psig (1380 and 2070 kPa, respectively), ASTM B819, Type K copper shall be used.

(d) Except as provided in 4-4.1.2.1(h) and (i), joints in copper shall be brazed using capillary fittings complying with ANSI B16.22, *Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings*. Cast fittings shall not be used for brazed joints.

NOTE: It is recognized that brass and other acceptable materials (other than copper) are used in the manufacture of some medical gas equipment.

(e) Valves, fittings, and other piping components shall be cleaned for oxygen service by the manufacturer in accordance with CGA Pamphlet G-4.1, *Cleaning Equipment for Oxygen Service.*

(f) Piping systems shall be designed and sized to deliver the required flow rates at the utilization pressures.

(g) Piping shall be supported from the building structure in accordance with MSS Standard Practice SP-69, *Piping Hangers and Supports — Selection and Application.* Hangers and supports shall comply with MSS Standard Practice SP-58, *Piping Hangers and Supports — Materials, Design and Manufacture.* Portions of hangers in contact with copper tube shall have a copper finish or other protection against galvanic corrosion. Maximum support spacing shall be as follows:

3/8 in. nominal	6 ft
1/2 in. nominal	6 ft
3/4 in. nominal	7 ft
1 in. nominal	8 ft
1 1/4 in. nominal	9 ft
1 1/2 in. nominal and larger	10 ft

(h) Joints in medical gas tube shall be brazed except that memory-metal couplings having temperature and pressure ratings not less than that of a brazed joint shall be permitted. Flared and compression fittings shall be prohibited. Valves and fittings having flared or compression joints shall be prohibited.

(i) Listed or approved metallic gas tube fittings that, when made up, provide a permanent joint having the mechanical, thermal, and sealing integrity of a brazed joint shall be permitted to be used in lieu of brazed joints.

(j) Turns, offsets, and other changes in direction in piping shall be made with fittings complying with 4-4.1.2.1(d).

(k) Buried piping shall be protected against frost, corrosion, and physical damage. Piping under roadways, driveways, parking areas, or other locations subject to surface loads shall be installed in a protective sleeve or casing. Piping in concrete floors or walls shall be installed in a continuous conduit.

(l) Medical gas risers shall be permitted to be installed in pipe shafts if protected from physical damage, effects of excessive heat, corrosion, or contact with oil.

(m) Piping shall not be installed in kitchens or electrical switchgear rooms.

(n) Medical gas piping shall be permitted to be located in the same service trench or tunnel with fuel gas lines, fuel oil lines, electrical lines, steam lines, and similar utilities provided that the space is ventilated (naturally or mechanically) and the ambient temperature around the medical gas piping is limited to 130°F (54°C) maximum. Medical gas piping shall not be located where subject to contact with oil, including flooding in the case of a major oil leak.

(o) Where piping penetrates fire-rated construction, openings around the piping shall be fire-stopped.

(p) Piping exposed in corridors and other areas where subject to physical damage from the movement of carts, stretchers, portable equipment, or vehicles shall be suitably protected.

(q) Hoses and flexible connectors, both metallic and nonmetallic, shall be no longer than necessary and shall not penetrate or be concealed in walls, floors, ceilings, or partitions. Flexible connectors, metallic or nonmetallic, shall have a minimum burst pressure of 1000 psig (6900 kPa gauge). [*See 4-4.1.2.1(i).*]

(r) Where a system originally used or constructed for use at one pressure and for a gas is converted for operation at another pressure or for another gas, all provisions of 4-4.1.2.4, 4-4.1.3, 4-4.1.4, Section 4-5, and the Exception to 4-4.1.2.1(c) shall apply as if the system were new. **Vacuum systems shall never be converted for use as gas systems.**

4-4.1.2.2 Gas Shutoff Valves. (*See Appendix C-4.2.*)

NOTE: See 4-4.1.5 for additional requirements for shutoff valves used in systems at nonstandard pressures.

(a) Shutoff valves accessible to other than authorized personnel shall be installed in valve boxes with frangible or removable windows large enough to permit manual operation of valves.

(b) A shutoff valve shall be placed at the immediate outlet of the source of supply to permit the entire source of supply, including all accessory devices (such as air dryers, final line regulators, etc.), to be isolated from the piping system. The source valve shall be upstream of the main line shutoff valve and shall be located in the immediate vicinity of the source equipment. It shall be labeled "SOURCE VALVE FOR THE (SOURCE NAME)."

(c) The main supply line shall be provided with a shutoff valve so located as to be accessible in an emergency. The main supply line valve shall be located downstream of the source valve and outside of the source room, enclosure, or where the main line first enters the building. This valve shall be identified.

(d) Each riser supplied from the main line shall be provided with a shutoff valve adjacent to the riser connection.

(e) Station outlets shall not be supplied directly from a riser unless a manual shutoff valve located in the same story is installed between the riser and the outlet with a corridor wall intervening between the valve and the outlets (*see Figure 4-4.1*). This valve shall be readily operable from a standing position in the corridor on the same floor it serves. Each lateral branch line serving patient rooms shall be provided with a shutoff valve that controls the flow of medical gas to the patient rooms. Branch line shutoff valves shall be so arranged that shutting off the supply of medical gas to one branch will not affect the supply of medical gas to the rest of the system. A pressure gauge shall be provided downstream of each lateral branch line shutoff valve.

(f) In-line shutoff valves intended for use to isolate existing systems for piping maintenance or to extend to new piping systems shall be permitted. These valves shall be located in a secure area or locked open and labeled in accordance with 4-6.4.1.2.

(g) New or replacement valves shall be of a quarter-turn shutoff type with an indicating handle (i.e., ball or butterfly valve).

(h) Manual shutoff valves in boxes shall be installed where they are visible and accessible at all times. The boxes shall not be installed behind normally open or normally closed doors, or otherwise hidden from plain view.

4-4.1.2.3 Surface-Mounted Medical Gas Rail Systems.

(a) Listed or approved surface-mounted medical gas rail systems shall be permitted to be installed where multiple use of medical gases and vacuum at a single patient location are required or anticipated. The surface-mounted medical gas rail system shall be made of material as identified in 4-4.1.2.1(a) or a material exhibiting the mechanical, thermal, and sealing integrity of a brazed joint complying with 4-4.1.4.2. Individual gas channel sizes shall be in conformity with good engineering practice for proper delivery of maximum volumes specified. The ends of the surface-mounted medical gas rails shall not be used for station outlets.

(b) Station outlet locations for future expansion that are capped shall not be readily removable via screwdriver, pliers, wrench, etc., but shall require a special tool to remove them when expansion is undertaken.

(c) Openings in surface-mounted medical gas rail systems for station outlet assemblies or station outlet plug caps shall be gas-specific.

(d) All fittings used for internal and external connection of surface-mounted medical gas rail systems shall be made especially for brazed connection, or shall be assembled with screw-thread-type brass fittings with bronze- or copper-brazing-type fittings.

(e)* Connections of surface-mounted medical gas rail systems to piping systems of dissimilar metals shall require plating of the connecting components to prevent interaction between dissimilar metals.

(f) The installation of the surface-mounted medical gas rail system shall be tested per 4-4.1.4.

4-4.1.2.4 Gas Station Outlets. (*See Appendix C-4.2.*)

NOTE: See 4-4.1.5 for additional requirements for station outlets used in systems at nonstandard pressures.

(a)* Each station outlet for medical gases, whether threaded or noninterchangeable quick-coupler, shall be gas-specific and shall consist of a primary and a secondary valve (or assembly). The secondary valve (or unit) shall close automatically to stop the flow of medical gas when the primary valve (or unit) is removed. Each outlet shall be legibly identified with the name or chemical symbol of the gas contained. Where chemical symbols are used, they shall be in accordance with CGA Pamphlet P-2, *Characteristics and Safe Handling of Medical Gases.* Where supplementary color identification is used, it shall be in accordance with CGA Pamphlet C-9, *Standard Color-Marking of Compressed Gas Cylinders Intended for Medical Use.*

(b) Threaded outlets shall be noninterchangeable connections complying with CGA Pamphlet V-5, *Diameter-Index Safety System — Non-Interchangeable Low Pressure Connections for Medical Gas Applications.*

(c) Each station outlet, including those mounted in columns, hose reels, ceiling tracks, or other special installations, shall be designed so that parts or components that

are required to be gas-specific for compliance with 4-4.1.2.4(a) cannot be interchanged between station outlets for different gases.

(1) The use of common parts such as springs, O-rings, fasteners, seals, and shutoff poppets shall be permitted.

(d) Station outlets in patient rooms shall be located at an appropriate height above the floor to prevent physical damage to equipment attached to the outlet. They shall be permitted to be recessed or otherwise protected from damage.

(e) When multiple wall outlets are installed, including those for vacuum, there must be sufficient spacing between outlets to permit the simultaneous use of adjacent outlets with any of the various types of therapy equipment.

(f) Pressure gauges and manometers for medical gas piping systems shall be cleaned and degreased.

4-4.1.3 Gas Piping Systems (Additional Requirements).

4-4.1.3.1 Anesthetizing locations and other vital life-support and critical areas, such as postanesthesia recovery, intensive care units, and coronary care units, shall be supplied directly from the riser without intervening valves except as provided in 4-4.1.2.2(f), 4-4.1.3.2, or 4-4.1.3.3.

4-4.1.3.2 A shutoff valve shall be located immediately outside each vital life-support or critical care area in each medical gas line, and located so as to be readily accessible in an emergency. Valves shall be protected and marked in accordance with 4-6.4.1.2.

All gas-delivery columns, hose reels, ceiling tracks, control panels, pendants, booms, alarm panels, or other special installations shall be located downstream of this valve.

4-4.1.3.3 A shutoff valve shall be located outside each anesthetizing location in each medical gas 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 in accordance with 4-6.4.1.2.

4-4.1.3.4* Each yoke insert shall be drilled with two holes of a size and in locations specified in the "Pin-Index Safety System," in CGA Pamphlet V-1 (ANSI B57.1), *Compressed Gas Cylinder Valve Outlet and Inlet Connections* (Canadian Standard CSA-B96) for the gas contained in the piping to which it is attached.

4-4.1.3.5* 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 piping system. Each backflow check valve shall be designed to function properly at pressures up to 190 kg/cm^2 gauge (2700 psig) (18, 617 kPa gauge).

4-4.1.3.6 Cylinder valve outlet connections shall conform with CGA Pamphlet V-1 (ANSI B57.1), *Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connection (see 8-3.1.7 and Appendix A-4-4.1.3.4).*

4-4.1.4* Installation Requirements. Medical gas systems shall be installed using methods and procedures that maintain the interior cleanliness of the piping system, as required by this standard. Brazing shall be performed by individuals who are qualified under the provisions of 4-4.1.4.2(a) or 4-4.1.4.2(b).

4-4.1.4.1 General. Piping, valves, fittings, and other components for nonflammable medical gas systems shall have been thoroughly cleaned for oil, grease, and other readily oxidizable materials as if for oxygen service. Such material shall be plugged, capped, or otherwise sealed until final assembly. Particular care shall be taken in the storage and handling of such material to maintain its clean condition. Immediately before final assembly, such material shall be visually examined internally for contamination. Material that has become contaminated and is no longer suitable for oxygen service shall not be installed.

(a) Piping, valves, fittings, and other components shall be specially cleaned for oxygen service in a facility equipped to clean, rinse, and purge the material in accordance with the requirements of 4-4.1.2.1(e) or shall be prepared in accordance with 4-4.1.4.1(b).

(b) *On-site Cleaning.*

(1) On-site cleaning of the interior surfaces of tubes, valves, fittings, and other components shall be limited to recleaning surfaces in the immediate vicinity of the joints that have become contaminated prior to brazing.

(2) Where on-site cleaning is permitted, surfaces shall be cleaned by washing in a clean, hot water/alkaline solution, such as sodium carbonate or trisodium phosphate (1 lb to 3 gal of potable water). Interior surfaces shall be thoroughly scrubbed and rinsed with clean, hot, potable water.

4-4.1.4.2 Qualification of Brazing Procedures and Brazer Performance.

(a) Except as provided under 4-4.1.4.2(b), brazing procedures and brazer performance shall be qualified in accordance with either Section IX, "Welding and Brazing Qualifications," of the ASME *Boiler and Pressure Vessel Code,* or AWS B2.2, *Standard for Brazing Procedure and Performance Qualification*, both as modified below.

(1) Procedures and brazers shall be qualified by tension tests.

(2) The Brazing Procedure Specification shall address cleaning, joint clearance, overlap, internal purge gas, purge gas flow rate, and filler metal.

(3) The Brazing Procedure Qualification Record and the Record of Brazer Performance Qualification shall document filler metal used, cleaning, joint clearance, overlap, internal purge gas and flow rate used during brazing of the test coupon, and no internal oxidation exhibited on the completed test coupon.

(4) Brazing procedures qualified by a technically competent group or agency are permitted under the following conditions:

(i) The Brazing Procedure Specification and the Procedure Qualification Record shall meet the requirements of this standard and either ASME Section IX or AWS B2.2.

(ii) The employer shall obtain a copy of both the Brazing Procedure Specification and the supporting qualification records and shall sign and date these records, thereby accepting responsibility for the qualifications that were performed by the group or agency.

(iii) The employer shall qualify at least one brazer following each Brazing Procedure Specification used.

(5) An employer shall be permitted to accept Brazer Qualification Records of a previous employer under the following conditions:

(i) The brazer shall have been qualified following the same or an equivalent procedure as that which he/she will use for the new employer.

(ii) The new employer shall obtain a copy of the record of Brazer Performance Qualification tests from the previous employer and shall sign and date these records, thereby accepting responsibility for the qualifications performed by the previous employer.

(6) Performance qualification of brazers shall remain in effect indefinitely unless the brazer does not braze with the qualified procedure for a period exceeding 12 months, or there is a specific reason to question the ability of the brazer.

(b) Except as prohibited under 4-4.1.5, "Systems Having Nonstandard Operating Pressures," on-site testing of brazers shall be permitted subject to the approval of the authority having jurisdiction. The brazing procedure used shall meet the requirements of 4-4.1.4.3. The criteria for acceptance shall be in accordance with 4-4.1.4.3(j), including pressure testing to 150 psi (1034 kPa). Records shall be maintained of the brazing procedure specification used and individual brazer testing.

4-4.1.4.3* Brazed Joints.

(a) Brazed tube joints shall be the socket type. Filler metals shall bond with and be metallurgically compatible with the base metals being joined. Flux shall not be used except where permitted under 4-4.1.4.3(a)(2). Brazing filler metals shall comply with ANSI/AWS A5.8, *Specification for Brazing Filler Metal*, except that filler metals having compositions not conforming to the exact ANSI/AWS A5.8 classifications shall be permitted when used according to the manufacturer's installations.

(1) Copper-to-copper joints shall be brazed using a copper-phosphorus or copper-phosphorous-silver brazing filler metal (BCuP series) without flux.

(2) Dissimilar metals, such as copper and bronze or brass, shall be brazed using an appropriate flux with either a copper-phosphorus, copper-phosphorous-silver (BCuP series), or a silver (BAg series) brazing filler metal.

(b) Joints to be brazed in place shall be accessible for proper preparation, assembly, heating, filler application, cooling, cleaning, and inspection.

(c) Tube ends shall be cut square using a sharp tubing cutter to avoid deforming the tube. The cutting wheel shall be free from grease, oil, or other lubricant not suitable for oxygen service.

(d) The surfaces to be brazed shall be mechanically cleaned using a clean stainless steel wire brush or equivalent. The use of steel wool shall be prohibited due to the possible presence of oil. Mechanical cleaning shall not result in grooving of the surfaces to be joined. After mechanical cleaning, the surfaces shall be wiped using a clean, lint-free white cloth. During this cleaning, care shall be taken to avoid contamination of the "cleaned for oxygen" internal surfaces of the tube and components. Joints shall be recleaned if contaminated prior to brazing. Joints shall be brazed within 1 hour of being cleaned.

(e) Where dissimilar metals, such as copper and bronze or brass, are being brazed, flux shall be applied sparingly to minimize contamination of the inside of the tube with flux. The flux shall be applied and worked over the surfaces to be brazed using a stiff stainless steel bristle brush to ensure adequate coverage and wetting of the surfaces with flux. Where possible, short sections of copper tube shall be brazed to the noncopper component and the interior of the subassembly shall be cleaned of flux prior to installation in the piping system. Flux-coated brazing rods shall be permitted to be used in lieu of the application of flux to the surfaces to be joined on tube 3/4 in. nominal size and smaller.

(f) Tube ends shall be inserted fully into the socket of the fitting. Where flux is permitted, the joint shall be heated slowly until the flux has liquefied. Once this has occurred, or where flux is not used, the joint shall be heated quickly to the brazing temperature, taking care not to overheat the joint. Techniques for heating the joint, applying the brazing filler metal, and making horizontal, vertical, and large-diameter joints shall be as stated in sections on "Applying Heat and Brazing" and "Horizontal and Vertical Joints" in the chapter on "Joining and Bending" in the CDA *Copper Tube Handbook*.

(g)* **While being brazed, joints shall be continuously purged with oil-free dry nitrogen to prevent the formation of copper oxide on the inside surface of the joint. The flow of purge gas shall be maintained until the joint is cool to the touch.**

Exception: Purging of a connection to an existing system.

(h) During and after installation, openings in the piping system shall be kept capped or plugged to avoid unnecessary loss of purge gas while brazing and to prevent debris or other contaminants from entering the system, except that during brazing, a discharge opening shall be provided on the opposite side of the joint from where the purge gas is being introduced. During brazing, the purge gas flow rate shall be maintained at a level that will not produce a positive pressure in the piping system. After brazing, the discharge opening shall be plugged or capped to prevent contamination of the inside of the tube.

(i) After brazing, the outside of all joints shall be cleaned by washing with water and a stainless steel wire brush to remove any residue and permit clear visual inspection of the joint. Where flux has been permitted, hot water shall be used.

(j) Each brazed joint shall be visually examined after cleaning of the outside of the joint. The following conditions shall be considered unacceptable:

(1) Flux or flux residue.

(2) Excessive oxidation of the joint.

(3) Presence of unmelted filler metal.

(4) Failure of the filler metal to be clearly visible all the way around the joint at the interface between the socket and the tube.

(5) Cracks in the tube or component.

(6) Cracks in the braze filler metal.

(7) Failure of the joint to hold the test pressure under 4-5.1.2.3.

(k) Brazed joints that are found to be defective under 4-4.1.4.3(j)(1), (3), (4), (6), or (7) shall be permitted to be repaired, except that no joint shall be repaired more than twice. Brazed joints that are found to be defective under 4-4.1.4.3(j), conditions (2) and (5), shall be replaced.

4-4.1.4.4* Threaded Joints.

(a) Threads on pipe and fittings shall be tapered pipe threads complying with ANSI B1.20.1, *Pipe Threads, General Purpose.*

(b) Threaded joints in piping systems shall be tinned or made up with polytetrafluoroethylene (such as Teflon) tape or other thread sealant suitable for oxygen service. Sealants shall be applied to the male threads only.

4-4.1.4.5 Gas Piping System Installation.

(a) The installation of individual components shall be made in accordance with the instructions of the manufacturer. Such instructions shall include directions and information deemed by the manufacturer to be adequate for attaining proper installation, testing, maintenance, and operation of the medical gas systems. These instructions shall be left with the owner.

(b) The installation shall be made by qualified, competent technicians experienced in making such installations.

4-4.1.4.6 Prohibited Connections. No two medical gas pipelines shall be interconnected at any time. The pressure testing of the systems shall be accomplished by individual charging and measurement.

4-4.1.5 Systems Having Nonstandard Operating Pressures. The following requirements apply to gas piping systems having operating pressures other than the normal 50 to 55 psig (345 to 380 kPa) [or 160 psig (1103 kPa) for nitrogen], and are in addition to the minimum requirements listed in 4-4.1.2.

4-4.1.5.1 Pipelines, shutoff valves, and station outlets for systems at nonstandard pressures [50 psig (345 kPa) for systems other than nitrogen at 160 psig (1103 kPa)] shall be labeled for gas name and operating pressure.

4-4.1.5.2 Where operating pressures are 200 to 300 psig (1380 to 2068 kPa):

(a) Only Type K ASTM B819 (copper tube) shall be used.

(b) Brazing procedures and brazers shall be qualified as required under 4-4.1.4.2(a). On-site testing, as permitted under 4-4.1.4.2(b), shall be prohibited.

4-4.1.5.3 Station outlets for use with systems operated at nonstandard pressure [50 psig (345 kPa) for systems other than nitrogen at 160 psig (1103 kPa)] shall additionally meet the following criteria:

(a) Be gas-specific.

(b) Be pressure-specific where a single gas is piped at more than one operating pressure [e.g., a station outlet for oxygen, 80 psig (550 kPa) shall not accept an adapter for oxygen, 50 psig (345 kPa)].

(c) If operated at a pressure above 80 psig (550 kPa) but below 200 psig (1380 kPa), be either DISS style or comply with 4-4.1.2.4.

(d) If operated at a pressure between 200 and 300 psig (1380 to 2068 kPa), the station outlet shall be so designed as to prevent the removal of the adapter until the pressure has been relieved, to prevent the adapter injuring the user or others when removed from the outlet.

(e) Be labeled for the gas name and operating pressure [e.g., nitrogen, 250 psig (1725 kPa)].

4-4.1.5.4 Testing. When systems operated at different pressures are installed, each pipeline shall be tested separately.

4-4.2 Patient Gas Distribution — Type II (Manifold, Piping, Valving/Controls, Outlets/Terminals, Alarms).

4-4.2.1 Mechanical means shall be provided to ensure the connection of cylinders containing the proper gas to the piping system. Cylinder valve outlets for nonflammable gases and gas mixtures for medical purposes shall comply with CGA Pamphlet V-1, *Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections* (ANSI B57.1; CSA B96).

4-4.2.2 The provisions of 4-3.1.8.3 shall apply.

4-4.2.3 Threaded connections between the regulators and the piping system shall comply with CGA Pamphlet V-5, *Diameter-Index Safety System.*

4-4.2.4 Flexible connectors of other than all-metal construction used to connect outlets of pressure regulators to fixed piping shall not exceed 5 ft (1.5 m) in length and shall not penetrate walls, floors, ceilings, or partitions. Flexible connectors shall comply with the provisions of 4-4.2.3.

4-4.2.5 A shutoff valve or check valve shall be installed downstream of each pressure regulator.

4-4.2.6 A pressure relief valve set at 50 percent above normal line pressure shall be installed downstream of the shutoff or check valve required in 4-4.2.5. Pressure relief valves shall be of brass or bronze and designed for oxygen service.

4-4.2.7* Supply systems supplying a single treatment facility as outlined in 4-6.2.4.1(c) shall contain as a minimum:

4-4.2.7.1 Two cylinders of oxygen and two cylinders of nitrous oxide (if used) if storage is remote, or two cylinders of oxygen and one cylinder of nitrous oxide (if used) if storage is not remote.

4-4.2.7.2 The cylinders for each gas service shall be manifolded so that the cylinders can alternately supply the piping system. Each bank shall contain at least an average day's supply. When the content of the primary bank is unable to supply the system, the secondary bank shall be capable of being manually switched to supply the system. Automatic switchover shall be permitted.

4-4.2.7.3 When the supply system is remote, the switchover shall be automatic.

4-4.2.8* Supply systems supplying two single treatment facilities as outlined in 4-6.2.4.1(d) shall contain as a minimum:

4-4.2.8.1 Two cylinders of oxygen and two cylinders of nitrous oxide (if used).

4-4.2.8.2 The cylinders for each gas service shall be manifolded so that the cylinders can alternately supply the piping system. Each bank shall contain at least an average day's supply. When the content of the primary bank is unable to supply the piping system, the secondary bank shall automatically operate to supply the piping system.

4-4.2.9 Warning Systems for Gases.

4-4.2.9.1 An automatic pressure switch, which will actuate a visual and audible alarm when the line pressure drops below or increases above normal line pressure, shall be connected to each main supply line within a single treatment facility. (*See 4-5.2.4.*) The automatic pressure switch shall be installed downstream of any main supply line shutoff valve that may be required by the provisions of 4-4.2.12.2 or 4-4.2.12.3.

4-4.2.9.2 A warning system as required in 4-4.2.9.1 shall be installed in each single treatment facility served by the supply system. The warning system shall be comprised of an audible and noncancellable visual signal and shall be installed to be heard and seen at a continuously attended location during the time of operation of the facility.

4-4.2.9.3 A warning system as outlined in 4-4.2.9.2 shall be installed to indicate whenever automatic changeover occurs or is about to occur. The signal shall remain uncancellable until the reserve supply bank has been replenished. The sensor alarm shall be independent of the sensor actuator of 4-4.2.9.1. When two treatment facilities are served by a common supply system, the automatic changeover alarm shall indicate in both facilities.

4-4.2.9.4 Warning systems for two single treatment facilities shall conform to 4-4.2.9.1, 4-4.2.9.2, and 4-4.2.9.3, and shall be independent.

4-4.2.10 Pressure Gauges for Gas Systems. A pressure gauge shall be installed in the main line adjacent to the actuating switch required in 4-4.1.1.2(f). It shall be appropriately labeled and be readily visible from a standing position. (*See C-4.2.14.*)

4-4.2.11* Gas Piping.

4-4.2.11.1 The provisions of 4-4.1.2.1 shall apply.

Exception: Annealed (soft temper) ASTM B88 (Type K or L) copper tube that has been prepared for oxygen service according to CGA Pamphlet G-4.1, Cleaning Equipment for Oxygen Service, shall be permitted to be used up to $\frac{1}{2}$ in. OD maximum size.

4-4.2.11.2 Fittings shall comply with 4-4.1.2.1

Exception: Flared connections in ASTM B88 tube shall be permitted where exposed at station outlets and manifold connections.

4-4.2.12 Gas Shutoff Valves.

4-4.2.12.1* Where the central supply is remote from the medical gas system use points, the main supply line shall be provided with a shutoff valve so located in the single treatment facility as to be accessible from use-point locations in an emergency.

4-4.2.12.2 Where the supply is remote from a single treatment facility, the main supply line shall be provided with a shutoff valve so located in the single treatment facility as to be accessible from use-point locations in an emergency. Such valves shall be labeled to indicate the gas controlled and shall shut off only the gas to that single treatment facility. A remotely activated shutoff at the supply cylinder shall not be used for emergency shutoff. For clinical purposes, such a remote actuator shall not fail-closed in the event of a loss of electric power. If remote actuators are the type that fail-open, it shall be mandatory that cylinder shutoff valves be closed whenever the system is not in use. (*See 4-6.2.4.7.*)

4-4.2.12.3 Where the central supply system supplies two single treatment facilities, each facility shall be provided with a shutoff valve so located in each treatment facility as to be accessible from the use-point locations in an emergency. Such valves shall be labeled to indicate the gas controlled and shall shut off only the gas to that single treatment facility. A remotely activated shutoff at the supply manifold shall not be used for emergency shutoff valves for dual treatment facility installations. For clinical purposes, such a remote actuator shall not fail-closed in the event of a loss of electric power. If remote actuators are the type that fail-open, it shall be mandatory that cylinder shutoff valves be closed whenever the system is not in use. (*See 4-6.2.4.7.*)

4-4.2.12.4 The provisions of 4-4.1.2.2(d) shall apply to any installation with risers off the main line.

4-4.2.13 Gas Station Outlets.

4-4.2.13.1 The provisions of 4-4.1.2.4 shall apply.

4-4.2.13.2 Station outlets shall be located at an appropriate height above the floor to prevent physical damage to equipment attached to the outlet.

NOTE: Station outlets may be recessed or otherwise protected from damage.

4-4.2.13.3 Station outlets shall be located to avoid physical damage to the valve and attached equipment.

4-4.3 Laboratory Gas Distribution (Manifold, Piping, Valving/Controls, Outlets/Terminals, Alarms).

4-4.3.1 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 1 hour and be ventilated in accordance with 4-3.1.2, 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 shall be permitted to be waived.

4-4.3.2 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 4-4.3.1, and

(c) Cylinders shall be secured in position.

4-4.3.3 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.

4-4.3.4 Pressure regulators shall be compatible with the gas for which they are used.

4-4.3.5* 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.*

4-4.3.6 Piping systems for gaseous hydrogen shall comply with NFPA 50A, *Standard for Gaseous Hydrogen Systems at Consumer Sites.*

4-4.3.7 Piping systems for nonflammable gases shall comply with Type I gas systems as specified in this chapter.

4-4.3.8 Piping systems for acetylene shall comply with NFPA 51, *Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes.*

4-4.3.9 Supply and discharge terminals of piping systems shall be legibly and permanently marked at both ends with the name of the gas piping, after testing, to establish their content and continuity.

4-4.3.10 Piping systems shall not be used for gases other than those for which they are designed and identified.

4-4.3.11 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 when oil, grease, or other readily oxidizable materials are present; 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.

4-4.4 Other Gases. (*See NFPA 54, National Fuel Gas Code, for information on fuel gases.*)

4-5 Gas Systems Performance Criteria and Testing.

4-5.1 Patient Gas System — Type I.

4-5.1.1 General. Inspection and testing shall be performed on all new piped gas systems, additions, renovations, or repaired systems, to assure the facility, by certification, that all applicable provisions of this document have been adhered to and system integrity has been achieved or maintained.

This inspection and testing shall include all components of the system or portions thereof including, but not limited to, gas bulk source(s), manifolds, compressed air source systems (e.g., compressors, dryers, filters, regulators), source alarms and monitoring safeguards, master alarms, pipelines, isolation valves, area alarms, zone valves, station outlets, and terminal outlets.

All systems that are breached and components that are subject to additions, renovations, or replacement (e.g., new gas sources-bulk, manifolds, compressors, dryers, alarms) shall be inspected and appropriately tested.

Systems shall be deemed breached at the point of pipeline intrusion by physical separation or by system component removal, replacement, or addition. The breached portions of the systems, subject to inspection and testing, shall be all the new and existing components in the immediate zone or area that is located upstream and downstream of the point or area of intrusion.

The inspection and testing reports shall be certified and submitted directly to the responsible facility authority, the authority having jurisdiction, and the installer. These reports shall contain detailed listings of all findings, results, and any corrective actions that may have been performed.

The responsible facility authority shall review these inspection and testing records prior to the use of all systems. This responsible facility authority shall ensure that all findings and results of the inspection and testing have been successfully completed, and all documentation pertaining thereto shall be maintained on-site within the facility.

Before piping systems are initially put into use, the health care facility 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.

4-5.1.2 Installer Performance Testing. The following tests shall be conducted by the installer or representative prior to those tests listed in 4-5.1.3, "System Verification." Test gas shall be oil-free dry nitrogen.

4-5.1.2.1* Pressure Test (Initial). Before attachment of system components (e.g., pressure-actuating switches for alarms, manifolds, pressure gauges, or pressure relief valves), but after installation of the station outlets, with test caps (if supplied) in place (e.g., rough-in assembly), and before closing of the walls, each section of the piping system shall be subjected to a test pressure of 1.5 times the

working pressure [minimum 150 psig (1 MPa gauge)] with oil-free, dry nitrogen (*see Section 2-2, "Definitions"*). This test pressure shall be maintained until each joint has been examined for leakage by means of soapy water or other equally effective means of leak detection safe for use with oxygen. The source shutoff valve shall be closed. Leaks, if any, shall be located, repaired, and retested in accordance with this paragraph.

4-5.1.2.2 Blowdown Test. After installation of the piping, but before installation of the station outlets and other medical gas system components (e.g., pressure-actuating switches for alarms, manifolds, pressure gauges, or pressure relief valves), the line shall be blown clear by means of oil-free dry nitrogen (*see Section 2-2, "Definitions"*).

4-5.1.2.3* Pressure Test. After testing of each individual medical gas system in accordance with 4-5.1.2.1, the completely assembled station outlets and all other medical gas system components (e.g., pressure-actuating switches for alarms, manifolds, pressure gauges, or pressure relief valves) shall be installed, and all piping systems shall be subjected to a 24-hour standing pressure test at 20 percent above the normal operating line pressure. The test gas shall be oil-free, dry nitrogen (*see definitions*). The source shutoff valve shall be closed.

(a) After the piping system is filled with test gas, the supply valve and all outlets shall be closed and the source of test gas disconnected. The piping system shall remain leak-free for 24 hours. When making the standing pressure test, the only allowable pressure changes during the 24-hour test period shall be those caused by variations in the ambient temperature around the piping system. Such changes shall be permitted to be checked by means of the following pressure-temperature relationship: the calculated final absolute pressure (absolute pressure is gauge pressure plus 14.7 psig if gauge is calibrated in psig) equals the initial absolute pressure times the final absolute temperature (absolute temperature is temperature reading plus 460°F if thermometer is calibrated in Fahrenheit degrees), divided by the initial absolute temperature.

$$\left(P_f = \frac{P_i \times T_f}{T_i}\right)$$

(b) Leaks, if any, shall be located, repaired, and retested in accordance with 4-5.1.2.3

4-5.1.2.4 Piping Purge. In order to remove particulate matter in the pipelines, a heavy, intermittent purging of the pipeline shall be done. The appropriate adapter shall be obtained, and a high-flow purge shall be put on each outlet. The outlet shall be allowed to flow fully until the purge produces no discoloration in a white cloth.

4-5.1.2.5 Cross-Connection Test.

(a) Prior to closing of walls, it shall be determined that no cross-connection of piping systems exists. All medical gas systems shall be reduced to atmospheric pressure. All sources of test gas shall be disconnected from all of the medical gas systems with the exception of the one system to be checked. This system shall be pressurized with oil-free nitrogen (*see definitions*) to 50 psig (350 kPa gauge). With appropriate adapters matching outlet labels, each individual station outlet of all medical gas systems installed shall be checked to determine that test gas is being dispensed only from the outlets of the medical gas system being tested.

(1) The source of test gas shall be disconnected and the system tested shall be reduced to atmospheric pressure. Proceed to test each additional piping system in accordance with 4-5.1.2.5(a).

(2) Where a medical vacuum piping system is installed, the cross-connection testing shall include that piped vacuum system with all medical gas piping systems.

(3) All medical-surgical vacuum systems shall be in operation so that these vacuum systems are tested at the same time the medical gas systems are tested.

(4) Each station outlet shall be identified by label (and color marking, if used).

(b) The presence and correctness of labeling required by this standard for all components (e.g., station outlets, shutoff valves, and signal panels) shall be verified.

4-5.1.3 System Verification. The following tests shall be performed after those listed in 4-5.1.2, "Installer Performance Testing." The test gas shall be oil-free, dry nitrogen.

This testing shall be conducted by a party technically competent and experienced in the field of medical gas pipeline testing.

4-5.1.3.1 Cross-Connection Test.

(a) After closing of walls and completion of requirements of 4-5.1.2, it shall be determined that no cross-connection of piping systems exists. All medical gas systems shall be reduced to atmospheric pressure. All sources of test gas from all of the medical gas systems, with the exception of the one system to be checked, shall be disconnected. This system shall be pressurized with oil-free nitrogen (*see definitions*) to 50 psig (350 kPa gauge). With appropriate adapters matching outlet labels, each individual station outlet of all medical gas systems installed shall be checked to determine that test gas is being dispensed only from the outlets of the medical gas system being tested.

(1) The source of test gas shall be disconnected and the system tested reduced to atmospheric pressure. Proceed to test each additional piping system in accordance with 4-5.1.3.1(a).

(2) Where a medical vacuum piping system is installed, the cross-connection testing shall include that piped vacuum system with all medical gas piping systems.

(3) An alternate method of testing to ensure that no cross-connections to other piping systems exists follows:

(i) Reduce the pressure in all medical gas systems to atmospheric.

(ii) Increase the test gas pressure in all medical gas piping systems to the values indicated in Table 4-5.1.3.1(a)(3). Simultaneously maintain these nominal pressures throughout the test.

(iii) Any medical-surgical vacuum systems shall be in operation so that these vacuum systems are tested at the same time the medical gas systems are tested.

Table 4-5.1.3.1(a)(3) Alternate Test Pressures

Medical Gas	Pressure psig	Pressure kPa gauge
Gas Mixtures	20	140
Nitrogen	30	210
Nitrous Oxide	40	280
Oxygen	50	350
Compressed Air	60	420

NOTE: Systems at nonstandard pressures shall be tested at a pressure at least 10 psi (69 kPa) greater or less than any other system.

(iv) Following the adjustment of pressures in accordance with 4-5.1.3.1(a)(3)(ii) and (iii), each station outlet for each medical gas system shall be tested using the gas-specific connection for each system with a pressure (vacuum) gauge attached. Each pressure gauge used in performing this test shall be calibrated with the line pressure regulator gauge used to provide the source pressure.

(v) Each station outlet shall be identified by label (and color marking, if used), and the pressure indicated on the test gauge shall be that listed in 4-5.1.3.1(a)(3)(ii) for the system being tested.

(b) The presence and correctness of labeling required by this standard for all components (e.g., station outlets, shutoff valves, and signal panels) shall be verified.

4-5.1.3.2 Valve Test. Valves installed in each medical gas piping system shall be tested to verify proper operation and rooms or areas of control. Records shall be made listing the rooms or areas controlled by each valve for each gas. The information shall be utilized to assist and verify the proper labeling of the valves.

4-5.1.3.3 Flow Test.

(a) All outlets shall be tested for flow. Tests shall be performed with the use of oil-free, dry nitrogen as described in CGA P-9, *Inert Gases: Argon, Nitrogen and Helium.*

(b) Oxygen, nitrous oxide, and air outlets shall deliver 3.5 SCFM with a pressure drop of no more than 5 psig (35 kPa), and static pressure of 50 psig (349 kPa).

(c) Nitrogen outlets shall deliver 5.0 SCFM with a pressure drop of no more than 5 psig and static pressure of 160 psig (1118 kPa).

4-5.1.3.4 Alarm Testing.

(a) *General.* All warning systems for each medical gas piping system shall be tested to ensure that all components function properly prior to placing the piping system in service. Permanent records of these tests shall be maintained. (*See Appendix C-4.1.*)

Warning systems that are part of an addition to an existing piping system shall be tested prior to the connection of the new piping to the existing system.

(b) *Warning Systems.* Tests of warning systems for new installations (initial tests) shall be performed after the cross-connection testing (4-5.1.3.1), but before the purging and verifying (4-5.1.3.5). Initial tests of warning systems that may be included in an addition or extension to an existing piping system shall be completed before connection of the addition to the existing system. Test gases for the initial tests shall be oil-free, dry nitrogen.

(c) *Master Alarm Systems.*

(1) The master alarm system tests shall be performed for each of the nonflammable medical gas piping systems. Permanent records of these tests shall be maintained with those required under 4-6.3.1.

(2) The audible and noncancellable visual signals of 4-4.1.1.2(f) shall indicate if the pressure in the main line increases or decreases 20 percent from the normal operating pressure.

(d) *Area Alarm Systems.* The warning signals for all medical gas piping systems supplying anesthetizing locations and other vital life-support and critical care areas, such as postanesthesia recovery, intensive care units, coronary care units, etc., shall indicate if the pressure in the piping system increases or decreases 20 percent from the normal operating pressure. [*See 4-4.1.1.3(a).*]

4-5.1.3.5 Piping Purge Test. In order to remove any traces of particulate matter deposited in the pipelines as a result of construction, a heavy, intermittent purging of the pipeline shall be done. The appropriate adapter shall be obtained from the facility or manufacturer, and high purge rates of at least 225 L per min. (8 cfm) shall be put on each outlet. After the purge is started, it shall be rapidly interrupted several times until the purge produces no discoloration in a white cloth loosely held over the adapter during the purge. In order to avoid possible damage to the outlet and its components, this test shall not be conducted using any implement other than the proper adapter.

For each positive-pressure gas system, cleanliness of piping system shall be verified. Filter a minimum of 35 cu ft (1000 L) of gas through a clean, white 0.45-micron filter at a minimum flow of 3.5 SCFM (100 Lpm). Filter shall show no discoloration, and shall accrue no more than 0.1 mg of matter. Each zone shall be tested at the outlet most remote from the source. Test shall be performed with the use of oil-free, dry nitrogen described in CGA P-9.

4-5.1.3.6 Piping Purity Test. For each positive-pressure system, the purity of the piping system shall be verified. Test each zone at the most remote outlet for dew point, total hydrocarbons (as methane), and halogenated hydrocarbons, and compare with source gas. The two tests shall in no case exceed variation as specified in the Maximum Allowable Variation Table, which follows. Test shall be performed with the use of oil-free nitrogen gas as described in CGA P-9.

Maximum Allowable Variation Table

Dew Point	5°C @ 50 psig
Total Hydrocarbons as Methane	± 1 ppm
Halogenated Hydrocarbons	± 2 ppm

4-5.1.3.7* Final Tie-in Test. Prior to the connection of any work or any extension or addition to an existing piping system, the tests in 4-5.1.3.1 through 4-5.1.3.6 shall be successfully performed. After connection to the existing system and before use of the addition for patient care, the

tests in 4-5.1.3.8 through 4-5.1.3.10 shall be completed. Permanent records of these tests shall be maintained in accordance with 4-6.3.1.

The final connection between the addition and existing system shall be leak-tested with the gas of system designation at the normal operating pressure. This pressure shall be maintained until each joint has been examined for leakage by means of soapy water or other equally effective means of leak detection safe for use with oxygen.

4-5.1.3.8 Operational Pressure Test.

(a) Piping systems, with the exception of nitrogen systems, shall maintain pressure at 50 +5/-0 psig (345 +35/-0 kPa gauge) at all station outlets at the maximum flow rate in 4-5.1.3.8(d) and (e).

(b) A nitrogen system shall be capable of delivering at least 160 psig (1100 kPa gauge) to all outlets at flow in 4-5.1.3.8(e).

(c) Piping systems that vary from the normal pressures in 4-5.1.3.8(a) and (b) shall be capable of delivering flows and pressures consistent with their intended use.

(d) Oxygen, nitrous oxide, and air outlets shall deliver 3.5 SCFM with a pressure drop of no more than 5 psig (35 kPa) and static pressure of 50 psig (350 kPa).

(e) Nitrogen outlets shall deliver 5.0 SCFM with a pressure drop of no more than 5 psig (35 kPa) and static pressure of 160 psig (1118 kPa).

4-5.1.3.9 Medical Gases Concentration Test.

After purging each system with the gas of system designation, the following shall be performed:

(a) Each pressure gas source and outlet shall be analyzed for concentration of gas, by volume.

(b) Analysis shall be with instruments designed to measure the specific gas dispensed.

(c) Allowable concentrations shall be within the following:

Oxygen	99 plus percent oxygen
Nitrous Oxide	99 plus percent nitrous oxide
Nitrogen	Less than 1 percent oxygen or 99 plus percent nitrogen
Medical Air	19.5 percent to 23.5 percent oxygen
Other Gases	Concentration as specified by their labeling ± 1 percent, unless otherwise specified

4-5.1.3.10 Medical Air Purity Test (Compressor). Analyze medical air source for concentration of contaminants, by volume. Take samples for air system test at a sample point. The compared tests shall in no case exceed variation as specified under the Maximum Allowable Variation Table (*see 4-5.1.3.6*). Allowable concentrations shall be as follows:

Dew Point	+39°F (4°C) @ 50 psig
Carbon Monoxide	≤10 ppm
Carbon Dioxide — Air	≤500 ppm
Gaseous Hydrocarbons — Air	≤25 ppm (as methane)
Halogenated Hydrocarbons — Air	≤2 ppm

4-5.1.4 Source Equipment Verification. This testing shall be conducted by a party technically competent and experienced in the field of medical gas pipeline testing.

4-5.1.4.1 Gas Supply Sources.

(a) The system apparatus shall be tested for proper function, including the changeover from one cylinder bank to the other and the actuation of the changeover signal, before the system is put into service.

Table 4-5.1.4 Required Master Alarm Signals

Source Equipment	Changeover	Reserve in Use	Reserve Failure	Reserve Low	Dew Point High
Manifolds	Yes	NA	No	Note A	No
Manifolds with Reserve	Yes	Yes	No	Note A	No
Cryogenic Bulk Gas Units (VIE) with Cryogenic Reserve	Yes	Yes	Yes	Yes	No
Cryogenic Bulk Gas Units (VIE) with Cylinder Reserve	Yes	Yes	No	Note A	No
Air Compressors	No	No	No	No	Yes
Vacuum Pumps	No	No	No	No	No
Reference(s)	4-3.1.5.1 4-3.1.6.1(b) 4-3.1.7.1(a)	4-3.1.6.1(c) 4-3.1.6.3 4-3.1.7.1	4-3.1.7.2(c)	4-3.1.6.2 4-3.1.7.2(b)	4-3.1.9.8

Note A: This signal is required only where cylinder reserves have no check valves for each cylinder lead.

Pipeline	High Pressure or Vacuum	Low Pressure or Vacuum	Reference(s)
All Pressure Gas Systems	Yes	Yes	4-4.1.1.2(f)
Vacuum Systems	No	Yes	4-9.1.1.7(a) and (e)

This table has been added for the convenience of the user of the document. Readers should turn to the text referenced for specific requirements.

(b) The system apparatus shall be tested for proper function, including the changeover from primary to secondary supply (with its changeover signal) and the operation of the reserve (with its reserve in use signal), before the system is put into service.

(c) If the system has an actuating switch and signal to monitor the contents of the reserve, its function shall be tested before the system is put into service.

(d) The bulk supply signal and the master signal panel installations shall be arranged with the owner or the organization responsible for the operation and maintenance of the supply system for the testing of the bulk supply signals to ensure proper identification and activation of the master signal panels to be sure the facility can monitor the status of that supply system. These tests shall also be conducted when changing storage units.

(e) For master alarm systems, the manufacturer's operating instructions shall be followed, or the assistance of the owner or the organization responsible for the operation and maintenance of the bulk supply system shall be requested for the following tests.

(1) Pressurize the piping system and connect the electric power to the signal panels.

(2) Check the main-line pressure gauge [*see 4-4.1.1.4(a)*] to ascertain that it indicates the desired pressure (*see 4-5.1.3.8*) and is properly labeled. Check the alarm signal panels to ensure that they indicate normal operation and that none of the warning signals are activated.

4-5.1.4.2 Medical Air Compressor.

(a) The proper functioning of the medical compressed air system shall be tested before it is put into service. This shall include the purity test for air quality, and the test of the alarm sensors after calibration and setup per the manufacturer's instructions and automatic switchover as outlined in 4-3.1.9.8.

(b) The following tests shall be conducted at the sample point of the medical air system.

(1) The operation of the system control sensors, such as dew point, air temperature, and all other air-quality monitoring sensors and controls, shall be checked for proper operation and function before the system is put into service.

(2) The quality of medical compressed air as delivered by the compressor air supply shall be verified upon installation and after 24 hours of operation at a sample point downstream of the pressure regulator and upstream of the piping system as defined in Figure 4-3.1.9.

4-5.2 Patient Gas System — Type II.

4-5.2.1 (Reserved)

4-5.2.2 (Reserved)

4-5.2.3 Gas System Test (Pressure, Valves, Etc.).

4-5.2.3.1 The medical gas system, including cylinders and pressure regulators, shall deliver gas at a pressure per 4-5.1.3.8.

4-5.2.3.2 Flexible connectors of other than all-metal construction used to connect outlets of pressure regulators to fixed piping shall have a minimum burst pressure of 1000 psig (7000 kPa gauge). (*See 4-4.2.4.*)

4-5.2.3.3 The pressure relief valve specified in 4-4.2.6 shall close automatically when excess pressure has been released.

4-5.2.4 Alarm Testing for Gas Systems. The automatic pressure switch connected to each main supply line within a single treatment facility shall actuate a visual and audible alarm when the line pressure drops approximately 20 percent below or increases approximately 20 percent above normal line pressure. (*See 4-4.2.9.*)

4-5.2.5* Installation and Testing of Gas Piping Systems. The provisions of 4-5.1.2 and 4-5.1.3 shall apply.

4-6 Administration of Gas Systems.

4-6.1 Responsibility of Governing Body. (Reserved)

4-6.2 Policies.

4-6.2.1 Gases in Cylinders and Liquefied Gases in Containers.

4-6.2.1.1* Handling of Gases. Administrative authorities shall provide regulations to ensure 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 facility.

4-6.2.1.2 Special Precautions — Oxygen Cylinders and Manifolds. 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 CGA 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 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 all persons.

(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 cylinder or any other cylinder.

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

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

(l) Oxygen equipment that 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 or her 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 will 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) Valves shall be closed on all empty cylinders in storage.

(q) 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*.

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

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

(t) 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.

(u) 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.

(v) Markings used for the identification of contents of cylinders shall not be defaced or removed, including decals, tags, stenciled marks, and upper half of shipping tag.

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

(x) 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.

(y) 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.

(z) Cylinders and containers shall not be dropped, dragged, or rolled.

(aa) Freestanding cylinders shall be properly chained or supported in a proper cylinder stand or cart.

(bb) Cylinders shall not be chained to portable or movable apparatus such as beds and oxygen tents.

(cc) 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.

(dd) Very cold cylinders or containers shall be handled with care to avoid injury.

(ee) Cylinders and containers shall not be handled with hands, gloves, or other materials contaminated with oil or grease.

4-6.2.1.3 Making Cylinder and Container Connections.

(a) 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.

(b) Cylinder valves shall be opened and connected in accordance with the following procedure:

(1) Make certain that apparatus and cylinder valve connections and cylinder wrenches are free of foreign materials.

(2) 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.

(3) Make connection of apparatus to cylinder valve. Tighten connection nut securely with an appropriate wrench [*see 4-6.2.1.3(a)*].

(4) Release the low-pressure adjustment screw of the regulator completely.

(5) Slowly open cylinder valve to full open position.

(6) Slowly turn in the low-pressure adjustment screw on the regulator until the proper working pressure is obtained.

(7) Open the valve to the utilization apparatus.

(c) Connections for containers shall be made in accordance with the container manufacturer's operating instructions.

4-6.2.1.4 Care of Safety Mechanisms.

(a) Personnel using cylinders and containers and other equipment covered in this chapter shall be familiar with the Pin-Index Safety System (*see 8-3.1.2*) and the Diameter-Index Safety System (*see 8-3.1.3*), both designed to prevent utilization of the wrong gas.

(b) Safety relief mechanisms, noninterchangeable connectors, and other safety features shall not be removed, altered, or replaced.

4-6.2.1.5 Transfilling Cylinders.

(a) Mixing of compressed gases in cylinders shall be prohibited.

(b) Transfer of gaseous oxygen from one cylinder to another shall be in accordance with CGA Pamphlet P-2.5, *Transfilling of High Pressure Gaseous Oxygen to Be Used for Respiration*. Transfer of any gases from one cylinder to another in patient care areas of health care facilities shall be prohibited.

4-6.2.1.6 Transferring of Liquid Oxygen. 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.

4-6.2.1.7 Laboratory Gases.

(a)* *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.*)

(b) *Cylinders.* In a laboratory, gas cylinders being held for prompt use shall not exceed one cylinder of the sizes stated in 4-3.3.3 or 2 days' working needs, except as permitted in 4-4.3.1. Cylinders shall be in racks or secured in position.

(c) *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.

4-6.2.2 Storage of Cylinders and Containers.

4-6.2.2.1 Facility authorities, in consultation with medical staff and other trained personnel, shall provide and enforce regulations for the storage and handling of cylinders and 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 a 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.

4-6.2.2.2 Nonflammable Gases.

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

(b) 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.

(c) 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.

4-6.2.2.3 Flammable Agents. Facility administrative authorities, in consultation with the medical staff and others with training and expertise, shall determine the adequacy of storage space for flammable anesthetic and disinfecting agents and medicaments (*see 4-3.1.2.4*) 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.

4-6.2.3 Patient Gas Systems — Type I.

4-6.2.3.1 Piping systems shall not be used for the distribution of flammable anesthetic gases.

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

4-6.2.3.2 Nonflammable medical gas systems used to supply gases for respiratory therapy shall be installed in accordance with Sections 4-3 and 4-4 of this chapter.

4-6.2.3.3 Maintenance programs in accordance with the manufacturer's recommendations shall be established for the medical air compressor supply system as connected in each individual installation.

4-6.2.3.4* The responsible authority of the facility shall establish procedures to ensure that all signal warnings are promptly evaluated and that all necessary measures are taken to reestablish the proper functions of the medical gas system.

4-6.2.3.5 Piping systems for gases shall not be used as a grounding electrode.

4-6.2.3.6 Complete Loss of Any Medical Gas System. The facility shall have the capability and organization to implement a plan to cope with a complete loss of any medical gas system.

4-6.2.3.7 A periodic testing procedure for nonflammable medical gas and related alarm systems shall be implemented.

4-6.2.3.8 The test specified in 4-5.1.3.9 shall be conducted on the downstream portions of the medical gas piping system whenever a system is breached or whenever modifications are made or maintenance performed.

4-6.2.3.9 Periodic retesting of audible and visual alarm indicators shall be performed to determine that they are functioning properly, and records of the test shall be maintained until the next test. (*See Appendix C-4.2.*)

4-6.2.4 Patient Gas Systems — Type II.

4-6.2.4.1* Type II systems cover nonflammable gas system installations that:

(a) Have not more than 3000 cu ft (85 m^3) total capacity of all gases (excluding nitrogen) connected and in storage at one time, except that the total capacity of all gases shall be permitted to be increased to 5000 cu ft (143 m^3) (excluding nitrogen) if oxygen is used in a DOT Specification 4L (liquid) cylinder, and

(b) Have a listed pressure regulator directly connected to each cylinder, and

(c) Supply only a single treatment facility and also as a minimum comply with the specific requirements of 4-4.2.7, or

(d) Supply a maximum of two single treatment facilities and also as a minimum comply with the specific requirements of 4-4.2.8.

4-6.2.4.2 Single treatment facilities for nonhuman use of medical gas, such as veterinary medicine, shall not be subject to the provisions of 4-4.2.7 and 4-4.2.9.2.

4-6.2.4.3 The provisions of 4-3.1.3 and 4-6.2.3.3 apply.

4-6.2.4.4 Type II systems shall be installed in accordance with Type I systems except as provided by 4-6.2.4.

4-6.2.4.5 Medical gas systems not specifically provided for in 4-6.2.4.1, such as systems within a hospital served by a central supply system or systems serving three or more treatment facilities, as may be found in a medical or dental office building, shall comply in all respects with Type I systems.

4-6.2.4.6 Equipment shall be obtained from and be installed under the supervision of a manufacturer or supplier familiar with proper practices for its construction and use.

4-6.2.4.7 Every facility shall establish a procedure for manually turning off the gas supply at the cylinder valves at the end of the work day, or when the facility is not in use.

4-6.3 Recordkeeping for Gas Systems.

4-6.3.1* Patient Gas Systems — Type I. Prior to the use of any medical gas piping system for patient care, the responsible authority of the facility shall ensure that all tests required in 4-5.1 have been successfully conducted and permanent records of the test maintained in the facility files.

4-6.4 Information and Warning Signs for Gas Systems.

4-6.4.1 Patient Gas Systems — Type I.

4-6.4.1.1 The gas content and operating pressure of medical gas piping systems shall be readily identifiable by appropriate labeling with the name and pressure of the gas contained. 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 piping at intervals of not more than 20 ft (6 m) and at least once in each room and each story traversed by the piping system. Where supplementary color identification of piping is used, it shall be in accordance with the gases and colors indicated in CGA Pamphlet C-9, *Standard Color-Marking of Compressed Gas Cylinders Intended for Medical Use.*

4-6.4.1.2 The shutoff valves described in 4-4.1.2.2(a), 4-4.1.3.2, and 4-4.1.3.3 shall be labeled in substance as follows:

> CAUTION — (NAME OF MEDICAL GAS) VALVE
> DO NOT CLOSE EXCEPT IN EMERGENCY
> THIS VALVE CONTROLS SUPPLY TO . . .

4-6.4.1.3 Pressure gauges and manometers for medical gas piping systems shall be identified: (NAME OF GAS) USE NO OIL!

4-6.4.2 Patient Gas Systems — Type II. The shutoff valves of 4-4.2.12 shall be labeled to indicate the gas controlled and to indicate that they are to be closed only in an emergency.

4-6.5 Transport and Delivery.

4-6.5.1 Personnel concerned with use and transport of equipment shall be trained in proper handling of cylinders, containers, hand trucks, supports, and valve protection caps.

4-6.5.2 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 8-5.2.

NOTE: Sections 4-3 through 4-6 cover requirements for pressurized centrally piped *gas* systems; Sections 4-7 through 4-11 cover requirements for centrally piped *vacuum* systems.

4-7 Vacuum Systems.

4-7.1 Patient Vacuum Systems.

4-7.1.1 General. The locations and number of vacuum system station inlets in a system shall be determined by consultation with medical and facility staff having knowledge of the requirements for, and the utilization of, vacuum in each space or patient location.

4-7.1.2* Number of Vacuum Station Inlets. Table 4-7.1.2 sets forth the minimum number of vacuum system station inlets for patient suction therapy, but does not include station inlets for disposing of waste anesthetic gases.

4-7.2 Nonpatient Vacuum Systems. (Reserved)

4-8 Vacuum System Sources.

4-8.1 Patient Vacuum Source.

4-8.1.1* Medical-Surgical Vacuum Pumps.

(a) *Multiple Pumps.* The central vacuum source shall consist of two or more vacuum pumps that, alternately or simultaneously on demand, serve the vacuum system. Each

Table 4-7.1.2 Minimum Number of Vacuum Station Inlets (without Waste Anesthetic Gas Disposal)

NOTE: If it is intended to use the vacuum system for waste anesthetic gas disposal, provision for an additional station inlet should be made.

Anesthetizing Locations	
Operating Room	3/room
Cytoscopy	3/room
Delivery	3/room
Special Procedures	3/room
Other Anesthetizing Locations	3/room
Acute Care Locations (Nonanesthetizing Locations)	
Recovery Room	3/bed
Intensive Care Units (Except Cardiac)	3/bed
Special Procedures	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
Birthing Rooms	2/room
Subacute Patient Care Areas (Nonanesthetizing Locations)	
Nurseries	1/bed
Patient Rooms	1/bed
Exam and Treatment Rooms	1/bed
Respiratory Care	Convenience
Other	
Autopsy	1/table
Central Supply	Convenience
Equipment Repair, Calibration, and Teaching	Convenience

vacuum system shall be served by two or more vacuum pumps that, alternately or simultaneously on demand, supply the vacuum system. In the event that 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 centrally piped system and other pump(s) for maintenance or repair without loss of vacuum in the piping system.

NOTE 1: Depending on anticipated vacuum system demand and utilization, as determined by consultation with the medical hospital staff, two or more centrally piped 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 tube 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 problems.

NOTE 3: Consideration should be given to being able to interconnect two or more duplex pump systems.

(b) *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 facility.

(c)* *Backup Operation.* A device shall be provided to automatically activate the additional pump unit(s) if the pump in operation is incapable of maintaining minimum required vacuum.

A local audible and visual signal shall be provided to indicate when the reserve or off-duty vacuum pump is in operation.

(d) *Electrical Power.* Electrical equipment and wiring shall conform to the requirements of NFPA 70, *National Electrical Code*. Emergency electrical service for the vacuum pumps shall conform to the requirements of Chapter 3 of this document.

(e) *Pump Motors and Controls.* Each vacuum pump motor shall be provided with a separate disconnecting device, motor-starting device, and overload protection. The 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 any vacuum pump will not affect the operation of the remaining pump(s).

(f) *Receivers (Tanks).* Receiver(s) shall be installed where the size of the vacuum system would cause excessive cycling of the pump(s). Receivers shall comply with Section VIII ("Unfired Pressure Vessels") of the ASME *Boiler and Pressure Vessel Code* and shall meet the standing pressure tests of Section 4-10 of this chapter, and full vacuum. A suitable method shall be provided for drainage so that substances that might accumulate can be drained from the receiver(s) [tank(s)]. The method shall provide means to drain or service the receiver without interrupting the vacuum system.

NOTE: Characteristics of the vacuum pump and volume of the piping system are considerations for proper receiver sizing.

(g) *Piping.* All piping between vacuum pump(s), discharge(s), receiver(s), and vacuum main line valve shall be in accordance with 4-9.1.1.1(a).

(h)* *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. Where equipment is mounted on vibration isolators, flexible coupling shall be installed in the piping to and from the equipment. If used, flexible couplings shall be rated for temperature, and pressure or vacuum, at the point of installation.

(i) *Exhausts.* The exhaust from vacuum pumps shall be discharged outdoors in a manner that 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. Discharge of pumps utilizing common exhaust pipe shall be fitted with a check valve, a manual valve, or arranged to permit capping of the active pipe when removing or servicing a pump.

NOTE: Vacuum exhaust from separate pumps may be manifolded to a common exhaust line.

(j) *Typical Vacuum Source.* A schematic of a typical medical-surgical vacuum source is shown in Figure 4-8.1.1(j).

NOTICE
This paragraph (4-8.1.2) is under appeal to the NFPA Board of Directors. See NOTICE on page 14.

4-8.1.2 Waste Anesthetic Gas Disposal.

Where pumps are used in a dedicated vacuum system used for the disposal of anesthetic gases, these pumps shall conform to the requirements of 4-8.1.2.2.

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 4-11.2.1.6 and in 4-8.1.2.1.

4-8.1.2.1 Explosion Hazard. Flammable anesthetic or other flammable vapors shall be diluted below the lower flammable limit prior to disposal into the medical-surgical vacuum system.

NOTE 1: For further information, see Appendix A-5-4.2 on ANSI Z79.11, and Appendix C-12.1.3.1 on flammable anesthetic agents.

NOTE 2: Flammable and nonflammable gases are known to be incompatible with some 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 may cause deterioration of the vacuum system. The station inlet performance tests outlined in 4-11.2.1.4 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 vacuum system.

4-8.1.2.2 Pumps for Waste Anesthetic Gas Disposal.

Pumps of dedicated waste anesthetic gas disposal systems shall be water sealed or have inert materials in the compression chamber.

4-8.1.2.3 Fans for Waste Anesthetic Gas Disposal. (Reserved)

4-8.1.3 Dental Vacuum Source.

NOTE: The dental vacuum source provides suction for use in removing fluids and residue from operative procedures in oral cavities.

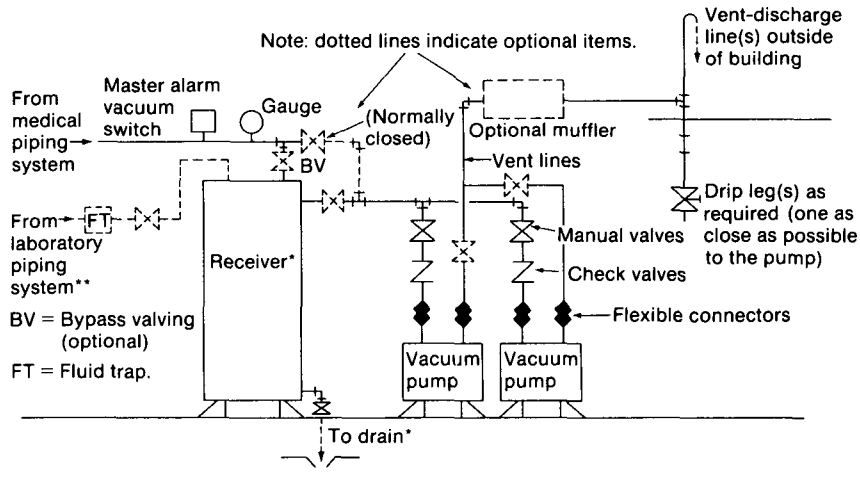
4-8.1.3.1 Dental vacuum pumps shall be suitable for the intended purpose. Dental vacuum discharge containing liquid shall be separated in a separator.

4-8.1.3.2 Fluids from the dental vacuum system shall be connected to the sanitary drainage system through an appropriately trapped drain.

4-8.1.3.3 The gas discharge from the dental vacuum system shall be piped to the outside, independent of the sanitary drainage system, and in accordance with 4-8.1.1(i).

4-8.2 Nonpatient Vacuum Source.

4-8.2.1 Laboratory Vacuum. Where only one set of vacuum pumps is available for a combined medical-surgical vacuum system and an analysis, research, or teaching laboratory vacuum system, such laboratories shall be connected separate from the medical-surgical system directly to the receiver tank through its own isolation valve and fluid trap located at the receiver. Between the isolation valve and fluid trap, a scrubber shall be permitted to be installed.



* See 4-8.1.1(i).
** See 4-8.2.1.

NOTE: Other arrangements that differ from this schematic in such items as the number of pumps, receivers, piping layout, etc., or other arrangements that meet specific recommendations of the vacuum source equipment manufacturer are permissible.

Figure 4-8.1.1(j) Typical medical-surgical vacuum source.

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 laboratory in patient care areas used in direct support of 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.

4-8.2.2 Other. (Reserved)

4-9 Vacuum System Distribution.

4-9.1 Patient Vacuum Distribution.

4-9.1.1 Medical-Surgical Vacuum (Piping, Valving/ Controls, Station Inlets, Alarms).

4-9.1.1.1 Vacuum System Piping Network.

(a) *Vacuum Piping.* All piping shall be constructed of seamless Type L, M, or ACR (ASTM B280) copper tube or other corrosion-resistant metallic tube such as stainless steel or galvanized steel. If vacuum tube is installed simultaneously with other medical gas tube, either it shall be labeled or otherwise identified prior to installation in order to preclude inadvertent inclusion into a medical gas system, or it shall be cleaned and degreased in accordance with 4-4.1.4. Copper tube shall be hard temper for exposed locations and soft temper for underground or concealed locations.

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 piping, or inadvertent switching of pipes. (*Also see Sections 4-3 through 4-6.*)

(b)* *Minimum Tube Sizing.* In both branch and main lines, the minimum tube size shall be not less than 1/2 in. nominal, except that smaller tube diameters shall be permitted for drops to individual station inlets and static lines to gauges and alarm actuators (vacuum switches). Tube size for drops to individual station inlets shall not be less than 1/4 in. inner diameter (ID).

(c) *Tube Supports.* Vacuum piping shall be supported directly from the building structure by pipe hooks, metal pipe straps, bands, or hangers suitable for the size of the tube and of proper strength and quality at proper intervals so that the supports are on the joints. Vacuum tube shall not be supported by other piping or ductwork. [*See Table 4-9.1.1.1(c).*] Piping supports shall be insulated from the pipe or be of a compatible material so as to prevent deterioration due to bimetallic electrolyte action.

Table 4-9.1.1.1(c) Intervals of Vacuum/Tube Support

1/2-in. tube	6 ft (1.83 m)
3/4-in. or 1-in. tube	8 ft (2.44 m)
1 1/4-in. or larger (horizontal)	10 ft (3.05 m)
1 1/4-in. or larger (vertical)	every floor level

(d) *Permanent Fittings.* All fittings used for connecting copper tube shall be copper, brass, or bronze made especially for brazed or soldered joining, except as provided in 4-9.1.1.1(e) and (f).

(e) *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.

(f) *Metallic Shape Memory Fittings.* Listed or approved metallic shape memory fittings that, when made up, provide a permanent joint equal to the mechanical, thermal, and sealing integrity of a brazed or soldered joint complying with 4-9.1.1.10(a) shall be permitted to be used anywhere in vacuum distribution lines.

(g) *Mechanically Formed Tube Fittings.* A listed or approved fabricating process that, when completed, provides a permanent joint equal to the mechanical, thermal, and sealing integrity of a brazed or soldered joint complying with 4-9.1.1.10(a) shall be permitted to be used anywhere in vacuum distribution lines.

(h) *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 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.

4-9.1.1.2 Vacuum System Valve Boxes. Valve boxes shall be permanently labeled in substance as follows:

CAUTION —
MEDICAL-SURGICAL VACUUM VALVE
DO NOT CLOSE EXCEPT IN EMERGENCY
THIS VALVE CONTROLS VACUUM TO. . . .

4-9.1.1.3 Vacuum System Valves Not in Boxes. All shutoff valves that are not in labeled boxes, such as in the main line, risers, or above suspended ceilings, 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. . . .

4-9.1.1.4 Vacuum System Station Inlets. Each station inlet for vacuum shall be legibly labeled in substance as follows:

SUCTION

or

VACUUM

or, if used,

WASTE ANESTHETIC GAS DISPOSAL

4-9.1.1.5 Vacuum System Shutoff Valves.

(a) *General.* Shutoff valves shall be provided to isolate appropriate sections or portions of the piping system for maintenance, repair, or planned future expansion need, and to facilitate periodic testing. All valves, other than those in valve boxes, shall be placed in a secure area accessible to authorized personnel only or locked open.

(b) *Valve Types.* Shutoff valves shall be metallic and of a type that will create no greater flow restriction than the piping to which they are connected.

(c) *Riser Valves.* Shutoff valves shall be provided at the base of vertical risers servicing more than one floor.

(d) *Section Valves.* A shutoff valve shall be provided on each floor between the riser and the first station 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.

(e) *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.

NOTE: Shutoff valves are not required for each anesthetizing room.

4-9.1.1.6 Vacuum System Station Inlets.

(a) *General.* Each station inlet for vacuum shall be equipped with a valve mechanism of a type not interchangeable with other systems (e.g., oxygen, compressed air) and either a threaded connection or a quick coupler.

NOTE: See 4-9.1.2 relative to waste anesthetic gas disposal.

(b) *Threaded Connections.* Valves with threaded connections shall conform to the Diameter-Index Safety System as described in the CGA Pamphlet V-5.

(c) *Secondary Check Valves.* Vacuum station inlets shall not incorporate a secondary check valve.

(d) *Physical Protection.* Station inlets shall be located so as to avoid physical damage to the valve or attached equipment.

(e) *Physical Spacing.* Careful consideration shall be given to provide adequate spacing between the station inlets and adjacent medical gas outlets.

(f) *Removable Assemblies.* Station 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.

4-9.1.1.7 Master Alarm System for Vacuum Systems.

(a) *General.* The vacuum system master alarm shall provide cancellable audible and noncancellable visual signals at a continuously monitored location so as to indicate when the vacuum in the main line drops below the level required in 4-10.1.2.6. 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.

(b) *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].

(c) *Alarm Panels.* The master alarm signal panel(s) required in 4-9.1.1.7(a) (each with visual and audible signal) shall be actuated by the vacuum switch described in 4-9.1.1.7(b).

(d) *Panel Labels.* The master alarm signal panel(s) shall be appropriately labeled.

(e) *Combined Alarm Signals.* The vacuum alarm signal shall serve only the medical-surgical vacuum system. (*See Sections 4-3 through 4-5 and Chapter 3.*)

NOTE 1: 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, or fire alarms, provided that the function of this alarm signal is clearly distinguished from the others by labeling as described in 4-9.1.1.7(d).

NOTE 2: See Table 4-5.1.4 for list of master alarm signals.

(f) *Alarm System Power.* The master alarm signal system shall be energized by the essential electrical system described in 4-8.1.1(d). (*See also Chapter 3.*)

(g) *Connection to Centralized Computers.* The connection of the master alarm(s) to a centralized computer (e.g., a building management system) shall be permitted. If computers are used as a secondary master alarm, the requirements of 4-9.1.1.7(e) and (f) shall be met. The primary master alarm shall be a separate device.

4-9.1.1.8 Area Alarm Systems for Vacuum Systems.

(a) *General.* Vacuum area alarm systems shall be provided in anesthetizing location areas and other life-support and critical care areas, such as postanesthesia recovery, intensive care units, or coronary care units.

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 Sections 4-3 and 4-4.

(b) *Visual and Audible Signals.* The vacuum area alarm system shall incorporate both cancellable audible and noncancellable visual signals that are activated by actuators (vacuum switches) connected to the vacuum line serving each specific area.

(c) *Alarm Panels.* The visual and audible signal panels shall be installed at nurses' stations or other suitable locations in the areas described in 4-9.1.1.8(a) and be appropriately labeled.

(d) *Actuator Switches.* The actuator (vacuum switch) for each area described in 4-9.1.1.8(a) shall connect to the vacuum line for that area, 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 station inlets in the area.

(e) *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).

(f) *Electrical Power.* The area alarm signal system shall be energized by the essential electrical system described in 4-8.1.1(d). (*See also Chapter 3.*)

4-9.1.1.9 Vacuum System Gauges.

(a) *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. Those with "normal range" display shall indicate normal only between 12 and 19 in. Hg (vacuum).

(b) *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. Those with "normal range" display shall indicate normal only between 12 and 19 in. Hg (vacuum).

(c) *Vacuum Gauge Identification.* All permanently installed vacuum gauges and manometers for the vacuum system shall be continuous reading, 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 central medical gas piping systems described in Sections 4-3 through 4-5.

4-9.1.1.10 Installation of Piping Systems for Vacuum Systems.

(a) *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, brazing material, or fittings complying with 4-9.1.1.1(f) or (g) having a melting point not less than 450°F (232°C). Joints in galvanized steel piping shall be threaded, flanged, gasketed couplings, or fittings complying with 4-9.1.1.1(f), 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, brazing [at minimum 1000°F (537.8°C) melting point] should be considered in order to avoid inadvertent soft soldering of nonflammable medical gas piping.

(b) *Flux.* Particular care shall be exercised in applying the flux to avoid leaving any excess inside the completed joints.

(c) *Cleaning.* The outside of the tube and fittings shall be cleaned by washing with hot water after assembly.

(d) *Purging.* After installation of the piping, but before attachment of the vacuum line to the vacuum pumps and receiver(s) [tank(s)], and before installation of the vacuum alarm switches, station inlets, and gauges, the line shall be blown clear by means of oil-free, dry nitrogen or air.

(e) *Threaded Connections for Vacuum Systems.* Threaded 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.

(f) *Piping 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 piping 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 piping. Arrows (when used) shall point from the station inlets and toward the receiver or pump.

4-9.1.1.11 Labeling. Labeling shall conform to 4-9.1.1.2 through 4-9.1.1.3.

4-9.1.2 Waste Anesthetic Gas Disposal. (*See Note in Table 4-7.1.2 and in 4-8.1.2.*) Waste anesthetic gas evacuation terminals, whose vacuum source is separate from the medical-surgical vacuum source, shall be equipped with a valve mechanism of a type not interchangeable with the medical-surgical vacuum system or with other systems.

4-9.1.3 Dental Vacuum Distribution. Piping materials shall be corrosion-resistant material having a smooth interior surface. Piping shall be sized according to the manufacturer's recommendations. All piping shall be provided with adequate and accessible clean-out facilities on mains and branches and shall be accessible for inspections, maintenance, and replacement.

4-9.2 Nonpatient Vacuum Distribution. (Reserved)

4-10 Vacuum System Performance Criteria and Testing.

4-10.1 Patient Vacuum System.

4-10.1.1 Performance.

4-10.1.1.1 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 station inlet farthest away from the central vacuum source when the calculated demand for the hospital is drawn in the system. (*See Appendix C-4.3 for examples.*)

NOTE: An operating range of 15 in. to 19 in. Hg is suggested at the receiver.

4-10.1.1.2 Overall System Pressure-Drop Criteria. Tube 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 station inlet when the calculated demand is drawn on the vacuum system, be limited to 3 in. Hg.

4-10.1.1.3 Minimum Flow and Pressure Requirements at Vacuum Station Inlets. Piping shall be sized such that 3 SCFM can be evacuated through any one station inlet without reducing vacuum pressure below 12 in. Hg at an adjacent station inlet.

NOTE: This is not a criterion for pump sizing purposes. See Appendix C-4.3 for pump sizing recommendations.

4-10.1.2 Testing. The following tests shall be conducted to ensure proper operation of the system upon completion of the installation, and before turnover to the facility for patient use.

4-10.1.2.1 Inspection of Vacuum Systems. A visual inspection of each soldered or brazed joint, if any, shall be made to ensure that the alloy has flowed completely in and around the joint and that hardened flux has not formed a temporary seal that holds test pressure. All excess flux shall be removed for clear visual inspection of connections.

4-10.1.2.2 Leakage Tests. Before attaching the vacuum lines to the vacuum pumps, receiver(s) [tank(s)], and alarm

signaling system(s) switches and gauges, each section of the vacuum piping system shall be subjected to a test pressure not less than 150 psig (1034 kPa gauge) 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 CGA Pamphlet G-10.1, Commodity Specification for Nitrogen.*)

4-10.1.2.3 Standing Pressure Test. After installing a vacuum system, including station inlets, but before attaching the vacuum lines to the vacuum pumps, receiver(s) [tank(s)], 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 (413 kPa gauge) 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 (345 kPa gauge) 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) [tanks(s)], alarm actuators (vacuum switches), and gauges.

NOTE: For information on how to correct pressure for temperature changes, see Sections 4-3 through 4-5.

4-10.1.2.4 Cross-Connection. Cross-connection testing shall be performed as described in 4-5.1.2.5 and 4-5.1.3.1.

4-10.1.2.5 After connecting the vacuum piping to the vacuum pumps, receiver(s) [tank(s)], vacuum gauges, and vacuum alarm switches, a vacuum test shall be performed on the entire system.

NOTE: An acceptable method of testing is by means of shutting down portions of the system using the shutoff valves described in 4-9.1.1.5 to determine the capability of that portion to maintain a vacuum. An acceptable condition is a vacuum level loss of less than 1.5 in. Hg in 1 hour with the vacuum system piping initially at a vacuum in excess of 12 in. Hg.

4-10.1.2.6 Vacuum System Alarm Testing. The vacuum system master alarm and any secondary master alarm shall signal when the vacuum in the main line drops below the level required to maintain 12 in. Hg (vacuum) at the station inlet farthest from the source.

4-10.2 Dental Vacuum System. (Reserved)

4-10.3 Nonpatient Vacuum System. (Reserved)

4-11 Administration of Vacuum Systems.

4-11.1 Responsibility of Governing Body. (Reserved)

4-11.2 Policies.

4-11.2.1 Vacuum System (Patient).

4-11.2.1.1* Maintenance. The facility shall establish routine preventive maintenance programs applicable to both the vacuum piping system and to the secondary equipment attached to vacuum station inlets to ensure the continued good performance of the entire vacuum system.

NOTE: Clogging of regulators, for example, with lint, debris, or dried body fluids reduces vacuum system performance.

4-11.2.1.2 Leakage Tests. The facility shall perform periodic tests for detecting leaks in the system in accordance with 4-10.1.2.

4-11.2.1.3 Station Inlet Performance Tests. Station inlet terminal performance, as required in 4-10.1.1.3, shall be tested on a regular preventive maintenance schedule as determined by the facility maintenance staff. The test shall be based on flow of free air (SCFM) into a station inlet 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 being fitted with the appropriate station inlet connector.

NOTE 2: The test procedure will be to measure the flow with the station inlet wide open while simultaneously measuring the vacuum level at an adjacent wall station inlet or other station inlet 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 facility personnel, based on past experience and use, to determine the acceptable alternate performance criterion for their system(s).

4-11.2.1.4 Instruction of Staff. The facility shall instruct its personnel in the proper uses of the vacuum system in order to eliminate practices that reduce the system's effectiveness, such as leaving suction tips and catheters open when not actually aspirating, and using equipment arrangements that are improperly trapped or 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 carryover 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 station inlet.

4-11.2.1.5 Contamination. Liquid or debris shall not be introduced into the medical-surgical vacuum system for disposal.

4-11.2.1.6 Nonmedical Use. The medical-surgical vacuum system shall not be used for vacuum steam condensate return or other nonmedical or nonsurgical applications.

4-11.2.1.7 Modifications. Whenever the medical-surgical vacuum system is breached, the tests of Section 4-10 shall be conducted on any new or modified portion of the system.

4-11.2.2 Vacuum System (Nonpatient). (Reserved)

4-11.3 Recordkeeping for Vacuum Systems. Upon completion of the tests described in 4-10.1, a written record of the performance of these tests shall be maintained in the permanent records of the facility.

4-11.4 Information and Warning Signs for Vacuum Systems.

4-11.4.1 Patient Vacuum Systems.

4-11.4.1.1 Piping Distribution System. Shall conform to 4-9.1.1.2 and 4-9.1.1.3.

4-11.4.1.2 Gauge Identification. Shall conform to 4-9.1.1.9(c).

4-11.4.2 Nonpatient Vacuum Systems. (Reserved)

Chapter 5 Environmental Systems

NOTE: The application of requirements contained in this chapter for specific types of health care facilities can be found in Chapters 12 through 18.

5-1 Scope. This chapter covers the performance, maintenance, and testing of the environmental systems used within health care facilities.

5-2 Nature of Hazards.

(See Sections 3-2 and 8-2 for information on hazards.)

5-3 Source.

5-3.1 Air exhausted from laboratory areas shall not be recirculated to other parts of the facility.

5-4 Distribution.

NOTE: For additional distribution requirements, see NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, and NFPA 90B, *Standard for the Installation of Warm Air Heating and Air Conditioning Systems*.

5-4.1* Ventilation — Nonflammable Anesthetizing Locations.

5-4.1.1 The mechanical ventilation system supplying nonflammable anesthetizing locations shall have the capability of controlling the relative humidity at a level of 35 percent or greater.

NOTE: Advantages claimed for humidity include avoidance of 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 may be minimized following procedures performed in those operating rooms in which the relative humidity is maintained at the level of 50 to 55 percent.

5-4.1.2 Supply and exhaust systems for windowless anesthetizing locations shall be arranged to automatically vent smoke and products of combustion.

5-4.1.3 Ventilating systems for anesthetizing locations shall be provided that automatically (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.

5-4.1.4 The electric supply to the ventilating system shall be served by the equipment system of the essential electrical system specified in Chapter 3, "Electrical Systems."

5-4.1.5 Window-type temperature regulating units (air conditioners) are permitted to be installed in exterior windows or exterior walls of anesthetizing locations (*see also 5-4.2.4 and 5-4.2.5*). Where such units are employed, the provisions of 5-4.1.1 or 5-4.2.1 shall be met.

5-4.1.6 Scavenging apparatus, if installed, shall exhaust the waste anesthetic gases to the outside of the facility in a manner that will preclude their reentry.

5-4.2* Ventilation — Flammable Anesthetizing Locations.

5-4.2.1 Relative humidity of not less than 50 percent, at a temperature range of 64.4°F (18°C) to 80.6°F (27°C), shall be maintained in flammable inhalation anesthetizing locations.

5-4.2.2 Requirements for ventilation and cooling set forth in 5-4.1.2 through 5-4.1.6 shall apply.

5-4.2.3 Duct Work for Air Handling. It is not required that duct work be fabricated of nonsparking material.

5-4.2.4 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 5-4.2.5.

5-4.2.5 Such a window-type temperature regulating unit shall be provided with a vertical divider that effectively prevents airflow from the room side to the outside side, and all electric equipment on the room side of this divider shall meet the requirements of 3-4.1.2.1(e)(2). 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 is permitted 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.

5-4.3 Ventilation — Laboratories.

5-4.3.1* 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 are permitted to be arranged for slight positive pressure when the safety of the arrangement is affirmed by a responsible laboratory official.

5-4.3.2 Exit corridors shall not be used as plenums to supply or exhaust air from laboratory areas.

5-4.3.3 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.

NOTE: The discharge side of fume hood exhaust fans is under positive pressure and often leaks toxic fumes into the surrounding environment; therefore, all fume hood exhaust fans should be installed outdoors, and not inside penthouses or other mechanical equipment enclosures that have to be frequented by maintenance and service personnel.

5-4.3.4 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.

5-4.4 Fume Hoods — Laboratories.

5-4.4.1 Fume hood requirements shall comply with NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals.*

5-4.4.2 Fume hoods shall be located in areas of minimum air turbulence, away from doors and windows, and in a manner that will not impede access to egress.

5-4.4.3 Glazing at the face of the hood shall be of a material that will provide protection to the operator or environment against the hazards normally associated with the use of the hood.

5-4.4.4 Fume hoods, and their associated equipment in the air stream, intended for use with perchloric acid shall be constructed of stainless steel or other material consistent with special exposures and shall 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.

Exception: When perchloric acid is transferred from one container to another.

5-4.4.5 Fume hoods intended for use with radioactive isotopes shall be constructed of stainless steel or other material suitable for the particular exposure.

NOTE: See NFPA 801, *Recommended Fire Protection Practice for Facilities Handling Radioactive Materials*, for related information.

5-4.4.6 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.

The operation of the these controls shall be tested annually by a qualified person who shall certify the result of the test.

NOTE: The qualified person may be a staff member of the facility.

5-4.4.7 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.

5-4.4.8 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.

5-5 Performance Criteria and Testing. (Reserved)

5-6 Administration.

5-6.1 Anesthetizing Locations.

5-6.1.1 Ventilating and humidifying equipment for anesthetizing locations shall be kept in operable condition and be continually operating during surgical procedures (*see A-5-4.1*).

5-6.1.2 All gas storage locations or manifold enclosures shall be routinely inspected to ensure that the ventilation requirements stated in 4-3.1.2.2 and 4-3.1.2.3 are not obstructed.

5-6.2* Laboratories. Warning signs describing the nature of any hazardous effluent content shall be posted at fume hoods' discharge points, access points, and filter locations.

Chapter 6 Materials

NOTE: The application of requirements contained in this chapter for specific types of health care facilities can be found in Chapters 12 through 18.

6-1 Scope. This chapter covers the hazards associated with the use of flammable and combustible materials used within health care facilities.

6-2 Nature of Hazards.

6-2.1 Flammability. (Reserved)

6-2.2 Combustible Loading. (Reserved)

6-2.3 Toxicity of Products of Combustion. Many substances, when subjected to a fire, undergo a chemical change resulting in a new toxic product. This is especially true of many plastic substances. Many highly toxic combustion products can 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 electrical conduit.

6-2.4 Chemical Burns. (Reserved)

6-2.5 Safety. (Reserved)

6-2.6 Radioactivity. (Reserved)

6-3 Source. (Reserved)

6-4 Distribution. (Reserved)

6-5 Performance Criteria and Testing. (Reserved)

6-6 Administration. (Reserved)

Chapter 7 Electrical Equipment

NOTE 1: The application of requirements contained in this chapter for specific types of health care facilities can be found in Chapters 12 through 18.

NOTE 2: For requirements of manufacturers of equipment, see Chapter 9.

7-1* Scope.

7-1.1 This chapter covers the performance, maintenance, and testing of electrical equipment used within health care facilities.

7-1.2 Although an appliance that yields erroneous data or functions poorly may be dangerous, quality and assurance of full appliance performance is not covered except as it relates to direct electrical or fire injury to patients or personnel.

7-1.3 This chapter does not require formal approval or listing of any appliance.

7-1.4 Experimental or research apparatus built to order or under development shall be used under qualified supervision and shall have a degree of safety equivalent to that described herein or have a degree of safety that has been deemed acceptable by the facility.

7-2 Nature of Hazards.

NOTE 1: This section (7-2) is intended to be informational.

NOTE 2: See also Section 3-2 for related electrical hazards.

7-2.1 Fire and Explosion. Transmission of electricity generates heat. The normal operating temperature of a device is a function of material and design. Equipment or wiring faults can cause abnormal temperature increases. These abnormal temperatures may cause fire and explosions. Use of oxygen or other oxidizing agents lowers ignition temperatures. Normal operating temperatures of equipment not designed for use in oxygen-enriched atmospheres may cause fires if used in oxygen-enriched atmospheres.

NOTE: See 8-2.1.2.4(c) for other fire ignition hazards.

7-2.2 Electrical Shock.

7-2.2.1 Elimination of Shock Hazards.

7-2.2.1.1 Personnel are cautioned to be aware of the hazards presented by defective or improperly employed electrical equipment (*see 7-2.2.2*) and avoid the use of defective electrical equipment (*see 7-6.2.2.4*).

7-2.2.1.2 Adequate grounding for electrical equipment is an important safeguard against fire and electric shock (*see 3-5.2 and 7-5.1.2.2*).

7-2.2.2 Effects of Moisture. Moisture, in the form of liquids, vapors, or mists, can degrade insulation to the point where fire, equipment malfunction, and electric shock hazard become a threat. Moisture may enter equipment as a result of defective seals, leaks, or inadvertent spillage. Vessels containing liquids should not be placed on electrical equipment. See 3-4.1.2.6, Wet Locations.

7-2.3 Burns.

7-2.3.1 Heated Surfaces. Sustained skin contact with surfaces of equipment that have temperatures in excess of 107°F (42°C) can cause burns. Caution is required when exposing patients to warmed surfaces, particularly when they are helpless.

7-2.3.2 High-frequency electromagnetic fields, particularly those from electrosurgical generators and from lasers, are used to intentionally destroy tissue. Inadvertent burns, or ignition of combustible materials, is a hazard. See Annex 2, "The Safe Use of High-Frequency Electricity in Health Care Facilities."

7-2.4 Interruption of Power. (Reserved)

7-2.5 RF Interference.

(*See Annex 2, "The Safe Use of High-Frequency Electricity in Health Care Facilities."*)

7-2.6 Mechanical Injury. (Reserved)

7-3 Source.

7-3.1 Electrical System.

NOTE: See Chapter 3.

7-3.2 Battery. (Reserved)

7-4 Distribution. (Reserved)

7-5 Performance Criteria and Testing.

7-5.1 Patient-Care-Related Electrical Appliances and Equipment.

7-5.1.1 Permanently Connected (Fixed).

7-5.1.1.1 Grounding of Appliances. Patient-connected electric appliances shall be grounded to the equipment grounding bus in the distribution panel by an insulated grounding conductor run with the power conductors.

7-5.1.1.2 Wiring. Wiring for fixed equipment installed outside the hazardous area of a flammable inhalation anesthetizing location shall comply with 3-4.1.2.1(e)(1).

7-5.1.1.3 Installation. All service equipment, switchboards, or panelboards shall be installed outside hazardous areas.

7-5.1.1.4 Control Devices. Devices or apparatus such as motor controllers, thermal cutouts, switches, relays, the switches and contactors of autotransformer starters, and 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 that may be operated from any

desired location. This recommendation applies particularly to foot and other switches that must be operated from a location at or near the floor.

7-5.1.1.5 Location. Equipment in storage locations for flammable anesthetic locations shall comply with 4-3.1.2.4(f).

7-5.1.2 Cord- and Plug-Connected (Portable).

7-5.1.2.1 General. All patient-care-related electrical equipment supplied by a flexible cord and plug, carrying 20 V or more, shall meet the requirements of 7-5.1.2.

7-5.1.2.2 Grounding of Appliances. All cord-connected electrically powered appliances used in the patient care 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.

7-5.1.2.3 Attachment Plugs. Attachment plugs installed by the facility shall meet the requirements of 9-2.1.2.1.

7-5.1.2.4 Power Cords. Power cords installed by the facility shall meet the requirements of 9-2.1.2.2.

7-5.1.2.5 Line Voltage Equipment — All Anesthetizing Locations.

(a) Portable equipment shall be provided with a storage device for its flexible cord.

(b) Flexible cord for portable lamps or portable electric appliances operating at more than 10 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 7-6.2 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 7-5.1.1.4 and 3-4.1.2.4(g) and (h)] may be inserted. Foot-treadle-operated controllers and their connector shall be splashproof but need not be explosionproof if used in a nonflammable anesthetizing location.

Exception No. 2: Listed double-insulated appliances with two-wire cords shall be permitted.

Exception No. 3: Small metal parts not likely to become energized (e.g., nameplates, screws) shall not be required to be grounded.

Exception No. 4: 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; and

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 3-4.1.2.4(d) for criteria of receptacles.

Exception No. 5: Overhead power receptacles, not in a hazardous location, are permitted to be supplied by a flexible cord (ceiling drop) that 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 3-4.1.2.4(d) for criteria of receptacles.

7-5.1.2.6 Low-Voltage Equipment and Instruments — All Anesthetizing Locations.

(a) Low-voltage equipment that is frequently in contact with the bodies of persons or has exposed current-carrying elements shall:

(1) Operate on an electrical potential of 10 volts or less, or

(2) Be approved as intrinsically safe or double-insulated equipment, and

(3) Be moisture resistant.

(b) Power shall be supplied to low-voltage equipment from:

(1) An individual isolating transformer (autotransformers shall not be used) connected to an outlet receptacle by means of a listed cord and plug [*see 3-4.1.2.4(d) through (f)*], or

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

(3) Individual dry-cell batteries, or

(4) Common batteries made up of storage cells located in a nonhazardous location.

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

7-5.1.2.7 Line Voltage Equipment — Flammable Anesthetizing Locations.

(a) 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 7-5.1.2.7(f)*].

(b) 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.

(c) 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 shall be permitted to be provided with an approved positive-pressure system for the tube head and cables within the hazardous area [*see 7-5.1.2.7(f)(2)*]. All devices and switches for X-ray equipment within the hazardous area shall conform to requirements of 7-5.1.1.3 and 12-4.1.3.5(f) and (h). X-ray equipment shall be provided with an approved method of eliminating electrostatic accumulation [*see 12-4.1.2.6(c) and 12-4.1.3.5(f)*].

(d) 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 7-5.1.1.4 and 12-4.1.3.9(c)*].

NOTE 2: For recommendations in connection with the use of cautery and high-frequency equipment in flammable anesthetizing locations, see 12-4.1.3.8(j); Appendix C-12.3, Regulation Set (1), 4(d) and Set (3), 4(e); and Annex 2, "Safe Use of High-Frequency Electricity in Health Care Facilities."

(e) 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 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 7-5.1.2.7(f).

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 3-4.3.3.

(f) The following shall be considered exceptions to 7-5.1.2.7(a) and (e).

(1) Equipment designed to operate on circuits of 10 volts or less shall comply with 7-5.1.2.6.

(2) Portable electric or electronic equipment mounted within an enclosure and protected by an approved positive-pressure ventilating system that 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 deenergize 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 7-5.1.1.5 is energized. The enclosure with its equipment shall be approved for use in Class I, Group C, Division 1 hazardous areas.

(3) Portable electric or electronic equipment, if it is mounted on a floor-borne movable assembly that will not overturn either when it is tilted through an angle of 20 degrees or 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 7-5.1.2.7(e). The entire assembly shall be approved for use in anesthetizing locations as defined in Section 2-2.

(4) 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.

(g) Photographic lighting equipment used in flammable anesthetizing locations shall comply with the provisions of 7-5.1.2.7 to prevent ignition of flammable gases. 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 that 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.

NOTE: Flash tube operation may be accompanied by sparking at switches, relays, and socket contacts, and by corona discharge of flashovers from high-voltage circuits.

(h) The exposed metal parts of photographic lighting equipment shall be grounded as specified in 7-5.1.2.2.

7-5.1.2.8 Low-Voltage Equipment — Flammable Anesthetizing Locations. Specifications for portable equipment operating on low-voltage power supplies that are not stated in 7-5.1.2.7(f)(1) and 12-4.1.3 are stated in 7-5.1.2.6.

7-5.1.2.9 Adapters and Extension Cords. Adapters and extension cords shall meet the following requirements:

(a) Attachment plugs shall meet the requirements of 9-2.1.2.1.

(b) Power cords shall be adequate for the application to avoid overload (i.e., 16 AWG or greater) and shall meet the requirements of 9-2.1.2.2.

NOTE: For policy on the use of extension cords, see 7-6.2.1.5.

7-5.1.3 Testing Requirements (Fixed and Portable).

7-5.1.3.1 Physical Integrity. The physical integrity of the power cord and attachment plug and cord-strain relief shall be confirmed by visual inspection or other appropriate tests.

7-5.1.3.2* 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 0.50 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 apply only to appliances that are used in the patient care vicinity. (*See Appendix A-7-5.1.3.2 for suggested test methods.*)

Exception: The requirement does not apply to escutcheons or nameplates, small screws, etc., that are unlikely to become energized.

7-5.1.3.3* Leakage Current Tests — General. The following requirements shall apply to all tests.

(a) *Resistance Test.* The resistance tests of 7-5.1.3.2 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 at nominal voltage of the equipment.

(c) *Frequency of Leakage Current.* The leakage current limits stated in 7-5.1.3.4, 7-5.1.3.5, and 7-5.1.3.6 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 7-5.1.3.4, 7-5.1.3.5, and 7-5.1.3.6 multiplied by the frequency, in kHz, up to a maximum of 10 mA.

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 waveform, provided that the contribution of each component to the total reading is weighted in accordance with 7-5.1.3.3(c). This weighting can be achieved by a frequency-response-shaping network that precedes a flat-response meter, or by a meter whose own frequency-response characteristic matches 7-5.1.3.3(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 in the position shown in Table 7-5.1.3.3(d), and with all operating controls in the position to cause maximum leakage current readings.

Table 7-5.1.3.3(d)

Par. No.	Power switch setting On and off	On
7-5.1.3.4	X	
7-5.1.3.5	X	
7-5.1.3.6(a)		X
7-5.1.3.6(b)		X
7-5.1.3.6(c)	X	
7-5.1.3.6(d)		X
7-5.1.3.6(e)		X

7-5.1.3.4 Chassis Leakage Current, Fixed Equipment. Permanently wired appliances in the patient care 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 3-5.2.1.3 ("Voltage Measurements") and 3-6.2.3.2 ("Criteria for Acceptability of Existing Grounding Systems").

7-5.1.3.5 Chassis Leakage Current, Portable Equipment.

(a) The leakage current for cord-connected appliances shall be measured. The limit shall be 300 microamperes. Figure 7-5.1.3.5 shows one method of performing this test.

If multiple devices are connected together and one power cord supplies power, the leakage current shall be measured as an assembly.

When multiple devices are connected together and more than one power cord supplies power, the devices shall be separated into groups according to their power supply cord and the leakage current shall be measured independently for each group as an assembly.

Exception: Where existing or special equipment (such as mobile X-ray machines) exhibit chassis leakage current between 300 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 ensure 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 microamperes, such as some types of ultrasound therapy devices or portable hypothermia units, 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.

(b) 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

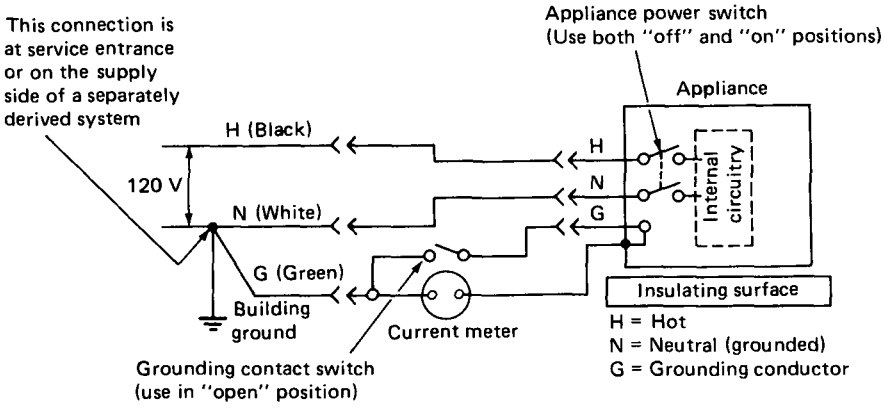


Figure 7-5.1.3.5 Test circuit for measuring chassis leakage current.

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.

7-5.1.3.6 Lead Leakage Current Tests and Limits, Portable Equipment.

(a) *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 7-5.1.3.6(a) is an example of an acceptable test configuration. The leakage current shall not exceed 100 microamperes for ground wire open and closed.

(b) *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 7-5.1.3.6(b) is an example of an acceptable test configuration. The leakage current shall not exceed 10 microamperes with the ground intact and 50 microamperes with the ground open.

(c) *Isolation Test (Isolated Input).* The current driven into the leads of an appliance that 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 7-5.1.3.6(c). The leakage current shall not exceed 20 microamperes in each case. The test is made with the appliance's 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 9-2.1.13.4(b), "Appliances with No Exposed Conductive Surfaces," that is also temporarily grounded.

Only isolated patient leads shall be connected to intracardiac catheters or electrodes.

(d) *Between Leads (Nonisolated Input).* The leakage current between any one lead (not ground) and each other lead shall be measured. Figure 7-5.1.3.6(d)/(e) is an example of an acceptable test configuration. The leakage current shall not exceed 50 microamperes for the ground wire open and closed.

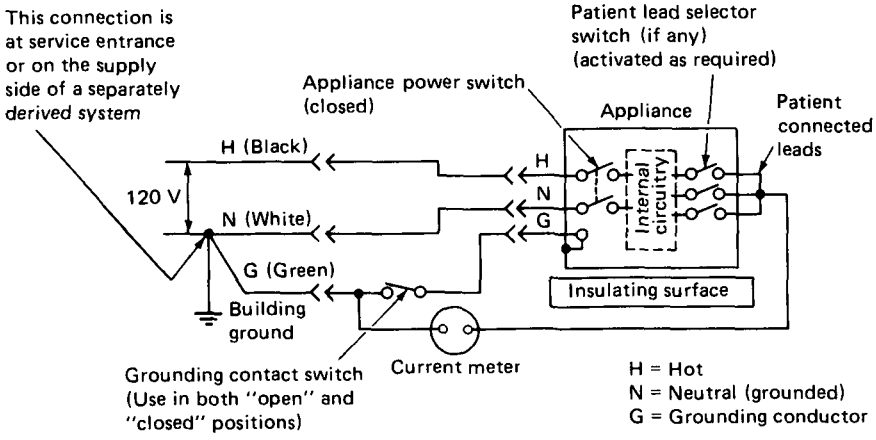


Figure 7-5.1.3.6(a) Test circuit for measuring leakage current between patient leads and ground (nonisolated).

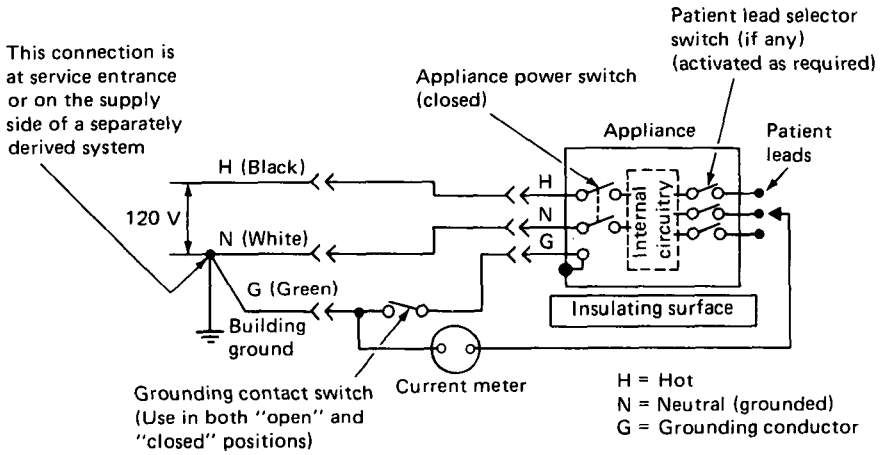


Figure 7-5.1.3.6(b) Test circuit for measuring leakage current between patient leads and ground (isolated).

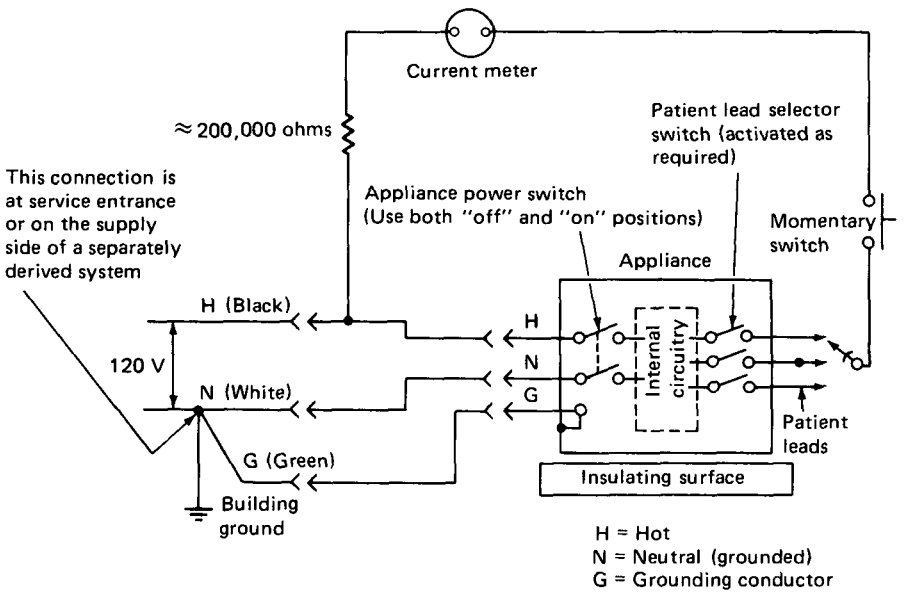


Figure 7-5.1.3.6(c) Test circuit for measuring the electrical isolation of isolated patient leads.

(e) *Between Leads (Isolated Input).* The leakage current between any one lead (not ground) and each other lead shall be measured. Figure 7-5.1.3.6(d)/(e) is an example of an acceptable test configuration. The leakage current shall not exceed 10 microamperes with the ground intact and 50 microamperes with the ground open.

7-5.2 Nonpatient Electrical Appliances and Equipment.

7-5.2.1 Permanently Connected (Fixed). (Reserved)

7-5.2.2 Cord- and Plug-Connected (Portable).

7-5.2.2.1 Patient Care Area. The leakage current for facility-owned appliances (e.g., housekeeping or maintenance appliances) that are used in a patient care vicinity and are likely to contact the patient shall be measured. The leakage current shall be less than 500 microamperes.

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 care vicinity. For example, electric typewriters, pencil sharpeners, and clocks at nurses' stations, or electric clocks or TVs that are normally outside the patient care vicinity but may be in a patient's room, shall not be required to have grounding conductors in their power cords.

7-5.2.2.2* Laboratory.

(a) Portable equipment intended for laboratory use shall be grounded or otherwise arranged with an approved method to protect personnel against shock.

(b) All electrical heating equipment to be used for laboratory procedures shall be equipped with overtemperature-limit controls so arranged that thermostatic failure will not result in hazardous temperatures.

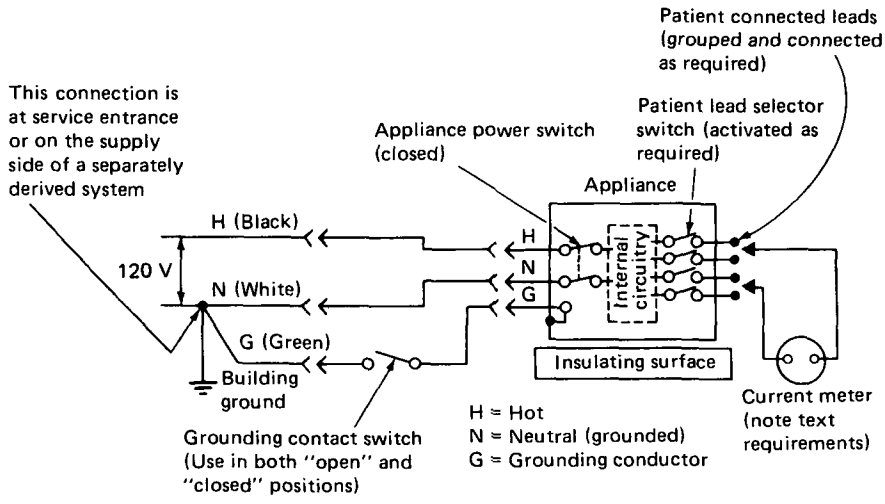


Figure 7-5.1.3.6(d)/(e) Test circuit for measuring leakage current between patient leads (nonisolated and isolated).

When such equipment is intended for use with flammable or combustible liquids, its electrical components shall be explosionproof, intrinsically safe, or ventilated in a manner that will prevent accumulation of flammable atmospheres under normal conditions of operation.

(c) 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.

7-6 Administration.

7-6.1 Responsibilities of Governing Body. (Reserved)

7-6.2 Policies.

7-6.2.1 General.

7-6.2.1.1 Medical and surgical electrical instrumentation 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 facility (e.g., leased, donated, constructed on-site, loaned, etc.), shall meet the safety performance criteria of 9-2.1, "Patient-Care-Related Electrical Appliances," in Chapter 9, "Manufacturer Requirements."

7-6.2.1.2 Testing Intervals.

(a) The facility shall establish policies and protocols for the type of test and intervals of testing for each appliance.

(b) All appliances used in patient care areas shall be tested in accordance with 7-5.1.3 or 7-5.2.2.1 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: 12 months
Critical Care Areas: 6 months
Wet Locations: 6 months.

Exception No. 1: The testing intervals listed are intended to be nominal values, and facilities 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: Facility-owned household or other appliances that are used in the patient care vicinity, but that are not intended to contact the patient, shall be tested at intervals deemed appropriate by the facility. Some equipment in this category requires only an infrequent visual inspection. The facility shall be permitted to structure a testing protocol and frequency for some equipment that may be more limited than that prescribed in 7-5.1.3.

Exception No. 3: The tests specified in 7-5.1.3.6, "Lead Leakage Current Tests and Limits, Portable Equipment," shall be required only for incoming inspections and following repairs and modifications that may have compromised the patient lead leakage current.

7-6.2.1.3 Protection of Patients with Direct Electrical Pathways to the Heart. Only equipment that is specifically designed for the purpose, i.e., provided with suitable isolated patient leads or connections (*see 9-2.1.12, "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 facility shall have a policy that prohibits the use of external cardiac pacemakers and pacing leads with external terminals that are not properly protected from potentially hazardous contact with conductive surfaces.

7-6.2.1.4 Controls. Electrical appliance controls (such as bed controls, pillow speakers, television controls, and nurse-call controls) that do not meet the minimum requirements of 9-2.1, "Patient-Care-Related Electrical Appliances," shall be mounted so that they cannot be taken into the bed.

Exception: Existing low-voltage controls used in general patient-care areas.

7-6.2.1.5 Adapters and Extension Cords. With the exception of three-to-two-prong adapters, adapters and extension cords shall be permitted to be used to permit appliances fitted with distinctive plugs 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.

7-6.2.1.6 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 that 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.

7-6.2.1.7 Specification of Conditions of Purchase. The procurement authority shall include in its purchasing documents any appropriate requirements or conditions specifically related to the facility's use of the appliance, including, but not restricted to, the following:

(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.

NOTE: The facility may wish to reference compliance with this chapter and Chapter 9 on its purchasing document.

7-6.2.1.8* 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 9-2.1.8.1(m).*]

7-6.2.1.9 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 system by the facility. 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 facilities from assembling their own systems.

7-6.2.1.10 Appliances Not Provided by the Facility. Policies shall be established for the control of appliances not supplied by the facility.

7-6.2.2 Servicing and Maintenance of Equipment.

7-6.2.2.1 Service manuals, instructions, and procedures provided by the manufacturer shall be used in the maintenance of equipment.

7-6.2.2.2 A scheduled preventive maintenance program shall be followed.

7-6.2.2.3 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.

7-6.2.2.4 Defective electrical apparatus shall be tagged and repaired or discarded.

7-6.2.2.5 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.

7-6.2.3 During Surgery.

7-6.2.3.1 Active electrodes or other applicators of electrosurgical devices shall be properly secured, as recommended by the manufacturer of the device, when not in active use. This includes, but is not limited to: electrosurgical devices, surgical lasers, electrocautery, and fiberoptics.

7-6.2.3.2 The cable that provides power from the electrosurgical generator to the active electrode shall be disconnected from the generator when contamination occurs.

7-6.2.4 During Administration of Respiratory Therapy.

7-6.2.4.1 Electrical equipment used within the site of intentional expulsion shall have no hot surfaces.

When only the remote control or signal leads of a device are to be used in the site of intentional expulsion, only the control or signal leads shall be required to comply with this section.

NOTE: For further information concerning criteria for equipment used within the site of intentional expulsion, see 9-2.1.9.3.

Exception: Small (less than 2 W), hermetically sealed heating elements such as light bulbs.

7-6.2.4.2 Electrical equipment used within oxygen delivery equipment shall be listed for use in oxygen-enriched atmospheres, or sold with the intent to be used in oxygen-enriched atmospheres.

NOTE: For further information concerning the criteria for equipment used in oxygen delivery equipment, see 9-2.1.

7-6.2.4.3 When high-energy-delivering probes (such as defibrillator paddles) or other electrical devices that do not comply with 7-6.2.4.1 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.

7-6.2.5 Laboratory.

7-6.2.5.1* Electrical equipment for laboratory use shall be tested for electrical safety against standards acceptable to the authority having jurisdiction.

7-6.2.5.2* Electrical equipment intended for use in hazardous areas in laboratories shall meet the requirements of NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals. (See definition of "hazardous area in laboratories" in 2-2 of Chapter 2.)*

7-6.3 Recordkeeping.

7-6.3.1 Patient Care Appliances.

7-6.3.1.1 Instruction Manuals. A permanent file of instruction and maintenance manuals as described in 9-2.1.8.1 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.

7-6.3.1.2* 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.

7-6.3.1.3 Test Logs. A log of test results and repairs shall be maintained and kept for an appropriate time.

7-6.4 Use. (Reserved)

7-6.5 Qualification and Training of Personnel.

7-6.5.1 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.

This program shall include periodic review of manufacturer's safety guidelines and usage requirements for electrosurgical units and similar appliances.

7-6.5.2 Personnel involved in the use of energy-delivering devices, including, but not limited to, electrosurgical units, surgical lasers, electrocauterizers, and fiberoptics, shall receive periodic training in fire suppression.

7-6.5.3 Equipment shall be serviced by qualified personnel only.

Chapter 8 Gas Equipment

NOTE: The application of requirements contained in this chapter for specific types of health care facilities can be found in Chapters 12 through 18.

8-1 Scope.

8-1.1 This chapter covers the performance, maintenance, and testing of gas equipment used within health care facilities.

8-1.2* This chapter applies to the use of nonflammable medical gases, vapors, and aerosols, and the equipment required for their administration, at normal atmospheric pressure.

8-1.3 When used in this chapter, the term oxygen is intended to mean 100 percent oxygen as well as mixtures of oxygen and air.

8-1.4 This chapter does not apply to special atmospheres, such as those encountered in hyperbaric chambers. (*See Chapter 19, "Hyperbaric Facilities."*)

8-2 Nature of Hazards.

NOTE: See 7-2.2.2 for electrical hazards associated with gas equipment.

8-2.1 Fire and Explosions.

8-2.1.1 Inhalation Anesthetizing Locations.

8-2.1.1.1 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.

8-2.1.1.2 Inhalation gases or vapors introduce fire, chemical, mechanical, and electrical hazards that 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 that may be found on or near patients include hair oils, oil-based lubricants, skin lotions, clothing, linens, paper, rubber, alcohols, acetone, and some plastics.

8-2.1.1.3 A hazard exists if any of the components of an oxygen or nitrous oxide supply system become contaminated with oil or grease.

8-2.1.1.4 Sources of ignition may include open flames, burning tobacco, electric heating coils, defective electrical equipment, and adiabatic heating of gases.

NOTE 1: 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.

NOTE 2: Sudden compression or recompression of a gas to high pressure can generate large increase in temperature [up to 2000°F (1093°C)] that can ignite any organic material present, including grease. (*See also NFPA 53M, Fire Hazards in Oxygen-Enriched Atmospheres*).

8-2.1.1.5 A hazard exists if either oxygen or nitrous oxide leaks into a closed space, creating an oxygen-enriched atmosphere.

8-2.1.1.6 A hazard exists if improper components are employed to connect equipment containing pressurized oxygen or nitrous oxide.

8-2.1.2 During Respiratory Therapy Administration.

8-2.1.2.1 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.

(a) 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.

(b) Materials not normally considered to be combustible may be so in an oxygen-enriched atmosphere.

8-2.1.2.2 Combustible materials that may be found near patients who are to receive respiratory therapy include hair oils, oil-based lubricants, skin lotions, facial tissues, clothing, bed linen, tent canopies, rubber and plastic articles, gas-supply and suction tubing, cyclopropane, ether, alcohols, and acetone.

8-2.1.2.3 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.

(a) 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.

(b) Oxygen-enriched atmospheres may exist in the immediate vicinity of all oxygen administration equipment. (*See definition of "site of intentional expulsion" 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.

(c) If oxygen is supplied by a container that 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 nonuse 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 4-3.1.2.1(h)*].

8-2.1.2.4 Sources of ignition include not only the usual ones in ordinary atmospheres, but others that become significant hazards in oxygen-enriched atmospheres [*see 8-2.1.2.1(a)*].

(a) Open flames, burning tobacco, and electric radiant heaters are sources of ignition.

(b) The discharge of a cardiac defibrillator may serve as a source of ignition.

(c) 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.

(d) Electrical equipment not conforming to the requirements of 7-6.2.3.1, 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 7-6.2.3.1*).

(e) A static discharge having an energy content that 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 8-6.2.2.4*).

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.

(f) 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.

8-2.2 Toxicity.

8-2.2.1 During Respiratory Therapy Administration.

8-2.2.1.1 Chemical hazards may be associated with the presence of residual sterilant in high-pressure equipment.

8-2.2.1.2 Some breathing mixtures may decompose in contact with hot surfaces and produce toxic or flammable substances (*see 8-6.2*).

8-2.2.1.3 Smoldering combustion of flammable substances may occur with the production of significant amounts of toxic gases and fumes.

8-2.3 Safety (Mechanical Injury; Cross-Connection, etc.).

8-2.3.1 Inhalation Anesthetizing Locations.

8-2.3.1.1 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.

8-2.3.2 During Respiratory Therapy Administration.

8-2.3.2.1 Mechanical Hazards.

(a) Cylinders and containers may be heavy and bulky and can cause personal injury or property damage (including to the cylinder or container) if improperly handled.

(b) In cold climates, cylinders or containers stored outdoors or in unheated ventilated rooms may become extremely cold [*see 4-6.2.1.2(dd) and 4-6.2.1.2(ee)*]. A hazardous situation could develop if these cylinders or containers are heated [*see 4-6.2.1.2(cc)*].

8-2.3.2.2 Improper maintenance, handling, or assembly of equipment may result in personal injury, property damage, or fire.

8-2.3.2.3 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.

8-2.3.2.4 A hazardous condition exists if there is improper labeling of cylinders or containers or inattention to the manufacturer's label or instructions.

8-2.3.2.5 A hazardous condition exists if care is not exercised in making slip-on and other interchangeable connections when setting up equipment.

8-2.3.2.6 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.

8-2.3.2.7 Extreme danger to life and property can result when compressed gases are mixed or transferred from one cylinder to another.

8-2.3.2.8 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.

8-2.3.2.9 Hazardous conditions are created when pressure-reducing regulators or gauges are defective.

8-2.4 Electric Shock. (Reserved)

NOTE: See 7-2.2 for additional information.

8-3 Source.

8-3.1 Cylinders and Containers.

8-3.1.1 Cylinders and containers shall comply with 4-3.1.1.1.

8-3.1.2 Cylinder valve outlet connections shall conform to CGA V-1, *Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections* (ANSI B57.1) (includes Pin-Index Safety System for medical gases). (*See 4-3.1.1.1.*)

8-3.1.3 When low-pressure threaded connections are employed, they shall be in accordance with the Compressed Gas Association standard for noninterchangeable,

low-pressure connections for medical gases, air, and suction, CGA Pamphlet V-5, *Diameter-Index Safety System.*

8-3.1.4 Low-pressure quick-coupler connections shall be noninterchangeable between gas services.

8-3.1.5 Regulators and gauges intended for use in high-pressure service shall be listed for such service.

8-3.1.6 Pressure-reducing regulators shall be used on high-pressure cylinders to reduce the pressure to working pressures.

8-3.1.7 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 attach only to cylinders of gas for which they are designated.

8-3.1.8 Equipment that 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.

NOTE: Such mixing may result in a violent explosion.

8-3.1.9 Cylinder valve outlet connections for oxygen shall be Connection No. 540 as described in ANSI B57.1, *Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections.*

8-3.1.10 Cylinder valve outlet connections for nitrous oxide shall be Connection No. 326 as described in CGA V-1, *Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections* (ANSI B57.1).

8-3.1.11 Cylinders and containers shall be stored in accordance with 4-3.1.2 and 4-6.2.2.

8-3.2 Generators. (Reserved)

8-3.3 Gas Systems. (*See Chapter 4.*)

8-4 Distribution. (Reserved)

8-5 Performance Criteria and Testing.

8-5.1 Patient-Care-Related Gas Equipment.

8-5.1.1 Fixed. (Reserved)

8-5.1.2 Portable.

8-5.1.2.1 Anesthetic Apparatus.

NOTE: 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.

(a) Anesthetic apparatus shall be subject to approval by the authority having jurisdiction.

(b)* 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 V-1 (Pin-Index Safety System) (ANSI B57.1) (*see 4-4.1.3.6 and Appendix A-4-4.1.3.4*).

(c) 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 flowmeters and the oxygen flush valve if any. Interventions requiring such testing shall include, but not be limited to:

(1) Alteration of pipeline hoses or fittings;

(2) Alteration of internal piping;

(3) Adjustment of selector switches or flush valves;

(4) Replacement or repair of flowmeters 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-12.2*).

(d)* Yoke-type connections between anesthesia apparatus and flush-type cylinder valves (commonly used with anesthetic gas cylinders) shall be Connection No. 860 in accordance with CGA V-1, *Compressed Gas Cylinder Valve Outlet and Inlet Connections* (ANSI B-57.1) (*see Appendix A-4-4.1.3.4*).

8-5.1.2.2 Apparatus for Administering Respiratory Therapy.

(a) 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 U.S. Government Commercial Standard 223-59, *Casters, Wheels, and Glides for Hospital Equipment.*

(b) Oxygen tent canopies having flexible components shall be fabricated of materials having a maximum burning rate classification of "slow burning."

(1) Oxygen enclosures of rigid materials shall be fabricated of noncombustible materials.

(c) 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.

(d) 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.

(e) Humidifiers and nebulizers shall be equipped with provisions for overpressure relief or alarm if the flow becomes obstructed.

(f) 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.

8-5.2 Nonpatient Gas Equipment.

8-5.2.1 Carts and Hand Trucks.

8-5.2.1.1 Construction. 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.

8-5.2.1.2 Use. Carts and hand trucks that 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 12-4.1.

8-5.2.2 Gas Equipment — Laboratory. 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.

8-6 Administration.

8-6.1 Responsibility of Governing Body. (Reserved)

8-6.2 Policies.

8-6.2.1 Elimination of Sources of Ignition.

8-6.2.1.1 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.

8-6.2.1.2 No sources of open flame, including candles, shall be permitted in the area of administration.

8-6.2.1.3 Patients and hospital personnel in the area of administration shall be advised of respiratory therapy hazards and regulations.

(a) Visitors shall be cautioned of these hazards through the prominent posting of signs (*see 8-6.4.2*).

(b) Sparking toys shall not be permitted into any pediatrics nursing unit.

NOTE: Such toys have been associated with fire incidents in health care facilities.

8-6.2.2 Misuse of Flammable Substances.

8-6.2.2.1 Flammable or combustible aerosols or vapors, such as alcohol, shall not be administered in oxygen-enriched atmospheres as outlined in 8-2.1.2.3(a).

8-6.2.2.2 Oil, grease, or other flammable contaminants shall not be used with oxygen equipment.

8-6.2.2.3 Flammable and combustible liquids and flammable gases, such as ether, shall not be permitted within the site of intentional expulsion. When flammable anesthetics, such as ether, are administered, the area shall be considered a flammable anesthetizing location. (*See 12-4.1 for requirements for flammable anesthetizing locations.*)

8-6.2.2.4 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.

(a) 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.

(b) Equipment operated at oxygen pressures under 60 psig (0.414 kPa gauge) shall be permitted to be sterilized with nonflammable mixtures such as ethylene oxide and carbon dioxide or ethylene oxide and fluorocarbon diluents.

(c) Cylinders and containers shall not be sterilized.

8-6.2.3 Prevention of Chemical Breakdown.

8-6.2.3.1 Equipment capable of producing surface temperatures sufficient to cause chemical breakdown of the atmosphere within a patient enclosure shall not be permitted therein.

(a) 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.

8-6.2.4 Servicing and Maintenance of Equipment.

8-6.2.4.1 Defective equipment shall be immediately removed from service.

8-6.2.4.2 Defective electrical apparatus shall not be used.

8-6.2.4.3 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.

8-6.2.4.4 Service manuals, instructions, and procedures provided by the manufacturer shall be used in the maintenance of equipment.

8-6.2.4.5 A scheduled preventive maintenance program shall be followed.

8-6.2.5 Gases in Cylinders and Liquefied Gases in Containers. (*See 4-6.2.1.*)

8-6.2.6 Ambulatory Patients. Ambulatory patients on oxygen therapy, whether in or out of a health care facility, shall be permitted free access to all areas that prohibit smoking and that have no open flames.

8-6.3 Recordkeeping. (Reserved)

8-6.4 Use (Including Information and Warning Signs).

8-6.4.1 Labeling.

8-6.4.1.1 Equipment listed for use in oxygen-enriched atmospheres shall be so labeled.

8-6.4.1.2 Oxygen-metering equipment and pressure-reducing regulators shall be conspicuously labeled:

OXYGEN — USE NO OIL

8-6.4.1.3 Flowmeters, 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.

8-6.4.1.4 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.

NOTE: A suggested minimum text for labels is:

CAUTION
OXYGEN IN USE
KEEP FLAMES AWAY
NO SMOKING
NO ELECTRICAL APPLIANCES

8-6.4.1.5 Oxygen-metering equipment, pressure-reducing regulators, humidifiers, and nebulizers shall be labeled with the name of the manufacturer or supplier.

8-6.4.1.6 Cylinders and containers shall be labeled in accordance with ANSI/CGA C-4, *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.

8-6.4.1.7 All labeling shall be durable and withstand cleansing or disinfection.

8-6.4.2* Signs. 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 or to building walls or be supported by other appropriate means.

NOTE 1: Special signs and additional precautionary measures should be employed whenever foreign languages present a communication problem.

NOTE 2: 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.

This sign is intended to caution those not familiar with this chapter.

NOTE 3: A suggested text for precautionary signs for oxygen tent canopies and oxygen hoods (*see Note 2 above*) used in pediatric nursing units is:

CAUTION
OXYGEN IN USE
ONLY TOYS APPROVED BY
NURSES MAY BE GIVEN
TO CHILD

8-6.4.3 Transportation, Storage, and Use of Equipment.

8-6.4.3.1 Flow-control valves on administering equipment shall be closed prior to connection and when not in use.

8-6.4.3.2 Apparatus shall not be stored or transported with liquid agents in reservoirs.

8-6.4.3.3 Care shall be observed in attaching connections from gas services to equipment and from equipment to patients.

8-6.4.3.4 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.

8-6.4.3.5 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.

8-6.4.3.6 Equipment for respiratory therapy need not be electrically conductive unless intended for use in a hazardous location.

8-6.5 Qualification and Training of Personnel.

8-6.5.1 Equipment shall be serviced by qualified personnel only.

Chapter 9 Manufacturer Requirements

NOTE: The application of requirements contained in this chapter for specific types of health care facilities can be found in Chapters 12 through 18.

9-1 Scope. This chapter covers the performance, maintenance, and testing, with regard to safety, required of manufacturers of equipment used within health care facilities.

9-2 Electrical Equipment.

9-2.1 Patient-Care-Related Electrical Appliances.

NOTE 1: It is the intent that 9-2.1 should not be used by authorities having jurisdiction over health care facilities to limit health care facilities' 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 health care facilities to conduct tests using these manufacturer requirements to verify that their patient-care-related electrical appliances are in conformance with the requirements of this chapter. In this respect, it is the intent of the Committee that health care facilities perform only those tests specified in 7-5.1.

NOTE 2: See Chapter 2, "Definitions," for the definition of patient-care-related electrical appliance.

9-2.1.1 Mechanical Construction.

9-2.1.1.1 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.

9-2.1.1.2 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, 12-4.1 applies.

9-2.1.2 Electrical Requirements — Appliances Equipped with Power Cords.

9-2.1.2.1 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, and C73.46; and 410-56, 410-57, and 410-58 of NFPA 70, National Electrical Code.*)

Exception No. 1: Appliances, used in special locations or for special purposes, equipped with plugs approved for the location (e.g., 3-4.1.2.4).

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 9-2.1.2.2(e), "Cords without Grounding Conductors"].

Exception No. 3: Appliances supplied by other than 120-V 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; if the conductor is not twisted, it 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 are permitted to 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.

9-2.1.2.2 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(A) of 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 the cord 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 9-2.1.13.2, "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 9-2.1.3.2, "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 9-2.1.13.2, "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 or isolated power systems, shall be connected in accordance with the conventions of a grounded system. (*See 200-2 through 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 shall be permitted to 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.

(h) *Storage.* See 7-5.1.2.5(a).

9-2.1.3 Wiring within Appliances Equipped with Power Cords.

9-2.1.3.1 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.

9-2.1.3.2 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.

9-2.1.3.3 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.

9-2.1.3.4 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.

9-2.1.3.5 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 9-2.1.13.4, "Leakage Current from Appliance to Ground," are performed.

9-2.1.3.6 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 9-2.1.3.5).

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.

9-2.1.3.7 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.

9-2.1.3.8 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 9-2.1.13.

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 9-2.1.13.

9-2.1.4 Connectors and Connections to Devices.

9-2.1.4.1 Indexing of Receptacles for Patient Leads. Receptacles on appliances shall be designed and constructed so that those contacts that deliver electric current in a way and of a magnitude greater than 500 microamperes, when measured in accordance with 9-2.1.13.5(a), (b), (d), and (e), are female and indexed. Receptacles and plugs shall be polarized if improper orientation can create a hazard.

9-2.1.4.2 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 that permits the inadvertent delivery of a hazardous current to a patient.

9-2.1.5 Line Voltage Variations and Transients — General. All appliances shall be capable of operating within line voltage variations that conform with ANSI C84.1, *Voltage Ratings: 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.

9-2.1.6 General Design and Manufacturing Requirements.

9-2.1.6.1 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).

9-2.1.6.2 Toxic Materials. Surfaces that contact patients shall be free of materials that commonly cause toxic reactions. Coatings used on these surfaces shall conform to ANSI Z66.1, *Specifications for Paints and Coatings Accessible to Children to Minimize Dry Film Toxicity.*

9-2.1.6.3 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.

9-2.1.6.4 Operation with Essential Electrical System.

(a) *General.* Equipment (fixed or appliances) shall be designed to operate normally when energized by a standby power source that conforms to the requirements of Chapter 3.

(b) *Power Transfer.* Following transfer of power between the normal power system and the essential electrical system, a patient-care-related appliance shall resume function in the mode of operation that existed prior to the transfer.

Exception: If the appliance cannot maintain its mode of operation in the event of a power transfer, it shall default to a nonhazardous status and clearly indicate by audible or visible signals that its mode of operation has changed.

(c) *Programmable Appliances.* Deenergization of the power supply of a programmable appliance shall not result in the loss or change of any part of the program or data required for normal operation.

Exception No. 1: This requirement does not apply to computers and programmable appliances that are not directly related to patient care.

Exception No. 2: Patient-care-related appliances that may suffer loss of program or vital data shall default to a start-up status and clearly indicate by audible or visual signals that its program or data has been altered or lost.

9-2.1.7 Fire and Explosion Hazards.

9-2.1.7.1 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 it is essential to their intended function.

9-2.1.7.2 Oxygen-Enriched Atmospheres. Electric appliances employing oxygen, or that are intended to be used in oxygen-enriched atmospheres, shall comply with the appropriate provisions of Chapter 8, "Gas Equipment"; Chapter 19, "Hyperbaric Facilities"; and NFPA 99B, *Standard for Hypobaric Facilities*, in addition to all applicable provisions of this chapter.

NOTE: See also NFPA 53M, *Manual on Fire Hazards in Oxygen-Enriched Atmospheres.*

9-2.1.7.3 Inhalation Anesthetizing Locations. Electric appliances used in inhalation anesthetizing locations shall comply with the provisions of Chapter 7, "Electrical Equipment" and 12-4.1, in addition to all applicable provisions of this chapter.

9-2.1.8 Instruction Manuals and Labels.

9-2.1.8.1 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 that 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 — 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.

9-2.1.8.2 Operating Instructions on Appliances. Condensed operating instructions shall be visibly and permanently attached to, or displayed on, any appliance that is intended to be used in emergency situations and that could result in injury or death to the operator or patient if improperly used.

9-2.1.8.3 Labeling. The manufacturer shall furnish, for all appliances, labels that are readily visible and legible and that 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 12-4.1.*)

9-2.1.9 Additional Requirements for Special Appliances.

9-2.1.9.1 Signal Transmission Between Appliances.

(a)* *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 the grounding interconnection of the appliances.

(b) *Outdoor Signal Transmission.* Outdoor signal transmission lines from appliances attached to patients 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.

9-2.1.9.2 Appliances Intended to Deliver Electrical Energy.

(a) *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 that 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.

(b) *Specific Requirements by Type of Device.*

(1) Electrically Powered Transducers. Exposed metal parts of these devices shall be considered electrodes and meet the applicable requirements of 9-2.1.13, "Manufacturers' Tests for Safety of Patient-Care-Related Electrical Appliances." 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.

(2) 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 9-2.1.13.5, "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.

(3) Electrotherapeutic Devices. Appliances that 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 electrosleep, electroanesthesia, and electroshock.

(4)* Electrosurgery. Electrosurgical devices shall meet the requirements of 9-2.1.9.2(a), "Conditions for Meeting Safety Requirements."

NOTE 1: See Annex 2, "The 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 that cause fibrillation or stimulation. DC monitoring currents may cause chemical burns. Capacitive or inductive coupling may occur.

(5) Cardiac Defibrillation. Cardiac defibrillators 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.

9-2.1.9.3 Electrical Equipment in Oxygen-Enriched Atmospheres. Electrically powered equipment intended to be used within oxygen delivery equipment shall comply with (a), (b), (c) or (d) as listed below. When only a remote control or signal leads of a device are to be used in the site of intentional expulsion, only the control or signal leads shall be required to comply with this section.

(a) Listed for use in oxygen-enriched atmospheres.

(b) Sealed so as to prevent an oxygen-enriched atmosphere from reaching electrical components. The sealing material shall be of the type that will still seal even after repeated exposure to water, oxygen, mechanical vibration, and heating from the external circuitry.

(c) Ventilated so as to limit the oxygen concentration surrounding electrical components to below 23.5 percent by volume.

(d) Both of following:

(1) No hot surfaces over 573°F (300°C).

Exception: Small (less than 2-W) hermetically sealed heating elements such as light bulbs.

(2) No exposed switching or sparking points of electrical energy that fall to the right of the curve for the appropriate type of circuit contained in Figures 9-2.1.9.3(a) through (f). The dc (or peak ac) open-circuit voltage and short-circuit current shall be used.

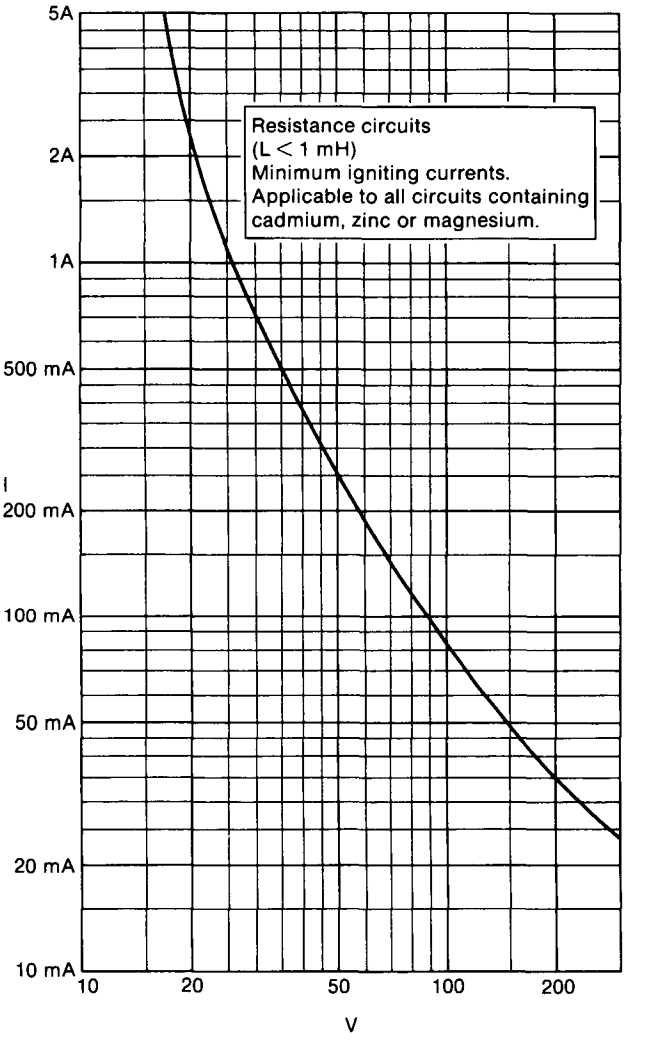


Figure 9-2.1.9.3(a).

9-2.1.10 Low-Voltage Appliances and Appliances Not Connected to the Electric Power Distribution System.

9-2.1.10.1 General. Appliances and instruments operating from batteries or their equivalent or from, an external source of low voltage, or that are not connected to the electric power distribution system shall conform to all applicable requirements of 9-2.1, "Patient-Care-Related Electrical Appliances." This shall include communication, signaling, entertainment, remote-control, and low-energy power systems.

Exception: Telephones.

9-2.1.10.2 Rechargeable Appliances. Battery-operated appliances that are rechargeable while in use shall meet all the requirements of 9-2.1.13.3, "Leakage Current Tests," for line-operated appliances.

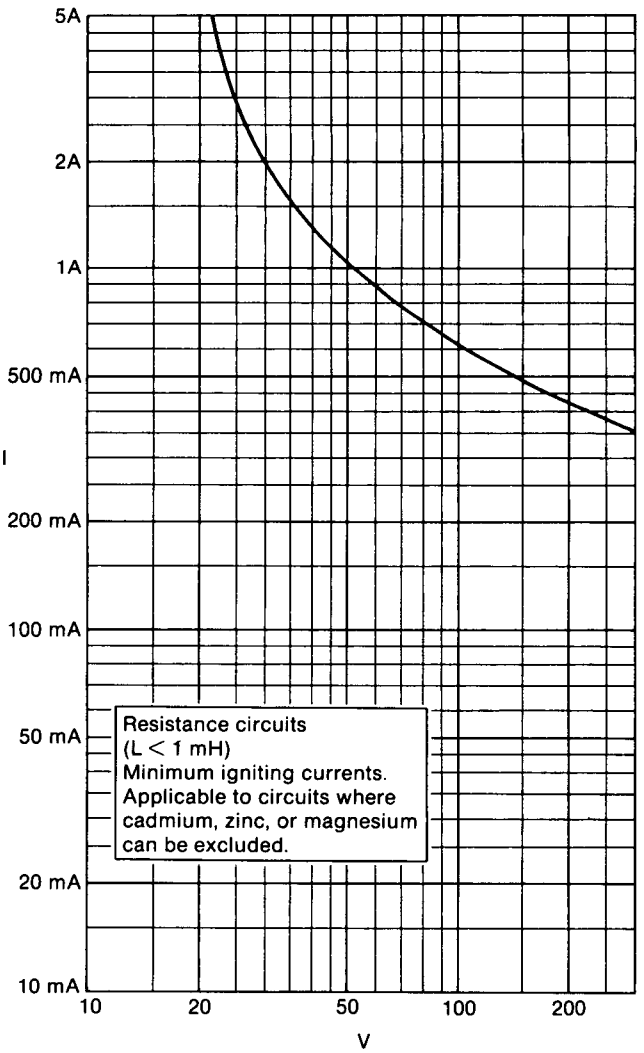


Figure 9-2.1.9.3(b).

9-2.1.10.3 Low-Voltage Connectors. Attachment plugs used on low-voltage circuits shall have distinctive configurations that do not permit interchangeable connection with circuits of other voltages.

9-2.1.10.4 Isolation of Low-Voltage Circuits. Circuits of 30 volts (dc or ac rms) or less shall be electrically isolated from the power distribution system. Grounded low-voltage circuits shall be permitted provided that load currents are not carried in the grounding conductor.

9-2.1.11 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 critical care shall include protection against equipment damage during defibrillation of the patient.

9-2.1.12 Direct Electrical Pathways to the Heart. The requirements of this section shall apply only to manufacturers except where specifically noted.

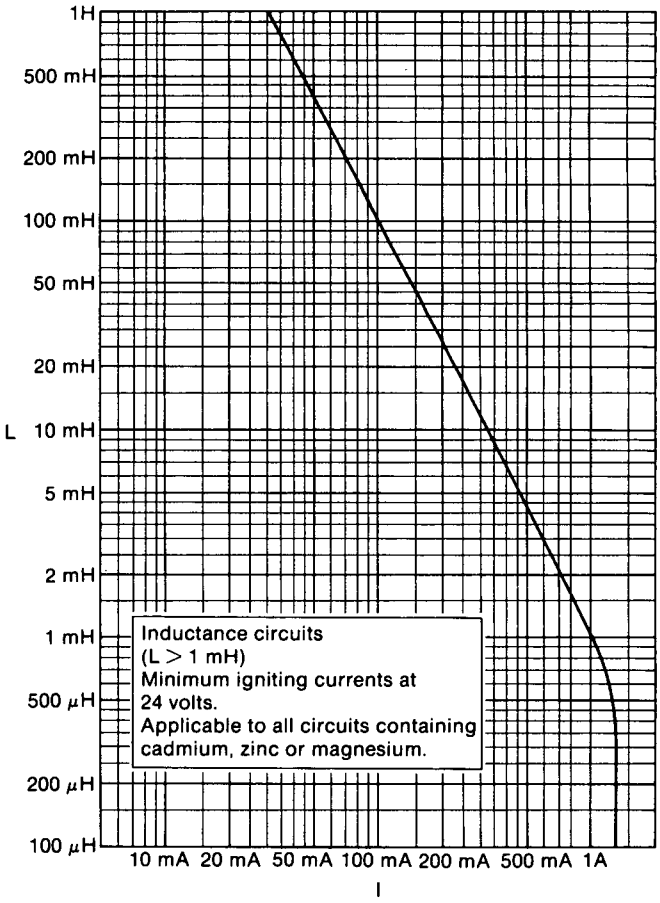


Figure 9-2.1.9.3(c).

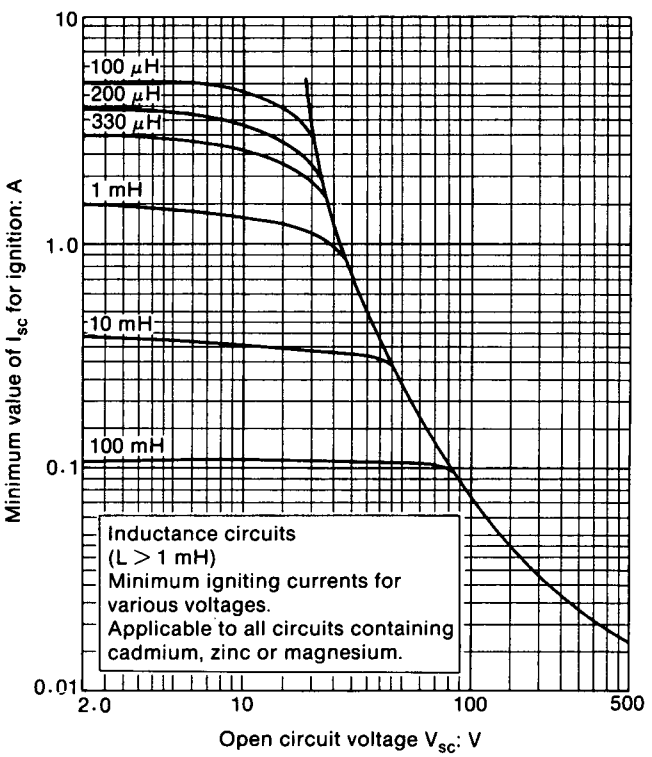


Figure 9-2.1.9.3(d).

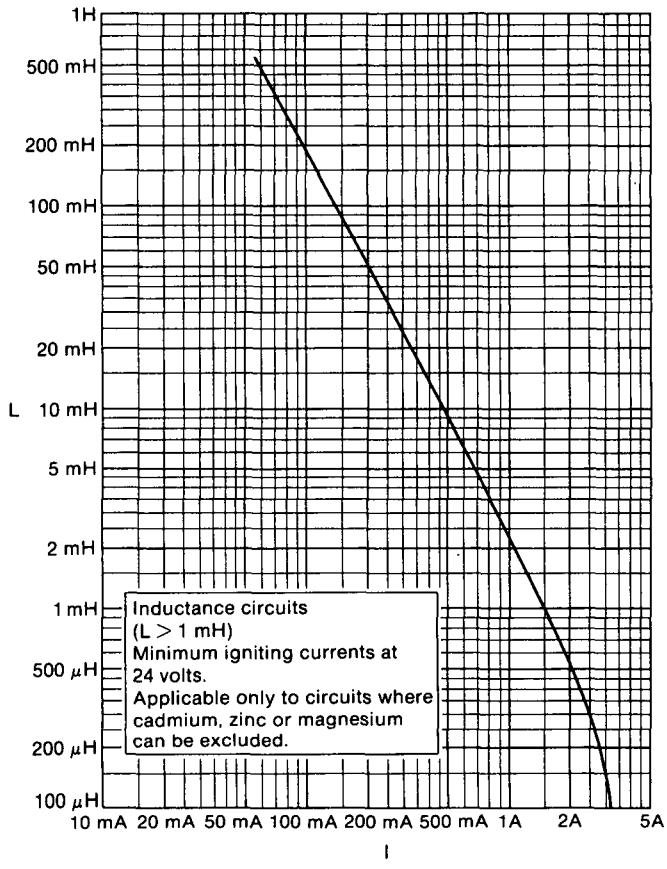


Figure 9-2.1.9.3(e).

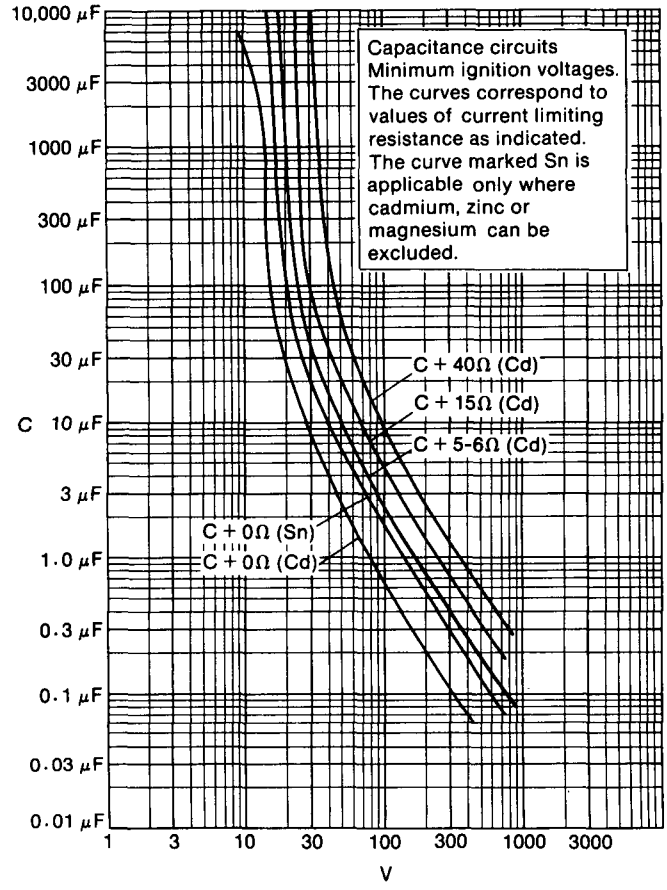


Figure 9-2.1.9.3(f).

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, or a 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.

9-2.1.12.1 Cardiac Electrodes.

(a) *General.* Appliances that have isolated patient leads shall be labeled as having isolated patient leads in accordance with 9-2.1.13.5, "Lead Leakage Current Tests and Limits."

(b) *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 user is required to have a policy to protect pacing leads with external terminals from potentially hazardous contact with conductive surfaces (*see 7-6.2.1.3, "Protection of Patients with Direct Electrical Pathways to the Heart"*).

Exception No. 1: Metal stylets or guide wires temporarily introduced into a vein or artery for purposes of positioning a catheter need not be insulated. When such guide wires 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 guide wire 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.

(c) *Safety Requirements for Cardiac Electrodes.* The electrode catheter, fitting, and associated appliance, when assembled, shall meet the applicable requirements of 9-2.1.13.5, "Lead Leakage Current Tests and Limits," for isolated patient leads.

(d) *Insulation of Pacemaker Connections.* Uninsulated or open-type connectors shall not be used for external cardiac pacemaker terminals.

9-2.1.12.2 Liquid-Filled Catheters.

(a) *Cardiac Catheter System.* Any conductive element of a liquid catheter system that 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.

(b) *Nonconductive Cardiac Catheters.* A nonconductive catheter containing a conductive liquid, when connected to its appropriate system, shall meet the applicable requirements of 9-2.1.13.5, "Lead Leakage Current Tests and Limits," for isolated patient leads, with the patient end of the liquid-filled catheter considered to be an electrode.

(c) *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.

9-2.1.12.3 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.

9-2.1.13 Manufacturers' Tests for Safety of Patient-Care-Related Electrical Appliances.

9-2.1.13.1 General. This section describes tests by manufacturers for the safe operation of an appliance. The tests in this subsection are in addition to the design requirements of the entire Section 9-2.1, "Patient-Care-Related Electrical Appliances." The appliance manufacturer shall perform the testing adequate to ensure that each finished appliance will meet the specified test limits of this section.

Exception: Tests that are potentially destructive need only be performed by the manufacturer to ensure design compliance for new appliances.

9-2.1.13.2 Grounding Circuit Continuity.

(a) *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.

9-2.1.13.3* Leakage Current Tests.

(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 9-2.1.13.4, "Leakage Current from Appliance to Ground," and 9-2.1.13.5, "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 9-2.1.13.4 and 9-2.1.13.5 multiplied by the frequency, in kHz, up to a maximum of 10 milliamperes.

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 waveform, provided that the contribution of each component to the total reading is weighted in accordance with 9-2.1.13.3(b).

This "weighting" can be achieved by a frequency-response-shaping network that precedes a flat response meter, or by a meter whose own frequency response characteristic matches 9-2.1.13.3(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 9-2.1.13.4 and 9-2.1.13.5 shall not be exceeded under any of these conditions.

9-2.1.13.4 Leakage Current from Appliance to Ground.

(a) *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 9-2.1.13.3. This test is illustrated in Figure 9-2.1.13.4(a).

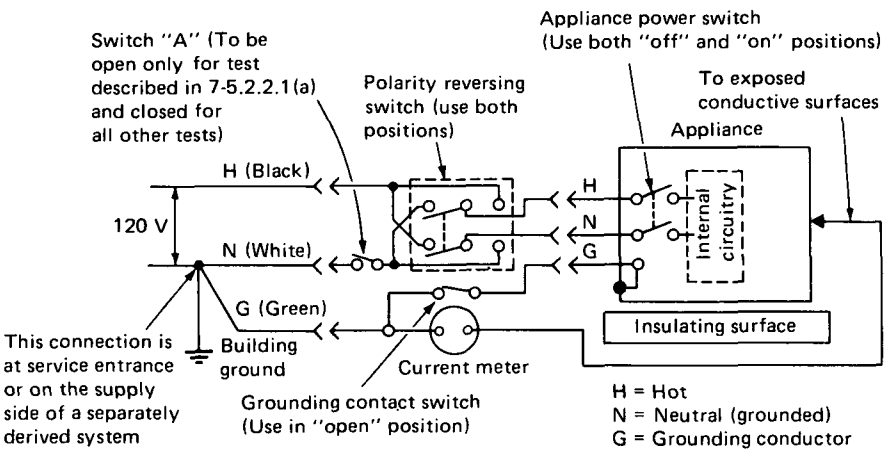


Figure 9-2.1.13.4(a) Test circuit for measuring leakage current from exposed conductive surfaces.

Appliances required to meet the limits of 7-5.2.2.1, "Patient Care Area," (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 9-2.1.13.4(c)(1) and (2), "Chassis Leakage Current Limits," shall be tested with switch "A" closed (connected neutral).

(b) *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.

(c)* *Chassis Leakage Current Limits.*

(1) Cord-Connected Appliances. Cord-connected appliances that are intended for use in the patient care vicinity shall not exceed 300 microamperes of chassis leakage current as measured in 9-2.1.13.4(a), "Test Methods."

(2) Permanently Wired Equipment. Permanently wired equipment installed in the patient care 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 facility. This measurement shall be made in accordance with 9-2.1.13.4(a) while the equipment is temporarily insulated from ground.

9-2.1.13.5 Lead Leakage Current Tests and Limits.

(a) *Lead to Ground (Nonisolated Input).* The lead leakage current to ground shall be measured under the conditions of 9-2.1.13.3, "Leakage Current Tests." 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 9-2.1.13.5(a) is an example of an acceptable test configuration. The leakage current shall not exceed 50 microamperes.

(b) *Lead to Ground (Isolated Input).* The leakage current to ground between each patient lead and ground shall be measured under the conditions of 9-2.1.13.3, "Leakage Current Tests." 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 9-2.1.13.5(b) is an example of an acceptable test configuration. The leakage current shall not exceed 10 microamperes with the ground intact and 50 microamperes with the ground open.

(c) *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 patient cables shall be measured. Figure 9-2.1.13.5(c) is an example of an acceptable test configuration. At the patient end of the leads, the leakage current shall not exceed 20 microamperes and at the apparatus terminals 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 9-2.1.13.4(b), "Appliances with No Exposed Conductive Surfaces," which is also temporarily grounded.

(d) *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 9-2.1.13.3, "Leakage Current Tests." 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 9-2.1.13.5(d)/(e) is an example of an acceptable test configuration. The leakage current shall not exceed 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.

(e) *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 9-2.1.13.3, "Leakage Current Tests." 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 9-2.1.13.5(d)/(e) is an example of an acceptable test configuration. The leakage current shall not exceed 10 microamperes with the ground intact and 50 microamperes with the ground open.

Exception: Measuring leakage current between any single lead and all other leads need only be performed to ensure the approval agency of design compliance.

9-2.2 Nonpatient Electrical Equipment. (Reserved)

9-3 Gas Equipment. (Reserved)

9-4 Material. (Reserved)

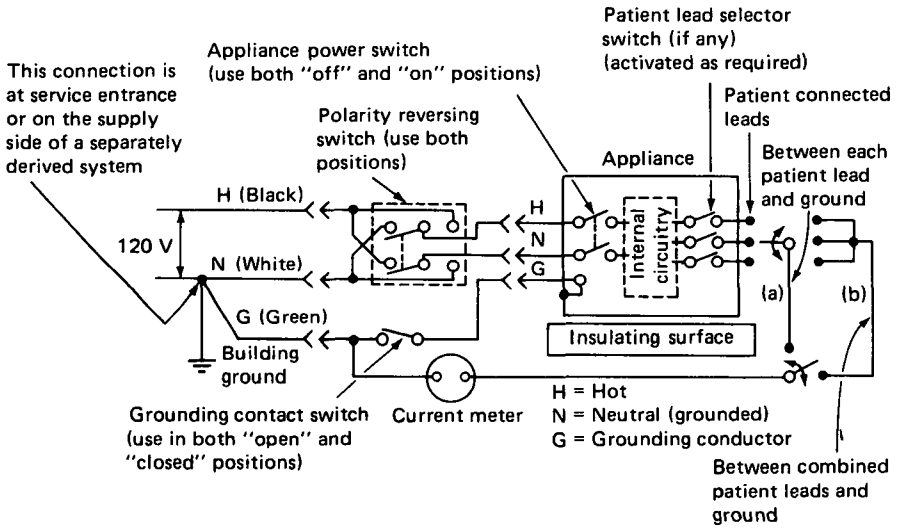


Figure 9-2.1.13.5(a) Test circuit for measuring leakage current between patient leads and ground (nonisolated).

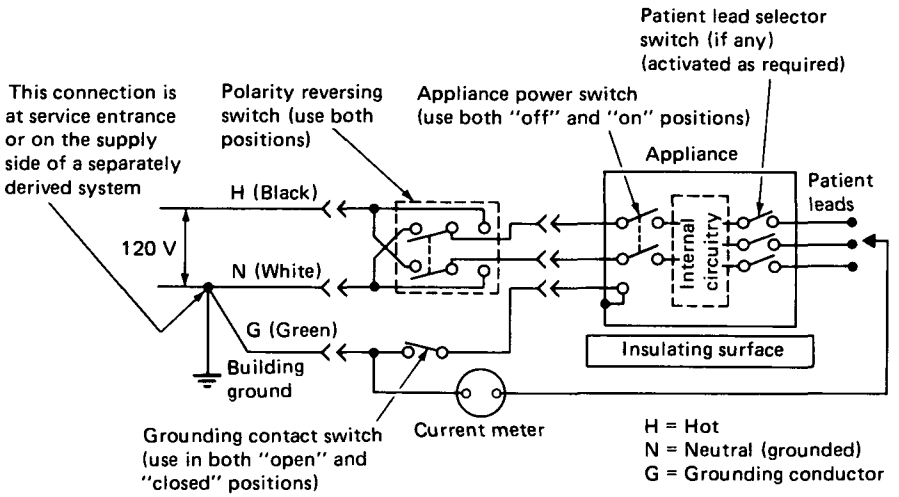


Figure 9-2.1.13.5(b) Test circuit for measuring leakage current between patient leads and ground (isolated).

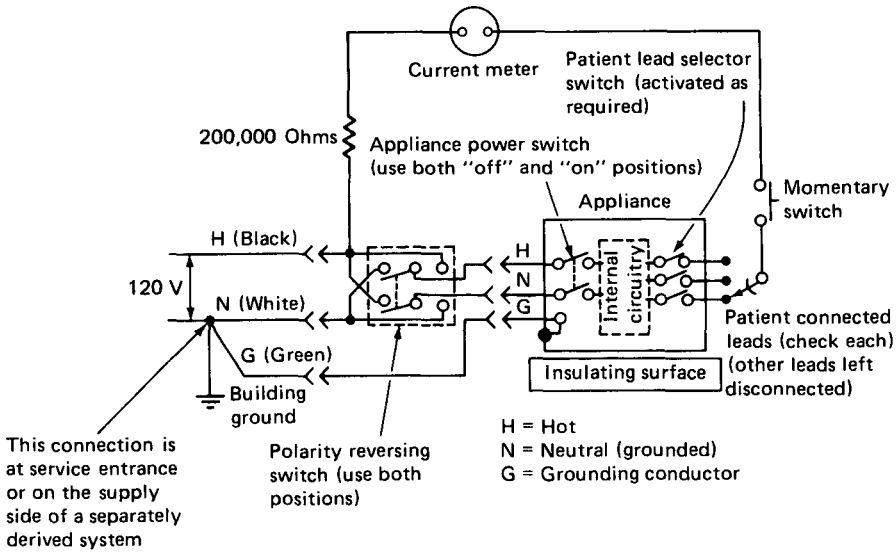


Figure 9-2.1.13.5(c) Test circuit for measuring the electrical isolation of isolated patient leads.

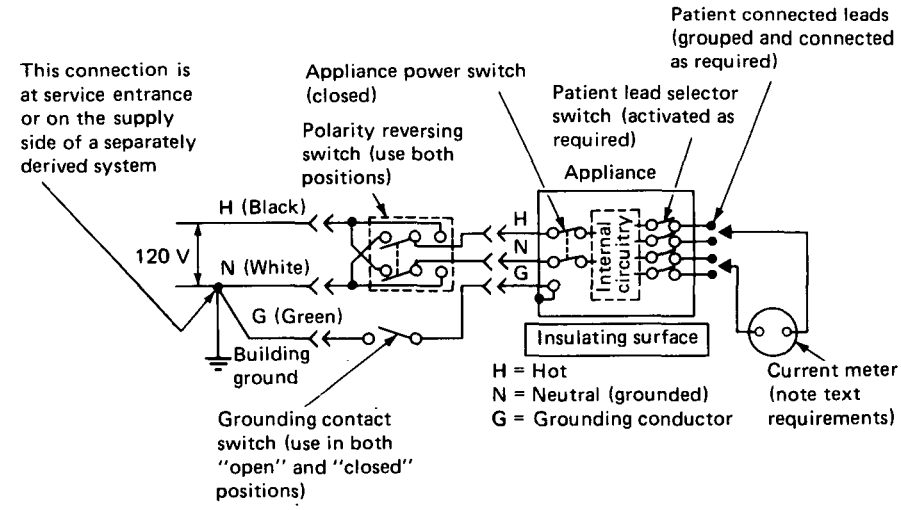


Figure 9-2.1.13.5(d)/(e) Test circuit for measuring leakage current between patient leads (nonisolated and isolated).

Chapter 10 Laboratories

NOTE: The application of requirements contained in this chapter for specific types of health care facilities can be found in Chapters 12 through 18.

10-1* Scope.

10-1.1* This chapter establishes criteria to minimize the hazards of fire and explosions in laboratories, as defined in Chapter 2.

NOTE 1: Laboratory facilities present fire hazards of a nature not encountered elsewhere in health-related institutions.

This section is not intended to cover hazards resulting from the misuse of chemicals, radioactive materials, or biological materials that 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.

NOTE 2: 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.

10-1.2 Interface with Existing Codes and Standards.

10-1.2.1* NFPA 45, *Fire Protection Standard for Laboratories Using Chemicals*, is the basic NFPA standard for laboratories that covers the construction, ventilation systems, and related fire protection of all laboratories in all facilities. However, this chapter (10) has more stringent requirements for laboratories located in health care facilities. Where interface with existing NFPA or other consensus codes and standards occurs, reference is made to the appropriate source in the text.

10-1.2.2 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.

10-2 Nature of Hazards.

10-2.1 Fire Loss Prevention.

10-2.1.1 Hazard Assessment.

10-2.1.1.1 An evaluation shall be made of 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 hazards associated with the nature of the proposed reactions (e.g., evolution of acid vapors or flammable gases).

10-2.1.1.2 Periodic reviews of laboratory operations and procedures shall be conducted with special attention given to any change in materials, operations, or personnel.

10-2.1.1.3 Unattended operations and automatic laboratory equipment shall be provided with periodic surveillance or with automatic monitoring devices to detect and report abnormal operation.

10-2.1.1.4 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.

10-2.1.2 Fire Prevention Procedures. Fire prevention procedures shall be established. (*See Section 10-8.*)

10-2.1.3 Emergency Procedures.

10-2.1.3.1 Procedures for laboratory emergencies shall be developed. Such procedures shall include alarm actuation, evacuation, and equipment shutdown procedures, and provisions for control of emergencies that 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.

10-2.1.3.2 Emergency procedures shall be established for controlling chemical spills.

10-2.1.3.3* Emergency procedures shall be established for extinguishing clothing fires.

10-2.1.4 Orientation and Training.

10-2.1.4.1 New laboratory personnel shall be taught general safety practices for the laboratory and specific safety practices for the equipment and procedures they will use.

10-2.1.4.2 Continuing safety education and supervision shall be provided, incidents shall be reviewed monthly, and procedures shall be reviewed annually.

10-2.1.4.3 Fire-exit drills shall be conducted at least quarterly. Drills shall be so arranged that each person shall be included at least annually.

NOTE: Interruption of essential services is not required.

10-3 Structure.

10-3.1* Construction and Arrangement.

10-3.1.1* Construction of laboratories shall comply with the requirements of NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, and NFPA 101, *Life Safety Code*, and with the following additional requirements. 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 3/4-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 shall be permitted to be held open only by an automatic release device complying with the applicable requirements in NFPA 101, Life Safety Code.

10-3.1.2 Interior finish in laboratories and means of egress shall comply with the applicable sections of NFPA 101, *Life Safety Code*.

10-3.2 Exit Details.

10-3.2.1* Any room arranged for laboratory work that has an area in excess of 1000 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.

A second means of access to an exit shall be provided for any laboratory work areas in which hazards exist as defined in 3-4.1 of NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals.*

10-3.2.2 Travel distance between any point in a laboratory unit and an exit access door shall not exceed 75 ft (22.9 m).

10-3.2.3 Exit access doors from laboratories shall meet the requirements of NFPA 101, *Life Safety Code.*

10-3.2.4 Laboratory corridors constituting access to an exit shall meet the requirements of NFPA 101, *Life Safety Code.* Corridors shall be maintained clear and unobstructed at all times.

10-3.2.5 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.

10-3.3 Exhaust Air. Exhaust air shall conform to 5-3.1.

10-3.4* Ventilation. Ventilation shall comply with 5-4.3 and with the requirements of NFPA 45, *Standard on Fire Prtoection for Laboratories Using Chemicals.*

10-3.5 Fume Hoods. Fume hoods shall conform to 5-4.4 and 5-6.2.

10-4 Equipment.

10-4.1 General. Laboratory apparatus shall comply with the requirements of NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals.*

10-4.2 Equipment Employing Liquids.

10-4.2.1 Tissue processors and similar automatic equipment that release ignitible (flammable or combustible) vapors into the ambient workspace shall be operated at least 5 ft (1.52 m) from the storage of combustible materials, unless separated by 1-hour fire-resistive construction.

NOTE: Tissue processors that operate as a closed system contain ignitible vapor hazards within the processor and thus do not pose a hazard requiring a 5-ft (1.52-m) separation.

10-4.2.2* Unattended laboratory operations employing flammable or combustible reagents shall be conducted in an area equipped with an automatic fire extinguishing system.

10-5* Fire Protection.

10-5.1* 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 1-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 2-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 6 of NFPA 75, *Standard for the Protection of Electronic Computer/Data Processing Equipment,* provides general information on the protection of computer room equipment.

10-5.2 Automatic fire extinguishment and fire detection systems, where required, shall be connected to the facility fire alarm system and shall be arranged to immediately sound an alarm.

10-5.3 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.*

10-6* 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.

10-7 Flammable and Combustible Liquids.

10-7.1 General. 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 references in Chapter 20 and Appendix B.*)

10-7.2* Storage and Use.

10-7.2.1* Flammable and combustible liquids shall be used from and stored in approved containers in accordance with NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals,* and NFPA 30, *Flammable and Combustible Liquids Code.*

10-7.2.2* Established laboratory practices shall limit working supplies of flammable or combustible liquids. The total volume of Class I, II, and IIIA liquids outside of approved storage cabinets and safety cans shall not exceed 1 gal (3.78 L) per 100 sq ft (9.23 sq m). The total volume of Class I, II, and IIIA liquids, including those contained in approved storage cabinets and safety cans, shall not exceed 2 gal (7.57 L) per 100 sq ft (9.23 sq m). No flammable or

combustible liquid 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.

Exception: Very small laboratory work areas acceptable to the authority having jurisdiction.

10-7.2.3 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.

10-7.2.4 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.

10-7.2.5* Class I flammable liquids shall not be stored in ordinary refrigerators, freezers, or coolers. If Class I flammable liquids are stored under refrigeration (e.g., for analytical purposes), the storage devices shall be listed flammable materials storage refrigerators or refrigerators listed for Class I, Division 1, Group C locations. The outside doors of refrigerators shall be labeled to denote whether or not they are acceptable for storage of flammable liquids. If the refrigerator is not listed for the purpose, the warning shall be worded to prohibit all storage of flammable liquids.

10-7.3 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.

10-7.4 Handling of Flammable and Combustible Liquids.

10-7.4.1 Flammable liquids and combustible liquids with flash points 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° (16.6°) of the flash point of the liquid.

10-7.4.2 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.

10-7.5* 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.

10-8* Maintenance and Inspection.

10-8.1 Procedures.

10-8.1.1 For adequate laboratory safety, careful maintenance and watchfulness are imperative.

10-8.1.2 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.

10-8.1.3 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.

10-8.1.4* 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.

10-8.1.5 Periodic safety inspection shall include the testing of all emergency showers, eye baths, and other emergency equipment.

10-8.1.6* 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.

10-8.2 Identification of Hazards.

10-8.2.1* All doors leading to laboratories in health-related facilities shall be marked with the emblem described in NFPA 704, *Standard System for the Identification of Fire Hazards of Materials*, to indicate the fire hazards of materials intended to be used within this area. No laboratory or other room shall be required to be identified with a hazard signal sign unless the area contains a significant quantity of hazardous material. No area shall be considered to contain a significant quantity of hazardous materials unless the contents include hazardous materials in glass containers that are 1 gal in size or larger, hazardous compressed gases or cryogenic liquids in containers greater than 5 in. in diameter and 15 in. in length, or dry hazardous materials in containers in excess of 5 lb. No area shall

be considered to contain a significant quantity of hazardous materials unless the quantity of hazardous materials exceeds 200 lb or 10 gal of flammable liquids. No laboratory or storage area shall be identified with a hazard signal sign unless hazardous materials in significant quantities have one or more hazard ratings of 2 or greater.

10-8.2.2 It shall be the responsibility of the laboratory safety officer to ensure periodically that the emblem properly indicates the nature of the materials being used within the identified space.

10-8.2.3 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.

10-9 Transfer of Gases.

10-9.1 Transfer of gaseous oxygen shall be in accordance with 4-6.2.1.5(b).

10-9.2 Transfer of all other gases from one cylinder to another within the laboratory shall be prohibited.

10-9.3 Transfer of liquid oxygen shall be in accordance with 4-6.2.1.6.

10-10 Laboratory Gas Cylinder Storage for Non-Piped Use.

10-10.1 Cylinder and Container Management. Requirements shall be in accordance with 4-3.1.1.

10-10.2 Storage Requirements (Location, Construction, Arrangement; Any Quantity; Flammable and Nonflammable Gases).

10-10.2.1 Storage shall be in cylinders complying with 4-3.1.1.

10-10-2.2. Flammable gas cylinder storage for a laboratory, if inside any health care facility, shall be (except as permitted in 4-4.3.1) in a separate room or enclosure reserved exclusively for that purpose, having a fire-resistance classification of at least 2 hours, and ventilated in accordance with 4-3.1.2.4. Cylinders in storage shall be kept in racks or secured in position.

10-10.2.3 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.

10-10.2.4 Enclosures for storage of nonflammable gases shall have at least 1-hour fire-resistive construction, in accordance with 4-3.1.2.1.

10-10.3 The total quantity and size of cylinders containing oxygen, flammable gas, liquefied flammable gas, and gas with Health Hazard Ratings of 3 or 4 shall comply with Table 8-2 of NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*. The number of reserve cylinders within general laboratory work areas shall not exceed 1 week's working supply.

Chapter 11 (Reserved)

Chapter 12 Hospital Requirements

12-1 Scope. This chapter addresses safety requirements of hospitals.

12-2 General Responsibilities.

12-2.1 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 that 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.

12-2.2 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.

12-2.3 To achieve the performance criteria of Chapters 1 through 11, the governing body of the hospital shall be permitted to assign responsibility to appropriate hospital personnel, consultants, architects, engineers, or others.

12-2.4 The hospital shall ensure that policies are established and maintained that permit the attending physician to satisfy the emergency needs of any patient that 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.

12-2.5 Electricity. 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.

The hospital shall establish policies and procedures related to the safe use of 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 that 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 (Chapter 3) and the inspection, testing, and maintenance of electrical appliances (Chapter 7).

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 patients.

12-2.6 Patient Care Areas. Areas of a hospital in which patient care is administered are classified as general care areas or critical care areas, either of which is permitted to be classified as a wet location. 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 area classification. (*See definition of patient care area in Chapter 2.*)

(a) General Care Area. (*See definition in Chapter 2.*)

(b) Critical Care Area. (*See definition in Chapter 2.*)

(c) Wet Location. (*See definition in Chapter 2.*)

12-2.7 Anesthesia. It shall be the responsibility of the governing body of the hospital to designate anesthetizing locations.

12-2.8 Laboratories. The governing boards of hospitals shall have the responsibility of protecting the facilities (for patient care and clinical investigation) and the personnel employed therein.

12-3 General Requirements.

12-3.1 (Reserved)

12-3.2 (Reserved)

12-3.3 Electrical System Requirements.

12-3.3.1 The normal electrical distribution system for patient care areas shall conform to the requirements in Chapter 3, "Electrical Systems."

These requirements apply to new construction. Existing installations need not be modified, provided that they meet the operational safety requirements in 3-5.2.1 through 3-5.2.3.

12-3.3.2 The essential electrical distribution system shall conform to a Type I system, as described in Chapter 3, "Electrical Systems."

12-3.4 Gas and Vacuum System Requirements.

12-3.4.1 Patient gas piping systems shall conform to Type I systems in Sections 4-3 through 4-6 of Chapter 4, "Gas and Vacuum Systems."

Exception: A Type II gas system as defined in 4-6.2.4.1 when it is not served by the hospital's central supply system.

12-3.4.2 Laboratory gas piping systems shall conform to 4-3.3, 4-4.3, and Section 4-6.

12-3.4.3 Patient vacuum piping systems shall conform to Sections 4-7 through 4-11.

12-3.4.4 Laboratory vacuum piping systems shall conform to Sections 4-7 through 4-11.

12-3.4.5 For nonmedical gas piping systems, 4-3.4 shall apply.

12-3.5 Environmental System Requirements. (Reserved)

(*See 12-4.1 and 12-4.2 for requirements for anesthetizing locations and laboratories, respectively.*)

12-3.6 Material Requirements. (Reserved)

12-3.7 Electrical Equipment Requirements.

12-3.7.1 Patient Care Areas. Electrical appliances shall conform to Chapter 7. (*See 7-5.1 and 7-5.2.2.1.*)

NOTE: The requirements of Chapter 7 apply to all electrical appliances. Chapter 7 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 for all appliances in patient care areas.

12-3.7.2 Laboratories. Equipment shall conform to the nonpatient electrical equipment requirements in Chapter 7. (*See 7-5.2.2.2 for performance criteria; see 7-6.2.5 for policies.*)

12-3.8 Gas Equipment Requirements.

12-3.8.1 Patient. Equipment shall conform to the patient equipment requirements in Chapter 8, "Gas Equipment."

12-3.8.2 Nonpatient. Equipment shall conform to the nonpatient equipment requirements in Chapter 8, "Gas Equipment."

12-4 Specific Area Requirements.

NOTE: This is in addition to any applicable requirements in Section 12-3.

12-4.1 Anesthetizing Locations.

12-4.1.1 General.

12-4.1.1.1 Foreword. When this material 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 material by NFPA and the use of this material 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 in facilities 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 material 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 section 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 requirements of this section 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-12.1.

12-4.1.1.2 Scope. The purpose of this section is to establish performance and maintenance criteria for anesthetizing locations and for equipment and facilities ancillary thereto in order to safeguard patients and health care personnel from fire, explosion, electrical, and related hazards associated with the administration of both flammable and nonflammable inhalation anesthetics.

This section applies to all anesthetizing locations and related storage areas within hospitals in which inhalation anesthetics are administered.

This section covers ambulatory care facilities that are part of a hospital as well as ambulatory care facilities in which flammable inhalation anesthetics are administered. This section does not apply to anesthetizing locations situated in freestanding ambulatory care facilities in which only nonflammable anesthetics are administered (*see 13-4.1*).

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

The provisions of this section 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.

12-4.1.1.3 Purpose. This section contains the requirements for administration and maintenance that shall be followed as an adjunct to physical precautions specified in 12-4.1.2.

12-4.1.1.4* Recognition of Hazards and Responsibility.

(a) 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 12-4.1.1 and 12-4.1.2 are 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.

(b) 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 approval programs.

(c) 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.

(d) By virtue of its responsibility for the professional conduct of members of the medical staff of the hospital, the organized medical staff shall adopt regulations with respect to the use of inhalation anesthetic agents and to the prevention of electric shock and burns (*see Appendix C-12.3*) and through its formal organization shall ascertain that these regulations are regularly adhered to.

(e) In meeting its responsibilities for safe practices in anesthetizing locations, the hospital administration shall adopt or correlate regulations and standard operating procedures to ensure 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 3-5.2.1*), and inspection of all electrical equipment, including testing of line isolation monitors.

12-4.1.1.5 Rules and Regulations.

(a) 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 ensure enforcement.

(b) This section recognizes that some hospitals contain operating and delivery rooms designed and maintained for the use of flammable anesthetic agents. It also recognizes that there are 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.

NOTE: Appendix C-12.3 contains three sets 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 that 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 that 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 that may be adopted by hospitals in which flammable anesthetizing locations and nonflammable anesthetizing locations coexist within the same building, allowing interchange of personnel and equipment between flammable and nonflammable anesthetizing locations.

(c) Anesthetizing locations shall be identified as noted in 12-4.1.5.5(a).

(d) The hazard symbols contained in NFPA 704, *Standard System for the 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.

(e) 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.

(f)* 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.

12-4.1.2 Requirements for ALL Anesthetizing Locations.

12-4.1.2.1 Ventilation. Ventilation of anesthetizing locations shall conform to 5-6.1; and to 5-4.1 for nonflammable anesthetizing locations and 5-4.2 for flammable anesthetizing locations.

12-4.1.2.2 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.

12-4.1.2.3 Smoking and Open Flames. Smoking and open flames shall be prohibited in all anesthetizing locations.

12-4.1.2.4 Electrical Safeguards.

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

(b) Scheduled inspections and written reports shall be maintained.

(c) Rules to require prompt replacement of defective electrical equipment shall be adopted and rigidly enforced.

(d) 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.

(e) All electrical equipment used in inhalation anesthetizing locations and areas ancillary thereto, or in other areas using conductive floors constructed in accordance with this section, shall be periodically tested for electrical safety. (*See Appendix C-12.1.2.1.2.*)

(f) 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 Chapter 7 (*see 7-5.1.1.1*).

(g) Line-powered equipment that 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.

12-4.1.2.5 Electric Connections and Testing.

(a) Administrative authorities shall ascertain that electric maintenance personnel are completely familiar with the function and proper operation of ungrounded electric circuits required by 12-4.1.3.2. 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.

(b) Extension cords shall not be connected to lighting fixtures in anesthetizing locations under any circumstances.

12-4.1.2.6 Electrical Systems.

(a) A grounded electrical distribution system shall be permitted to be installed in facilities that have a written policy prohibiting the use of flammable inhalation anesthetizing agents.

NOTE: If a nonflammable anesthetizing location is a wet location, the provisions of 3-4.1.2.6 apply.

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

(c) Approved permanently installed equipment shall be permitted to be supplied through a grounded single-phase or three-phase distribution system if installed in accordance with 12-4.1.3.3.

(d) An isolation transformer shall not serve more than one operating room except as provided in 12-4.1.2.6(e). 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 of 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 section (formerly NFPA 56A) where such systems were permitted.

(e) Isolation transformers shall be permitted to serve single receptacles in several patient areas when the receptacles are reserved for supplying power to equipment requiring 150 volts or higher, 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.

12-4.1.2.7 Gases.

(a) *Storage Locations or Manifold Enclosures for Oxygen and Nitrous Oxide.* The location and ventilation of storage roooms or manifold enclosures for oxygen and nitrous oxide shall comply with Chapters 4 and 5.

(b) *Nonflammable Medical Gas Piping Systems.* Oxygen and nitrous oxide manifolds and piping systems that supply anesthetizing locations shall comply with Chapter 4.

12-4.1.2.8 Anesthetic Apparatus. Anesthetic apparatus shall conform to the requirements in 8-5.1.2.1.

12-4.1.2.9 Electrical Equipment. (*See 12-3.7.1.*)

12-4.1.2.10 Fire Loss Prevention.

(a) *Hazard Assessment.*

(i) An evaluation shall be made of hazards that may be encountered during surgical procedures. The evaluation shall include hazards associated with the properties of electricity, hazards associated with the operation of surgical equipment, and hazards associated with the nature of the environment.

(ii) Periodic reviews of surgical operations and procedures shall be conducted with special attention given to any change in materials, operations, or personnel.

(b) *Fire Prevention Procedures.* Fire prevention procedures shall be established.

(c) *Emergency Procedures.*

(i) Procedures for operating room/surgical suite emergencies shall be developed. Such procedures shall include alarm actuation, evacuation, and equipment shutdown procedures, and provisions for control of emergencies that may occur in the operating room including specific detailed plans for control operations by an emergency control group within the organization or a public fire department.

(ii) Emergency procedures shall be established for controlling chemical spills.

(iii) Emergency procedures shall be established for extinguishing drapery, clothing, or equipment fires.

(d) *Orientation and Training.*

(i) New operating room/surgical suite personnel shall be taught general safety practices for the area and specific safety practices for the equipment and procedures they will use.

(ii) Continuing safety education and supervision shall be provided, incidents shall be reviewed monthly, and procedures shall be reviewed annually.

(iii) Fire-exit drills shall be conducted periodically.

12-4.1.3 Requirements for Flammable Anesthetizing Locations.

12-4.1.3.1 Areas Adjoining Flammable Inhalation Anesthetizing Locations and Flammable Anesthetizing Storage Locations.

(a) 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.

(b) Areas described in 12-4.1.3.1(a) may be ventilated in accordance with the applicable sections of NFPA 70, *National Electrical Code*, for ordinary locations.

(c) 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 12-4.1.3.8(b)*].

(d) Postanesthesia recovery rooms are not considered to be hazardous areas unless specifically intended for the induction of inhalation anesthesia with flammable anesthetic agents [*see 12-4.1.3.9(b)*].

(e) All doorways leading to flammable inhalation anesthetic agent storage locations shall be identified with NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*, symbols as appropriate.

12-4.1.3.2* Isolated Power Systems. A local ungrounded electric system shall be provided.

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 the 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. Patients and personnnel often are wet with prepping solutions, blood, urine, and other conductive fluids that 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.

(a) Hospitals complying with NFPA 56A, *Standard for the Use of Inhalation Anesthetics*, prior to 1970 shall not be required to change ground fault detectors to a line isolation monitor.

(b) The isolated electric system shall only be required to be explosionproof if installed in the hazardous areas of a flammable inhalation anesthetizing location.

12-4.1.3.3 Power for Fixed Equipment. Approved, fixed, therapeutic, and diagnostic equipment, permanently installed outside the hazardous area of a flammable anesthetizing location, may be supplied by a grounded single- or three-phase system of less than 600 V provided (a) the equipment complies with 7-5.1.1.1; (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 V or less, supplied by an isolating transformer; and (c) wiring is installed in accordance with NFPA 70, *National Electrical Code*, Section 517-61.

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 radiotherapy or for the delivery of other forms of energy.

12-4.1.3.4 Fixed Lighting. Branch circuits supplying only fixed lighting shall be permitted to 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*, Article 517, Part D; and (c) wiring for grounded and ungrounded circuits is installed in accordance with NFPA 70, *National Electrical Code*, Article 517, Part D.

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

12-4.1.3.5 Ceiling-Suspended Fixtures.

(a) Ceiling-suspended surgical lighting fixtures shall be supplied from an ungrounded electric distribution system (*see 12-4.1.3.2*), which shall be monitored by a line isolation monitor as required by 3-4.3.3.1. 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 shall be permitted to 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 V.

(b) 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 was approved for hazardous areas.

(c) 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 area.

(d) 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.

(e) 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*.

(f) 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.

(g) *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 that 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 shall be permitted to be of the totally enclosed type or so constructed as to prevent the escape of sparks or hot metal. Such viewing boxes shall be permitted to 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.

(h) Control units and other electric apparatus installed or intended for use in a flammable anesthetizing location shall comply with the requirements of 7-5.1.1 [*see also 12-4.1.3.5(d) and 12-4.1.5.6(d)*].

12-4.1.3.6 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*.

12-4.1.3.7 Piping. This section (12-4.1) prohibits the piping of flammable anesthetic gases (*see 4-6.2.3.1*).

12-4.1.3.8 Reduction in Electrostatic Hazard.

(a) *Purpose.*

(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-12.1.3.1*).

(2) The prevention of the accumulation of static charges revolves about a number of safeguards that 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) The methods employed to prevent such accumulation include the installation of conductive flooring [*see 12-4.1.3.8(b)*], the maintenance of the relative humidity at 50 percent at least, and the use of certain items of conductive equipment, accessories, and wearing apparel.

(b)* *Conductive Flooring.*

(1) Conductive flooring shall be installed in those areas specified in 12-4.1.3.8(a)(2). Conductive flooring installed in corridors or passageways in compliance with 12-4.1.3.8(a)(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.

(2) A conductive floor shall meet the resistance provisions through its inherent conductive properties. The surface of the floor in the locations specified by 12-4.1.3.8(a)(2) and 12-4.1.3.8(b)(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 1/4 in. (6.4 mm) from a conductive element of the surface, except for insulated floor drains.

(3) The resistance of the conductive floor shall be less than an average of 1,000,000 ohms, as measured in accordance with 12-4.1.3.8(b)(7).

(4) The resistance of the floor shall be more than an average of 25,000 ohms, as measured in accordance with 12-4.1.3.8(b)(7).

(5) A deliberate connection of the conductive floor to the room ground shall not be required.

(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.

(7) The following test method shall be used (*see 12-4.1.3.12*).

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

(ii) 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 0.0005 in. (0.013 mm) to 0.001 in. (0.025 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 D2240-91).

(iii) Resistance shall be measured by a suitably calibrated ohmmeter that shall have a nominal open circuit output voltage of 500 V 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, Rx, the terminal voltage, V, shall be

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

(iv) Measurements shall be made between five or more pairs of points in each room and the results averaged. For compliance with 12-4.1.3.8(b)(3), the average shall be within the limits specified and no individual measurement value shall be greater than 5 megohms, as measured between two electrodes placed 3 ft (91 cm) apart at any points on the floor. For compliance with 12-4.1.3.8(b)(4), the average value shall be no less than 25,000 ohms with no individual measurement's 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 5 seconds may be considered to be the measured value.

(c) *Accessories.*

(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 1 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. The electrodes and ohmmeter used for these tests shall be of the type specified in 12-4.1.3.8(b)(7)(ii) and (iii), respectively.

(d) *Interconnecting Conductive Accessories.*

(1) All accessories that are required to be resilient or flexible on the anesthesia machine, and that 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 1 megohm when tested as specified in 12-4.1.3.8(e)(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.

(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, shall be permitted to be of antistatic material with antistatic properties good for the specified life of the material provided the 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 1 megohm when tested as specified in 12-4.1.3.8(e).

NOTE: *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) 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 graphitized oil or grease. If sleeve bearings are used, some means of conducting the charge from the pulley should be provided.

(4) Wherever possible, items that 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 12-4.1.3.8(d)(1)*].

NOTE: For essential elements in surgery, such as prosthetic and therapeutic devices, bacterial barriers, instruments, gloves (thermoplastic: for example, PVC), or biomechanical equipment, antistatic materials should be used if conductive materials are not available or are impractical. Any material may be employed if clearly nonhazardous owing to improbability of acquiring and holding a significant charge, e.g., suction catheter, endotracheal tube, plastic inserts in joint prostheses.

(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.

(6) Antistatic materials are not acceptable where they are relied upon to provide an interconnecting electrically conductive pathway.

(e) *Testing for Conductivity.*

(1) An ohmmeter of the type specified in 12-4.1.3.8(b)(7)(iii) 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 12-4.1.3.8(b)(7)(ii), where applicable; or, equivalent electrode contact shall be employed as practical. All items that 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 12-4.1.3.8(e)(2) through (8).

(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) 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 12-4.1.3.8(b)(7)(ii)*] resting on the item.

(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 12-4.1.3.8(e)(1) above except that, in place of the metal band electrode or the standard electrode of 12-4.1.3.8(b)(7)(ii), 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.

(5) Metal parts of machines that are required to be apparently insulated from each other by other nonconductive parts shall be suitably tested for electric interconnection; this shall be permitted to be an ohmmeter test. The resistance of the grounding path between these metal parts shall not exceed 0.1 ohm.

(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).

(7) While the above are given as standard test methods, where these methods cannot be applied, an equivalent test method is permitted to be used. Interconnecting conductivity is acceptable if the measured resistance is not greater than one megohm.

(8) Conductive items containing antistatic material shall have the antistatic properties tested as described in 12-4.1.3.8(f)(3) and (4).

(f) *Antistatic Accessories and Testing.*

(1) For conductive accessories containing antistatic material see 12-4.1.3.8(d)(1) and (2); the antistatic material of these accessories shall be tested as given in 12-4.1.3.8(f)(3) and (4). For other individual items that are permitted to be of antistatic material, see 12-4.1.3.8(d)(4).

(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 12-4.1.3.8(d)(4). They shall be of antistatic material throughout their specified life when tested as described in 12-4.1.3.8(f)(3) and (4).

(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 ± 2 percent RH at 23° ± 1°C for 25 hours or until equilibrium is reached, and tested at 50 percent ± 2 percent RH at 23° ± 1°C.

(i) Method 4046 of Federal Test Method Standard 101B. After the specimen has received its maximum charge from the application of 5000 V, the time for the indicated specimen potential to drop to 10 percent of its maximum value shall not exceed ½ second.

NOTE: The static detector head should be of a type that 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 V are applied to the electrodes for 10 seconds after the indicated potential of the sample reaches equilibrium before the charge decay rate is measured.

(ii) Method 76 of the AATCC. Applied voltage should be 102 V per in. (40 V per cm) of interelectrode spacing. The measured resistivity shall be less than 1×10^{11} ohms per unit square of material.

(4) Antistatic items other than sheeting, film, and textiles shall be tested in a manner as closely as possible equivalent to that given in 12-4.1.3.8(f)(3).

(5) The supplier of conductive and antistatic accessories shall certify that the item or items supplied meet the requirements of one of the tests specified in 12-4.1.3.8(f)(3). The supplier shall certify the conditions of storage, shelf life, and, in the case of reusable items, the methods of repreparation necessary to allow the product or device to return to its antistatic or conductive properties.

(g) *Conductive Footwear.*

(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 V [*e.g., see 12-4.1.3.8(b)(7)(iii)*].

(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) 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 12-4.1.3.10(a), (b), and (c) and 12-4.1.3.13(c).

(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.) that normally come in contact with the floor.

(h) *Textiles.* [*See also 12-4.1.3.10(d), (e), and (f).*]

(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 12-4.1.3.8(f)(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 materials, 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.

(i)* *Furniture.*

(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 5/8 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 that will not oxidize under conditions of normal use (so as to decrease the conductivity of the circuit), and that uninterrupted contact with the floor is at least 5/8 in. (1.6 cm) in one dimension [*see also 12-4.1.3.13(d)*].

(2) Surfaces on which movable objects are placed shall be without insulating paint, lacquer, or other nonconductive finish.

NOTE: An 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) The resistance between the conductive frame of the furniture referred to in 12-4.1.3.8(i)(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 12-4.1.3.8(b)(7)(iii).

(j) *High-Frequency Equipment.* Potential sources of ignition, such as electrosurgical units, shall be prohibited during the administration of flammable anesthetizing agents.

12-4.1.3.9 General Requirements for Flammable Anesthetizing Locations.

(a) Hospital authorities in consultation with others as noted in 4-6.2.2.3 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.

(b) All required precautions shall apply to all anesthetizing locations in which flammable inhalation anesthetics are used.

(c) 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.

(d) 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 12-4.1.3.5(f) and (g) and 7-5.1.2.7(c)*].

(e) 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.

NOTE: When the cover is removed from the anesthesia machine under such conditions, a static charge may be created that could ignite the gas confined beneath the cover.

(f) 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.

(g) Residual ether remaining in ether vaporizers at the end of each day shall be returned to its 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-12.4.1*).

(h) 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.

(i) 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 12-4.1.2.4(f)*]. Such equipment shall be approved for use in Class I, Group C, Division 1 hazardous areas or comply with 7-5.1.2.7(e). It shall be equipped with approved cords and attachment plugs [*see 7-5.1.2.5(a) and (b) and 3-4.1.2.4(g) and (h)*].

(j) High-frequency electric and electronic equipment, such as electrosurgery amplifiers, monitors, recorders, television cameras, portable electrical tools, maintenance equipment, and certain sterilizing equipment that does not comply with the provisions of 7-5.1.2.7(e) 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 7-5.1.2.7(d).

NOTE: See Annex 2, "The Safe Use of High-Frequency Electricity in Health Care Facilities."

12-4.1.3.10 Electrostatic Safeguards.

NOTE: Section 12-4.1.3.8 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 material 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 12-4.1.3.8(b)*] may contribute to the hazard unless all personnel wear conductive shoes and unless all objects in the room are electrically continuous with the floor.

(a)* 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 12-4.1.3.8(b)*] will minimize the possibility of static discharge from patients or personnel entering such anesthetizing locations.

(b) Electric connection of the patient to the operating table shall be ensured 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.

(c) Because of the possibility of percussion sparks, shoes having ferrous nails that 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.

(d) 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 12-4.1.3.8(f)(3) and (4).

NOTE: Rayon refers to regenerated cellulose, 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.

(e) Hosiery and underclothing in which the entire garment is in close contact with the skin shall be permitted to be of silk, wool, or synthetic material.

(f) 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 12-4.1.3.8(f)(3) and (4).

(g) Antistatic materials for use in flammable anesthetizing locations shall be handled and used in the following manner:

(1) 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.

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

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

(h) All antistatic accessories intended for replacement, including belting, rubber accessories, plastics, sheeting, and the like, shall meet pertinent requirements for conductivity as specified in 12-4.1.3.8(f).

12-4.1.3.11 Discretionary Use of Nonconforming Materials.

(a) Suture material, alloplastic or therapeutic devices, bacterial barriers, instruments, gloves (thermoplastic), surgical dressings, and biologic interfaces of these otherwise prohibited materials shall be permitted to be used at the discretion of the surgeon.

(b) Disposable supplies that contribute to the electrostatic hazard shall be so labeled on the unit package.

12-4.1.3.12 Maintenance of Conductive Floors.

(a) 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.

(b) Floors that 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 section (12-4.1) for a period of not less than 2 years, during which no change or modification beyond normal washing is performed.

(c) 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.

(d) Conductive floors shall be tested as specified in 12-4.1.3.8(b).

12-4.1.3.13 Other Conductive Equipment.

(a) The resistance of conductive accessories shall be tested prior to use as described in 12-4.1.3.8(c) or (d). Thereafter, measurements shall be taken at intervals of not more than 1 month. A permanent record of the readings shall be kept.

(b) Antistatic plastics shall meet the requirements of 12-4.1.3.8(f)(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 that are reused [e.g., antistatic tubing incorporating a continuous conductive pathway as described in 12-4.1.3.8(d)(1)] shall be tested [*see 12-4.1.3.8(f)(1)*] periodically to ensure retention of conductive properties.

(c) 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-12-4.1.3.10(a).*]

(d) The resistance of furniture [*see 12-4.1.3.8(i) and Appendix A-12-4.1.3.8(i)*] and equipment shall be tested prior to use as described in 12-4.1.3.8(i)(3). Thereafter, measurements shall be taken at intervals of not more than 1 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 exceeds 5 megohms.

(e) 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 that insulates them and defeats the purpose for which they are used, and also to avoid transporting to conductive floors such materials from other areas.

(f) Excess lubrication of casters shall be avoided to prevent accumulation of oil on conductive caster wheels and sides. Dry graphite or graphitized oil are preferable lubricants.

12-4.1.4 Requirements for Nonflammable Anesthetizing Locations.

12-4.1.4.1 Requirements contained in this part are in addition to those contained in 12-4.1.2.

12-4.1.4.2 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 shall be employed.

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

RESTRICTED TO NONFLAMMABLE
INHALATION ANESTHETIC AGENTS

12-4.1.4.3 Each operating suite containing only nonflammable anesthetizing locations shall contain prominently posted regulations similar to those contained in Appendix C-12.3, Set (2).

12-4.1.4.4* 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 12-4.1.3.8(b)(7), is carried out, and in no case shows 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 12-4.1.3.8(b)(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 that will modify their conductive properties. [*See 12-4.1.3.12(b).*]

NOTE: No requirements on upper limit.

12-4.1.4.5 In nonflammable facilities, the requirements of 12-4.1.3.10, "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.

12-4.1.5* Requirements for Mixed Facilities.

12-4.1.5.1 General. The mixed facility is defined in Chapter 2.

12-4.1.5.2 Construction of Anesthetizing Locations and Storage Locations.

(a) Flammable anesthetizing locations shall be designed, constructed, and equipped as stated in 12-4.1.2 and 12-4.1.3.

(b) Nonflammable anesthetizing locations shall be designed, constructed, and equipped as stated in 12-4.1.2 and 12-4.1.4.

(c) Storage locations for flammable anesthetics shall be constructed as provided in 4-3.1.2.4. Storage locations for nonflammable medical gas cylinders shall be constructed as provided in 4-3.1.2.1.

12-4.1.5.3 Conductive Flooring. The provisions of 12-4.1.4.4 shall apply to permanently designated and posted nonflammable anesthetizing locations that exist within a mixed facility.

12-4.1.5.4 Provision for Connection of Patient to Operating Table. Electric connection of the patient to the operating table shall be ensured 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.

12-4.1.5.5 Precautionary Signs.

(a) 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

(b) 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.

(c) 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 Note to 12-4.1.1.5(b)*]. Suggested text of such regulations is contained in Appendix C-12.3, Set (3).

12-4.1.5.6 Movable Equipment and Furniture.

(a) All equipment intended for use in both flammable and nonflammable anesthetizing locations shall meet the antistatic requirements of 12-4.1.3.8.

(b) Equipment intended for use only in nonflammable anesthetizing locations shall be labeled in accordance with 7-5.1.2.7(a), and shall not be introduced into flammable anesthetizing locations. This equipment is not required to meet the antistatic requirements of 12-4.1.3.8.

(c) No portable equipment, including X-ray equipment, shall be introduced into mixed facilities unless it complies with the requirements of 7-5.1.2.7(c) 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.

(d) 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 7-5.1.2.7(f).

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 3-4.3.3.

(e) Furniture intended for use in both flammable and nonflammable anesthetizing locations of mixed facilities shall meet the antistatic requirements of 12-4.1.3.8(i).

(f) Furniture intended for use only in nonflammable anesthetizing locations of mixed facilities shall comply with 12-4.1.3.8(i) or shall be conspicuously labeled and not be introduced into flammable anesthetizing locations.

12-4.2* Laboratories. Laboratories in hospitals shall comply with the requirements of Chapter 10 as applicable and the requirements of NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, as applicable.

Chapter 13 Ambulatory Health Care Center Requirements

13-1 Scope. This chapter addresses safety requirements for ambulatory health care centers.

13-2 General Responsibilities.

13-2.1 Laboratories. The governing boards of ambulatory health care centers shall have the responsibility of protecting the facilities (for patient care and clinical investigation) and the personnel employed therein.

13-3 General Requirements.

13-3.1 (Reserved)

13-3.2 (Reserved).

13-3.3 Electrical System Requirements.

13-3.3.1 Normal Electrical Distribution System. (Reserved)

13-3.3.2 Essential Electrical Distribution System. The essential electrical distribution system shall conform to the Type I system as described in Chapter 3 if critical care areas are present in the facility. Otherwise, the essential electrical distribution system shall conform to a Type III system as described in Chapter 3.

13-3.4 Gas and Vacuum System Requirements.

13-3.4.1 Patient gas piping systems in facilities that do not include critical care areas shall be permitted to have a Type II gas system in accordance with Sections 4-3 through 4-6 of Chapter 4. Patient gas piping systems in facilities that include critical care areas shall conform to Type I gas systems in accordance with Sections 4-3 through 4-6 in Chapter 4.

13-3.4.2 Laboratory gas piping systems shall conform to 4-3.3, 4-4.3, and 4-6.

13-3.4.3 Patient vacuum piping systems shall conform to Sections 4-7 through 4-11.

13-3.4.4 Laboratory vacuum piping systems shall conform to Sections 4-7 through 4-11.

13-3.4.5 For nonmedical gas piping systems, 4-3.4 shall apply.

13-3.5 Environmental Systems. (Reserved)

13-3.6 Material Requirements. (Reserved)

13-3.7 Electrical Equipment Requirements.

13-3.7.1 Patient Care Areas. Electrical appliances shall conform to Chapter 7.

13-3.7.2 Laboratories. Equipment shall conform to 7-5.2.2 and Section 7-6.

13-3.8 Gas Equipment Requirements.

13-3.8.1 Patient. Equipment shall conform to the patient equipment requirements in Chapter 8.

13-4 Specific Area Requirements.

NOTE: This is in addition to any applicable requirements in Section 13-3.

13-4.1 Anesthetizing Locations.

13-4.1.1 General.

13-4.1.1.1 Foreword.

(a) This section 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 attention 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.

(b) 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 requirements of this chapter will be effective, or even permissible, only when accompanied by compliance with the full program of precautionary measures.

(c) 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 atomspheres.

13-4.1.1.2 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 section was prepared because of the variety of hazards attendant upon the use of some of these agents in the outpatient setting.

13-4.1.1.3 Scope.

(a) This section states the composite methods by which hazards of fire and the handling of compressed gases, when these agents are employed in anesthetizing locations in the ambulatory care facility, can be mitigated.

(b) This section 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.

(c) Provisions of this section do not apply to the manufacture, storage, transportation, or handling prior to the delivery to the consuming facility of any of these gases. This section does not apply to any use other than in an anesthetizing location.

(d) 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.

13-4.1.1.4 General. This section is concerned with certain features in the construction of ambulatory care facilities. This section, with equal emphasis, deals with the installation, maintenance, performance, and use of equipment within these facilities.

13-4.1.1.5 Relation to Appendix Material. The material of this section and Appendix C-13 are interdependent. For the informed development of an effective ambulatory-care safety program, it is necessary that thorough reference be made to all parts of these requirements.

13-4.1.1.6 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.

13-4.1.1.7 Applicability.

(a) This section applies to nonhospital-based facilities wherein general anesthesia or relative analgesia are administered to ambulatory patients.

(b) This section does not apply to hospital-based ambulatory care facilities. In such facilities, appropriate provisions of 12-4.1, "Anesthetizing Locations," Chapter 8, "Gas Equipment," and Chapter 4, "Gas and Vacuum Systems," shall apply.

13-4.1.2 Requirements for All Anesthetizing Locations.

13-4.1.2.1 (Reserved)

13-4.1.2.2 (Reserved)

13-4.1.2.3 Smoking shall be prohibited in all anesthetizing locations.

13-4.1.2.4 (Reserved)

13-4.1.2.5 (Reserved)

13-4.1.2.6 Electrical Systems. The governing body of the ambulatory health care center shall decide what complexity of treatment and anesthesia will be offered in order to determine the type of electrical system required. When surgical procedures are intended to be performed in wet locations, the requirements of 12-4.1.2.6 shall apply.

13-4.1.2.7 (Reserved)

13-4.1.2.8 Anesthetic Apparatus. Anesthetic apparatus shall conform to the requirements in 8-5.1.2.1.

13-4.1.2.9 Electrical Equipment. (*See 13-3.7.1.*)

13-4.1.2.10 Fire Loss Prevention. The requirements of 12-4.1.2.10 shall apply.

13-4.1.3 Requirements for Flammable Anesthetizing Locations. This section does not apply to the administration of flammable agents. In ambulatory care facilities wherein flammable agents are employed, the provisions of 12-4.1.3, "Requirements for Flammable Anesthetizing Locations (in Hospitals)," shall apply.

13-4.1.4 Requirements for Nonflammable Anesthetizing Locations.

13-4.1.4.1 Equipment.

(a) *Central Supply Systems.* Central supply systems shall be installed and tested in accordance with 13-3.4.1.

(b) *Special Precautions — Oxygen Cylinders, Manifolds, and Cylinder Storage Facilities.* The requirements of 4-6.2.1.2 shall apply.

13-4.1.4.2 Posted Regulations.

(a) Rules and regulations necessary for the implementation of this chapter (*see Appendix C-13.2 for suggested text*), where appropriate, shall be posted in the ambulatory care facility.

13-4.2* Laboratories. Laboratories in ambulatory health care centers shall comply with the requirements of Chapter 10 as applicable and the requirements of NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, as applicable.

Chapter 14 Clinic Requirements

14-1 Scope. This chapter addresses safety requirements of clinics.

14-2 General Responsibilities.

14-2.1 Laboratories. The governing boards of clinics shall have the responsibility of protecting the facilities (for patient care and clinical investigation) and the personnel employed therein.

14-3 General Requirements.

14-3.1 (Reserved)

14-3.2 (Reserved)

14-3.3 Electrical System Requirements.

14-3.3.1 Normal Electrical Distribution System. (Reserved)

14-3.3.2 Essential Electrical Distribution System. The essential electrical distribution system shall conform to the Type III system as described in Chapter 3.

Exception: If electrical life support equipment is required, the essential electrical distribution system shall conform to a Type I system as described in Chapter 3.

14-3.4 Gas and Vacuum System Requirements.

14-3.4.1 Patient gas piping systems shall conform to Chapter 4, Sections 4-3 through 4-6, Type II systems if they meet the requirements of 4-6.2.4.1.

14-3.4.2 Laboratory gas piping systems shall conform to 4-3.3, 4-4.3, and 4-6.

14-3.4.3 Patient Vacuum Systems. (Reserved)

14-3.5 Environmental Systems. (Reserved)

14-3.6 Material Requirements. (Reserved)

14-3.7 Electrical Equipment Requirements.

14-3.7.1 Patient Care Areas. (Reserved)

14-3.7.2 Laboratories. Equipment shall conform to 7-5.2.2 and 7-6.

14-3.8 Gas Equipment Requirements.

14-3.8.1 Patient. Equipment shall conform to patient equipment requirements in Chapter 8.

14-4 Specific Area Requirements.

NOTE: This is in addition to other clinic requirements listed in Section 14-3.

14-4.1* Laboratories. Laboratories in clinics shall comply with the requirements of Chapter 10 as applicable and the requirements of NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, as applicable.

Chapter 15 Medical and Dental Office Requirements

15-1 Scope. This chapter addresses safety requirements of medical and dental offices.

15-2 General Responsibilities.

15-2.1 Laboratories. The governing boards of medical and dental offices shall have the responsibility of protecting the facilities (for patient care and clinical investigation) and the personnel employed therein.

15-3 General Requirements.

15-3.1 (Reserved)

15-3.2 (Reserved)

15-3.3 Electrical System Requirements.

15-3.3.1 Normal Electrical Distribution System. (Reserved)

15-3.3.2 Essential Electrical Distribution System. The essential electrical distribution system shall conform to a Type III system as described in Chapter 3.

Exception: If electrical life support equipment is required, the essential electrical distribution system shall conform to a Type I system as described in Chapter 3.

15-3.4 Gas and Vacuum System Requirements.

15-3.4.1 Patient gas piping systems shall conform to Chapter 4, Sections 4-3 through 4-6, Type II systems if they meet the requirements of 4-6.2.4.1.

Exception: When the delivery of gases to meet the facility's needs is not available within a 48-hour interval, a second nonconnection storage reserve location complying with 4-3.1.2.3 shall be permitted. The locations shall not be adjacent to each other or directly across the hallway with facing louver doors.

15-3.4.2 Laboratory gas piping systems shall conform to 4-3.3, 4-4.3, and 4-6.

15-3.4.3 Dental vacuum piping systems shall conform to 4-8.1.3 and 4-9.1.3.

15-3.5 Environmental Systems. (Reserved)

15-3.6 Material Requirements. (Reserved)

15-3.7 Electrical Equipment Requirements.

15-3.7.1 Patient Care Areas. (Reserved)

15-3.7.2 Laboratories. Equipment shall conform to 7-5.2.2 and 7-6.

15-3.8 Gas Equipment Requirements.

15-3.8.1 Patient. Gas equipment shall conform to the patient equipment requirements in Chapter 8.

15-4 Specific Area Requirements.

NOTE: This in addition to other medical and dental office requirements listed in Section 15-3.

15-4.1 Laboratories. Laboratories in medical and dental offices shall comply with the requirements of Chapter 10, as applicable.

Chapter 16 Nursing Home Requirements

16-1 Scope. This chapter addresses safety requirements of nursing homes.

16-2 General Responsibilities.

16-2.1 Laboratories. The governing boards of nursing homes shall have the responsibility of protecting the facilities (for patient care and clinical investigation) and the personnel employed therein.

16-3 General Requirements.

16-3.1 (Reserved)

16-3.2 (Reserved)

16-3.3 Electrical System Requirements.

16-3.3.1 Normal Electrical Distribution System. (Reserved)

16-3.3.2 Essential electrical distribution systems shall conform to the Type II systems as described in Chapter 3.

Exception: Any freestanding nursing home that:

(a) Maintains admitting and discharge policies that preclude the provision of care for any patient or resident who needs 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 equipment that will be effective for at least 1 1/2 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 1 footcandle to exit lights, exit corridors, stairways, nursing stations, medication preparation areas, boiler rooms, and communication areas. This system must also supply power to operate all alarm systems.

16-3.3.2.1 Nursing homes that meet the requirement in the Exception to 16-3.3.2 shall be permitted to use a battery system or self-contained battery integral with equipment in lieu of the alternate power source required in 3-3.2.1.3.

16-3.4 Gas and Vacuum System Requirements.

16-3.4.1 Patient gas piping systems shall conform to Chapter 4, Sections 4-3 through 4-6, Type II systems if they meet the requirements of 4-6.2.4.1.

16-3.4.2 Laboratory gas piping systems shall conform to 4-3.3, 4-4.3, and 4-6.

16-3.4.3 Patient Vacuum Systems. (Reserved)

16-3.5 Environmental Systems. (Reserved)

16-3.6 Material Requirements. (Reserved)

16-3.7 Electrical Equipment Requirements.

16-3.7.1 Patient Care Areas. (Reserved)

16-3.7.2 Laboratories. Equipment shall conform to 7-5.2.2 and 7-6.

16-3.8 Gas Equipment Requirements.

16-3.8.1 Patient. Equipment shall conform to requirements for patient equipment in Chapter 8.

16-4 Specific Area Requirements.

NOTE: This is in addition to other nursing home requirements listed in Section 16-3.

16-4.1 Laboratories. Laboratories in nursing homes shall comply with the requirements of Chapter 10, as applicable.

Chapter 17 Limited Care Facility Requirements

17-1 Scope. This chapter covers safety requirements of limited care facilities.

17-2 General Responsibilities.

17-2.1 Laboratories. The governing boards of limited care facilities shall have the responsibility of protecting the facilities (for patient care and clinical investigation) and the personnel employed therein.

17-3 General Requirements.

17-3.1 (Reserved)

17-3.2 (Reserved)

17-3.3 Electrical System Requirements.

17-3.3.1 Normal Electrical Distribution System. (Reserved)

17-3.3.2 Essential electrical distribution systems shall conform to the Type II systems as described in Chapter 3.

Exception: Any freestanding limited care facility that:

(a) Maintains admitting and discharge policies that preclude the provision of care for any patient or resident who needs 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 equipment that will be effective for at least $1\frac{1}{2}$ 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 1 footcandle to exit lights, exit corridors, stairways, nursing stations, medication preparation areas, boiler rooms, and communication areas. This system must also supply power to operate all alarm systems.

17-3.3.2.1 Limited care facilities that meet the requirements in the Exception to 17-3.3.2 shall be permitted to use a battery system or self-contained battery integral with equipment in lieu of the alternate power source required in 3-3.2.1.3.

17-3.4 Gas and Vacuum System Requirements.

17-3.4.1 Patient gas piping systems shall conform to Chapter 4, Sections 4-3 through 4-6, Type II systems. Otherwise, conformance to the Type I gas systems, as listed in Sections 4-3 through 4-6 of Chapter 4, is required.

17-3.5 Environmental Systems. (Reserved)

17-3.6 Material Requirements. (Reserved)

17-3.7 Electrical Equipment Requirements.

17-3.7.1 Patient Care Areas. (Reserved)

17-3.7.2 Laboratories. Equipment shall conform to 7-5.2.2 and 7-6.

17-3.8 Gas Equipment Requirements. (Reserved)

17-4 Specific Area Requirements.

NOTE: This is in addition to other limited care facility requirements listed in Section 17-3.

17-4.1 Laboratories. Laboratories in limited care facilities shall comply with the requirements of Chapter 10, as applicable.

Chapter 18 (Reserved)

Chapter 19 Hyperbaric Facilities

19-1 Introduction and Scope.

NOTE: 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 a patient's body with oxygen, to treat certain medical conditions, or to prepare a 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.

Recently, however, the level of knowledge and expertise has increased so dramatically that the codes are in need of updating. By the end of 1988, there were 218 hyperbaric facilities in operation in the U.S. and Canada. These facilities supported hyperbaric medical treatments for 62,548 patients between 1971 and 1987. As these facilities provide therapy for disorders indicated for treatment, these numbers will continue to increase. As the number of facilities increases, the number of patients treated will also increase.

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.

In addition to being used for patient care, these chambers also are being employed for research purposes using experimental animals and, in some instances, humans.

The partial pressure of oxygen present in a 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.

There is continual need for human diligence in the establishment, operation, and maintenance of hyperbaric facilities.

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.

It is essential that personnel having responsibility for the hyperbaric facility establish and enforce appropriate programs to fulfill the provisions of this chapter.

Potential hazards can be controlled only when continually recognized and understood by all pertinent personnel.

19-1.1 Purpose.

19-1.1.1 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: Much is known about the safe application of hyperbaric medicine for the protection of hardware, personnel, and facilities. Nonetheless, as new medical instrumentation and engineering techniques are developed, new safety issues will continue to arise. Consequently, the Subcommittee on Hyperbaric and Hypobaric Facilities believes that this publication is needed for general guidance in areas of technological change and uncertainty as well as for firm requirements in areas where the technology is well understood and stable. Comments based on continuing experience are solicited so that this chapter may be revised from time to time.

19-1.1.2 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.

19-1.2 Scope.

19-1.2.1 This chapter applies to hyperbaric chambers and associated facilities that 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) (0 to 690 kPa gauge).

NOTE: This chapter does not apply to respiratory therapy employing oxygen-enriched atmospheres at ambient pressures. (*See Chapter 8, "Gas Equipment."*)

19-1.2.1.1 This chapter covers the recognition of and protection against hazards of an electrical, explosion, or implosion nature, as well as fire hazards.

19-1.2.1.2 Medical complications of hyperbaric procedures are discussed primarily to acquaint rescue personnel with these problems.

19-1.2.2 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 19-1.4*) for the purpose of defining the hazards and setting forth the safeguards within the chapter.

19-1.3 Application of This Chapter. This chapter shall be applied only to the following: new construction; new equipment added to new facilities; new equipment added to existing facilities. 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.

19-1.4 Classification of Chambers.

19-1.4.1 General. Chambers shall be classified according to occupancy in order to establish appropriate minimum essentials in construction and operation.

19-1.4.2 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 but equipped for access of personnel to care for the animals are classified as Class A for the purpose of this chapter.

19-1.5 Nature of Hazards.

19-1.5.1 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.

19-1.5.2 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-19.

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.

19-2 Construction and Equipment.

19-2.1 Housing for Hyperbaric Facilities.

19-2.1.1 Class A chambers and all ancillary service equipment shall be housed in fire-resistant construction of not less than 2-hour classification, which shall be a building either isolated from other buildings or separated from contiguous construction by 2-hour noncombustible (under standard atmospheric conditions) wall construction.

19-2.1.1.1 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.

19-2.1.1.2 The room or rooms housing the Class A or Class B chambers and service equipment shall be for the exclusive use of the hyperbaric operation.

19-2.1.1.3 The supporting foundation for any chamber shall be sufficiently strong to support the chamber. Consideration shall be given to any added floor stresses that will be created during any on-site hydrostatic testing.

19-2.1.2 A hydraulically calculated automatic wet pipe sprinkler system meeting the requirements of NFPA 13, *Standard for the Installation of Sprinkler Systems,* shall be installed in the room housing a Class A chamber and in any ancillary equipment rooms.

19-2.1.2.1 Chamber room sprinkler heads shall be an approved type equipped with fusible elements. The element temperature ratings shall be as low as possible, consistent with the requirements against false operation in NFPA 13.

NOTE: In addition to the functions of building protection, the chamber room sprinkler system must be designed to ensure a degree of protection to chamber operators and occupants who likely will not be able to immediately evacuate the premises in the event of a fire.

19-2.2 Fabrication of the Hyperbaric Chamber.

19-2.2.1 Chambers for human occupancy, and their supporting systems, shall be designed and fabricated to meet ANSI/ASME PVHO-1a, *Safety Standard for Pressure Vessels for Human Occupancy*, by personnel qualified to fabricate vessels under such codes. As a minimum, animal chambers shall be designed, fabricated, and stamped to meet ANSI/ASME Section VIII, Division 1 code requirements.

NOTE: Other chapters in NFPA 99 contain many requirements that may appear to relate to hyperbaric facilities, but may be inappropriate. The requirements of other chapters in NFPA 99 should be applied to hyperbaric facilities only where specifically invoked by this chapter.

19-2.2.2 Class A chambers shall be equipped with a floor that is structurally capable of supporting equipment and personnel necessary for the operation of the chamber according to its expected purpose.

19-2.2.2.1 The floor of Class A chambers shall be noncombustible.

19-2.2.2.2 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 12-4.1, "Anesthetizing Locations."

19-2.2.2.3 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.

19-2.2.2.4 If the interior floor of a Class A chamber consists of removable floor (deck) plates, the plates shall be mechanically secured and electrically bonded to the chamber to ensure a positive electrical ground and to prevent movement of the plate, which could cause injury to personnel.

19-2.2.3 The interior of Class A chambers shall be unfinished or treated with a finish that is inorganic-zinc-based or high-quality epoxy or equivalent, or that is flame resistant.

19-2.2.3.1 If the interior of a Class A chamber is treated (painted) with a finish listed above, a minimum of 72 hours shall pass before chamber operations with chamber personnel aboard, to allow sufficient time for off-gassing to occur.

19-2.2.3.2 If sound-deadening materials are employed within a hyperbaric chamber, they shall be flame resistant as defined in Chapter 2, "Definitions."

NOTE: Many commercial sound-deadening materials that may be flame resistant are porous, and will absorb water from activation of the fire-suppression system and retain odor. Metallic panels that contain a large quantity of small holes or are made of wire mesh and are installed about 1 inch away from the chamber wall can be used to form an acoustic baffle. These panels should be made from corrosive-resistant materials such as stainless steel or aluminum and may be painted in accordance with 19-2.2.3.

19-2.2.4 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.

NOTE: Prudent design considerations suggest that at least 50 percent excess pass-through capacity be provided, for future use, given the difficulty of adding pass-throughs to the chamber after it is constructed and tested.

19-2.2.4.1 Access ports in Class A chambers for monitoring and other electrical circuits shall be housed in enclosures that are weatherproof both inside and outside the chamber for protection in the event of sprinkler activation.

19-2.2.4.2 Viewports and penetrator plates shall be designed and fabricated according to ANSI/ASME PVHO-1a, *Safety Standard for Pressure Vessels for Human Occupancy.*

19-2.3 Illumination.

19-2.3.1 Unless designed for chamber use, sources of illumination shall be mounted outside the pressure chamber and arranged to shine through chamber ports or through chamber penetrators designed for fiberoptic or similar lighting.

19-2.3.1.1 Lighting fixtures used in conjunction with viewports shall be designed so that temperature ratings for the viewport material given in ANSI/ASME PVHO-1a are not exceeded.

19-2.3.1.2 Gasket material shall be of a type that permits the movement of thermal expansion and shall be suitable for the temperatures, pressures, and composition of gases involved. 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.

19-2.3.2 Fluorescent lamps shall be permitted to 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.

19-2.3.3 If it is necessary to employ portable surgical spot-illumination units in the chamber, these units shall be installed in a self-contained, vented, shatterproof fixture.

19-2.3.4 Permanent lighting fixtures installed within the hyperbaric chamber shall meet the requirements of 19-2.7.3.10 and shall be rated for an external working pressure of 1½ times maximum chamber operating pressures. Portable lighting units used in the chamber shall comply with the requirements for portable equipment in 19-2.7.3.11.

19-2.3.5 Emergency Lighting. Where normal chamber interior lighting is provided by internally mounted fixtures, provisions shall be made for externally mounted, automatically activated emergency lights.

19-2.4 Chamber Ventilation.

19-2.4.1 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 for hospital operating rooms as specified in 12-4.1, "Anesthetizing Locations."

Exception: Class A chambers that are not used in the capacity of an operating room shall maintain a temperature that is comfortable for the occupants [usually 75° ± 5°F (22° ± 2°C)]. The thermal control system should be designed to maintain the temperature below 85°F (29°C) during pressurization, if possible, and above 65°F (19°C) during depressurization, if possible.

NOTE: Section 12-4.1, "Anesthetizing Locations," specifies a desirable temperature of 68°F (20°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°F (22°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.

19-2.4.1.1 The minimum ventilation rate for a Class A chamber shall be 3 actual cu ft (0.085 actual m^3) per minute of air per chamber occupant not using a breathing mask overboard dump system that exhausts exhaled gases. The minimum threshold rate shall be 3 actual cu. ft. per minute (0.085 actual m^3 per minute).

Exception: The ventilation rate requirements of this paragraph are waived when saturation operations are conducted in the chamber, provided that carbon dioxide removal and odor control are accomplished and that the monitoring requirements of 19-2.8.5.1 and 19-2.8.6 are met.

NOTE: Experience and practice may dictate the need for a threshold ventilation rate in excess of the minimum specified for sanitary reasons. It is recommended that consideration be given, if necessary, to the use of odor filters in the chamber circulation system as a means of keeping sanitary ventilation rate requirements to a minimum.

19-2.4.1.2 If inhalation anesthetic agents are being utilized (e.g., nitrous oxide, methoxyflurane, halothane), a closed anesthetic system with exhaled-gas scavenging and overboard dumping shall be employed.

19-2.4.1.2.1 Flammable inhalation anesthetics (i.e., cyclopropane, ethyl ether, ethylene, and ethyl chloride) shall not be employed.

19-2.4.1.3 Provision shall be made for ventilation during nonpressurization of Class A chambers as well as during pressurization.

19-2.4.1.4 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 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 that may be encountered in the chamber. In the event of a fire within a chamber, provision shall be made to switch all breathing apparatus to an air supply that is independent of the chamber atmosphere.

19-2.4.1.5 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.

19-2.4.2 Sources of air for chamber atmospheres shall be such that toxic or flammable gases are not introduced. Compressor intakes shall be located so as to avoid air contaminated by exhaust from activities of vehicles, internal combustion engines, stationary engines, or building exhaust outlets.

NOTE: If intakes are located where it may be possible for maintenance to be conducted in the immediate vicinity, a warning sign should be posted.

19-2.4.2.1 Positive efforts shall be undertaken to ensure that air for chamber atmosphere is not fouled by handling. This air supply shall be monitored as required in 19-2.8.7.

19-2.4.3 Warming or cooling of the atmosphere within a Class A chamber shall be permitted 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 shall be permitted 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.

19-2.4.4 Ventilation of Class B Chambers.

19-2.4.4.1 Class B chambers, if ventilated with air, shall conform to the ventilation requirements of Class A chambers.

19-2.5 Fire Protection in Class A Chambers.

19-2.5.1 General Requirements.

19-2.5.1.1 A fire suppression system consisting of an independently supplied and operating handline and deluge system shall be installed in all Class A chambers.

19-2.5.1.2 Design of the fire suppression system shall be such that failure of components in either the handline or deluge system will not render the other system inoperative.

19-2.5.1.3 System design shall be such that activation of either the handline or the deluge system shall automatically cause the following:

(a) Visual and aural indication of activation shall occur at the chamber operator's console.

(b) All ungrounded electrical leads for power and lighting circuits contained inside the chamber shall be disconnected. Intrinsically safe circuits, including sound-powered communications, need not be disconnected.

(c) Emergency lighting (*see 19-2.3.5*) and communication, where used, shall be activated.

19-2.5.1.4 A fire alarm signaling device shall be provided at the chamber operator's control console for signaling the telephone operator or a suitable authority to activate the emergency fire/rescue network of the institution containing the hyperbaric facility.

NOTE: This requirement does not preclude the use of an alarm system affording direct fire department contact.

19-2.5.1.5 Fire blankets and portable carbon dioxide extinguishers shall not be installed in or carried into the chamber.

NOTE: Experience has shown that fire blankets, portable carbon dioxide extinguishers, and other methodology intended to "snuff out" fires by excluding air are not effective in controlling fires in oxygen-enriched atmospheres. Valuable time can be lost in attempting to use such devices.

19-2.5.1.6 Booster pumps, control circuitry, and other electrical equipment involved in fire suppression system operation shall be powered from a critical branch of the emergency electrical system as specified in 19-2.7.2.2(e).

19-2.5.2 A fixed water deluge extinguishing system shall be installed in all chamber compartments that are designed for manned operations. In chambers that consist of more than one chamber compartment (lock), the design of the deluge system shall ensure adequate operation when the chamber compartments are at different depths (pressures). The design shall also ensure the independent or simultaneous operation of deluge systems.

Exception: Chamber compartments that are used strictly as personnel transfer compartments (locks), and for no other purposes, are not required to have a fixed deluge system.

19-2.5.2.1 Manual activation and deactivation deluge controls shall be located at the operator's console and in each chamber compartment (lock) containing a deluge system. More than one control station may be required in a compartment (lock) depending on its size. Controls shall be designed to prevent unintended activation.

19-2.5.2.2 The deluge valve shall open within 1 second of a signal to activate the deluge. Water shall be delivered from the sprinkler heads beginning not less than 3 seconds after the activation signal.

19-2.5.2.3 The number and positioning of sprinkler heads shall be sufficient to provide reasonably uniform spray coverage with vertical and horizontal (or near horizontal) jets. Average spray density at floor level shall be not less than 2 gpm per square foot (81.5 L/min/m^2) with no floor area larger than 1 square meter receiving less than 1 gpm per square foot (40.75 L/min/m^2).

NOTE 1: Experience has shown that when water is discharged through conventional sprinkler heads into a hyperbaric atmosphere, the spray angle is reduced because of increased resistance to water droplet movement in the denser atmosphere. This is so even though the water pressure differential is maintained above chamber pressure. Therefore, it is necessary to compensate by increasing the number of sprinkler heads. It is recommended that spray coverage tests be conducted at maximum chamber pressure.

NOTE 2: Some chamber configurations, such as small-diameter horizontal cylinders, may have a very tiny "floor," or even no floor at all. For horizontal cylinder chambers and spherical chambers, "floor level" shall be taken to mean the level at 1/4 diameter below the chamber centerline or actual "floor level," whichever gives the larger floor area.

19-2.5.2.4 There shall be sufficient water available in the deluge system to maintain the flow specified in 19-2.5.2.3 simultaneously in each chamber compartment (lock) containing the deluge system for 1 minute. The limit on maximum extinguishment duration shall be governed by the chamber capacity (bilge capacity also, if so equipped) and/or its drainage system.

19-2.5.2.5 The deluge system shall have stored pressure to operate for at least 15 seconds without electrical branch power.

19-2.5.2.6 The deluge and handline systems shall be functionally tested at least annually per 19-2.5.2.3 for deluge systems and 19-2.5.3.4 for handline systems. If a bypass system is used, it shall not remain in the test mode after completion of the test.

19-2.5.3 A handline extinguishing system shall be installed in all chamber compartments (locks). At least two handlines shall be strategically located in treatment compartments (locks). At least one handline shall be located in each personnel transfer compartment (lock). If any chamber compartment (lock) is equipped with a bilge access panel, at least one handline shall be of sufficient length to allow use of the handline for fire suppression in the bilge area.

19-2.5.3.1 Handlines shall have a 1/2-inch minimum internal diameter and shall have a rated working pressure greater than the highest supply pressure of the supply system.

19-2.5.3.2 Each handline shall be activated by a manual, quick-opening, quarter-turn valve located within the compartment (lock).

19-2.5.3.3 Handlines shall be equipped with override valves placed in easily accessible locations outside the chamber.

19-2.5.3.4 The water supply for the handline system shall be designed to ensure a 50 psi (345 kPa) minimum water pressure above the maximum chamber pressure. The system shall be capable of supplying a minimum of 5 gpm (18.8 L/min) simultaneously to each of any two of the handlines at the maximum chamber pressure.

19-2.5.4 Automatic fire detection systems are optional. Whether installed and used in an alarm function or in an automatic deluge activation function, they shall meet the requirements set forth below.

19-2.5.4.1 Surveillance fire detectors responsive to the radiation from flame shall be employed. Type and arrangement of detectors shall be such as to respond within 1 second of flame origination.

19-2.5.4.2 The number of detectors employed and their location shall be dependent on the sensitivity of each detector and the configuration of the spaces to be protected.

NOTE: Additional detectors are recommended to avoid "blind" areas if the chamber contains compartmentation.

19-2.5.4.3 The system shall be powered from the critical branch of the emergency electrical system or shall have automatic battery back-up.

19-2.5.4.4 If used to automatically activate the deluge system, the requirements for manual activation/deactivation in 19-2.5.2.1 and deluge system response time in 19-2.5.2.2 shall still apply.

19-2.5.4.5 The system shall include self-monitoring functions for fault detection and appropriate fault alarms and indications.

19-2.6 Fire Protection for Class B and C Chambers.

19-2.6.1 Class B and C chambers shall not be required to comply with 19-2.5, "Fire Protection in Class A Chambers."

19-2.6.2 The provisions of NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall be referred to when applicable to any class of chamber.

19-2.7 Electrical Systems.

19-2.7.1 General.

19-2.7.1.1 The requirements of NFPA 70, *National Electrical Code*, or local electrical codes shall apply to electrical wiring and equipment in hyperbaric facilities within the scope of this chapter, except as such rules are modified in this section. Where unusual conditions exist in a specific facility, the authority having jurisdiction shall judge with respect to the application of specific rules.

19-2.7.1.2 All hyperbaric chamber service equipment, switchboards, panels, or control consoles shall be located outside of, and in the vicinity of, the chamber.

19-2.7.1.3 Console or module spaces containing both oxygen piping and electrical equipment shall be continuously ventilated or continuously monitored for excessive oxygen concentrations whenever the electrical equipment is energized.

19-2.7.1.4 For the fixed electrical installation, no circuit breakers, line fuses, motor controllers, relays, transformers, ballasts, lighting panels, or power panels shall be located inside of the chamber. If motors must be located in the chamber, they shall meet the requirements of 19-2.7.3.9.

NOTE: It is recommended that system design be such that electric motors not be located inside the chamber.

19-2.7.1.5 All electrical equipment connected to or used in conjunction with hyperbaric patients shall comply with

the requirements of Chapter 7, "Electrical Equipment in Health Care Facilities," and with the applicable paragraphs of 19-2.7.3.

19-2.7.1.6 In the event of activation of the room sprinkler system, electrical equipment shall be protected from sprinkler water to the maximal extent possible, but not need remain functional so long as manual means sufficient to safely terminate a dive are provided.

19-2.7.2 Electrical Service.

19-2.7.2.1 All hyperbaric facilities intended for human occupancy shall contain an electrical service that is supplied from two independent sources of electric power. For hyperbaric facilities located in a hospital, one power source shall be a prime-mover-driven generator set located on the premises of the facility. This service shall be designated as the Emergency System and shall meet the requirements of Chapter 3, "Electrical Systems," of this standard for hyperbaric systems based in health care facilities. NFPA 70, Article 700, "Emergency Systems," shall apply to hyperbaric systems located in facilities other than health care facilities.

19-2.7.2.2 Electrical equipment associated with life support functions of hyperbaric facilities shall be connected to the critical branch of the emergency system; that is, such equipment shall have electrical power restored within 10 seconds of interruption of normal power. Such equipment shall include, but not necessarily be limited to:

(a) Electrical power outlets located within the chamber.

(b) Chamber emergency lighting, whether internally or externally mounted.

(c) Chamber intercommunications.

(d) Alarm systems, including fire detectors.

(e) Chamber fire suppression system equipment and controls. Booster pumps (if installed) shall be on separate branch circuits serving no other loads.

(f) Other electrical controls used for chamber pressurization and ventilation control.

(g) A number of chamber room lights (either overhead or local) to ensure continued safe operation of the facility during a normal power outage.

19-2.7.2.3 Electric-motor-driven compressors and auxiliary electrical equipment normally located outside the chamber and used for chamber atmospheric control shall be connected to the equipment system (see Chapter 3, "Electrical Systems") or the emergency system (see NFPA 70, Article 700), as applicable. Such equipment shall be arranged for delayed-automatic or manual connection to the alternate power source so as to prevent excessive current draw on the system during restarting.

Exception: When reserve air tanks of sufficient capacity to maintain pressure and ventilation airflow within the chamber and to supply high-pressure air for the rapid pressurization of the chamber are provided, the compressor and auxiliary equipment need not have an alternate source of power. It is the intent of this paragraph that chamber occupants be assured of adequate ventilation air and that they are protected from rapid decompression in the event of a loss of normal power.

19-2.7.2.4 Electrical control and alarm systems design shall be such that hazardous conditions (e.g., loss of chamber pressure control, deluge activation, spurious alarms) do not occur during power interruption or during power restoration.

19-2.7.3 Wiring and Equipment inside Chambers. Electric wiring and fixed equipment installed in the chamber shall comply with NFPA 70, Article 500 for the hazard group classification as specified in the following paragraphs. No equipment installed or used in the chamber shall present an implosion or explosion hazard in the pressurized chamber environment.

Exception: Where conformance with Class I, Division 1 requirements is specified in the following paragraphs, conformance with Class I, Division 2 requirements may be substituted if the following condition is met:

(a) The limitations on the use in the chamber of alcohol and other agents that emit flammable vapors in the Exception to 19-3.1.5.2 are strictly observed and such restrictions are prominently posted.

19-2.7.3.1 Insulation. All conductors inside the chamber shall be insulated with a material classified as flame resistant as defined in Chapter 2. This requirement does not apply to conductors that form an integral part of electrical equipment that is approved for use inside of the chamber.

Exception: Ground conductors inside of a conduit need not be insulated.

19-2.7.3.2 Wiring Methods. Fixed wiring shall comply with the requirements for Class I, Division 1 locations of NFPA 70, Article 501-4, "Wiring Methods." Wiring classified as intrinsically safe for Class I, Division 1, Group B locations shall be permitted using any of the methods suitable for ordinary locations. Intrinsically safe wiring shall meet the installation requirements for Class I hazardous locations of ANSI/ISA-RP12.6, *Installation of Intrinsically Safe Systems in Hazardous Locations*. Fixed conduits, boxes, and enclosures shall be approved as explosionproof for Class I, Division 1, Group A or B locations.

19.2.7.3.3 Sealing and Drainage. Sealing and drainage shall be provided for the fixed conduit and equipment enclosures inside the chamber as required in NFPA 70, Article 501-5 for Class I, Division 1.

19-2.7.3.4 Flexible cords used to connect portable utilization equipment to the fixed electrical supply circuit shall be of a type approved for extra-hard utilization in accordance with NFPA 70, Table 70-4, shall include a ground conductor, and shall otherwise meet the requirements of NFPA 70, Article 501-11.

19-2.7.3.5 Receptacles and attachment plugs shall meet the requirements of NFPA 70, Article 501-12 and shall be approved for Group A or B locations. They shall be part of an approved unit device with an interlocking mechanism arranged so that the plug cannot be withdrawn or inserted when the circuit is energized.

NOTE: It should be recognized that interruption of any powered circuit, even of very low voltage, may produce a spark sufficient to ignite a flammable agent.

19-2.7.3.6 Switches shall meet the requirement of NFPA 70, Article 501-6, Class I, Division 1, except that switches for intrinsically safe circuits may be of a type for ordinary locations.

NOTE: It is recommended that all control switching functions inside the chamber be accomplished using intrinsically safe circuits that control power and control circuits located outside of the chamber.

19-2.7.3.7 No equipment shall be installed in or allowed in the chamber that does not meet the temperature rating requirements of NFPA 70, Article 500-3(a), (b), and (c).

19-2.7.3.8 There shall be no exposed live electrical parts other than those that are intrinsically safe.

19-2.7.3.9 Motors shall meet the requirements of NFPA 70, Article 501-8(a)(1) for the chamber pressure and oxygen concentration, or shall be of the totally enclosed types meeting NFPA 70, Article 501-8(a)(2) or (3).

19-2.7.3.10 Internally installed lighting fixtures shall be enclosed types that are protected by a positive-pressure ventilating system in which clean air or diluent gas is circulated at a pressure at least 1 in. (2.5 cm) of water above chamber pressure, and in which fixtures in which ventilation pressure differential drops below 1 in. (2.5 cm) of water or the ventilation gas temperature exceeds 140°F (60°C) are automatically deenergized.

19-2.7.3.11 Portable (including battery-operated) electric or electronic equipment used in the chamber and permanently installed sensors, communications, signaling, alarm, or remote-control equipment shall meet one of the following criteria:

(a) Is listed intrinsically safe for Class I, Division 1, Group B locations.

(b) Meets NFPA 70, Article 501-8(a)(2) or (3).

(c) Is hermetically sealed, filled with inert gas, and designed to be automatically deenergized when the internal temperature exceeds a maximum of 248°F (120°C) or when the internal pressure deviates from the initial charge pressure by more than 10 percent.

19-2.7.4 Grounding and Ground Fault Protection.

19-2.7.4.1 The chamber shall be grounded according to the requirement of NFPA 70, Article 250, "Grounding." Resistance between the chamber and ground point shall not exceed 1 ohm.

19-2.7.4.2 In health care facilities, electrical power circuits located within the chamber shall be supplied from an ungrounded electrical system equipped with a line isolation monitor with appropriate signal lamps and audible alarms. Such circuits shall meet the requirements of NFPA 70, Article 517-160, "Isolated Power Systems," and 517-160(b), "Line Isolation Monitor."

19-2.7.4.3 Wiring located both inside and outside the chamber, which serves line level circuits and equipment located inside the chamber, shall meet the grounding and bonding requirements of NFPA 70, Article 501-16.

19-2.7.5 Wiring outside the Chamber.

19-2.7.5.1 Those electrical components that must remain functional for the safe termination of a dive following activation of the room sprinkler system shall be enclosed in waterproof housing.

19-2.7.5.1.1 All associate conduits shall be waterproof and shall meet the requirements of NFPA 70. Such conduits shall be equipped with approved drains.

19-2.7.5.2 All other electrical devices outside the chamber shall meet the requirements of NFPA 70.

NOTE: It is necessary that these circuits be protected from exposure to water from the room sprinkler system protecting the chamber housing in the event of a fire in the vicinity of the chamber while it is in operation.

19-2.7.6 Wiring and Equipment inside Class B Chambers.

19-2.7.6.1 Electrical equipment inside Class B chambers shall be restricted to communication functions and patient physiological monitoring leads. Circuits shall not exceed 28 V and $\frac{1}{2}$ W.

19-2.7.6.2 Conductor insulation shall conform to 19-2.7.3.1 insulation.

19-2.7.6.3 Lighting inside the chamber must be supplied from external sources.

19-2-7.6.4 No flammable liquids, gases, or vapors shall be permitted inside any Class B chamber.

19-2.8 Communications and Monitoring.

19-2.8.1 General.

19-2.8.1.1 Detectors, sensors, transducers, and communications equipment located inside the chamber shall meet the requirements of 19-2.7.3.11. Wiring methods in the chamber shall meet the applicable requirements in 19-2.7.3.

19-2.8.1.2 Control equipment, power amplifiers, output transformers, and monitors associated with communications and monitoring equipment shall be installed outside the chamber or shall otherwise meet the requirements of 19-2.7.3.11.

19-2.8.2 Intercommunications.

NOTE: Intercommunications equipment is mandatory for safe operation of a hyperbaric facility.

19-2.8.2.1 An intercommunication system shall connect all personnel compartments (locks), main compartments (locks), and the chamber operator's control console. It is recommended that multiple compartment (lock) Class A chambers be equipped with multiple channel systems, and that, in addition, a sound-powered telephone or surveillance microphone be furnished.

19-2.8.2.2 Oxygen mask microphones shall be approved intrinsically safe at the maximum proposed pressure and 95 ± 5 percent oxygen.

19-2.8.3 Automatic fire detection equipment, when used, shall meet the applicable requirements in 19-2.6 and 19-2.5.4.

19-2.8.4 Combustible Gas Detection.

19-2.8.4.1 The chamber atmosphere shall be continuously monitored for combustible gas concentrations whenever any volatile agents (*see 19-2.4.1.2*) are used in the chamber. The monitor shall be set to provide audible and visual alarms at 10 percent lower explosion limit (LEL) for the particular gas used.

19-2.8.5 Oxygen Monitoring.

19-2.8.5.1 Oxygen levels shall be continuously monitored in any chamber in which nitrogen or other diluent gas is added to the chamber to reduce the volumetric concentration of oxygen in the atmosphere (saturation operations). Audible and visual alarms shall indicate unsafe low oxygen partial pressure in the chamber.

19-2.8.5.2 Oxygen levels shall be continuously monitored in Class A chambers when breathing mixtures containing in excess of 21 percent oxygen by volume are being breathed by patients or attendants and/or any flammable agents are present in the chamber. Audible and visual alarms shall indicate volumetric oxygen concentrations in excess of 23.5 percent.

19-2.8.6 Carbon Dioxide Monitoring. The chamber atmosphere shall be monitored during saturation operations whenever ventilation is not used (*see 19-2.4.1.1, Exception*) to ensure that carbon dioxide levels do not exceed safe levels.

19-2.8.7 Chamber Air Supply Monitoring.

19-2.8.7.1 The air supply of Class A and Class B chambers shall be sampled periodically for concentrations of carbon monoxide. The frequency of such monitoring shall depend on the location of the air intake relative to potential sources of contamination. It is recommended that air be sometimes sampled at the air intake location at times when the intake air is likely to have maximum impurities (for example, when vehicles or stationary engines upwind of the intake are running). Air supplied from oil-lubricated compressors shall be continuously monitored for volatilized hydrocarbons as well as carbon monoxide at a location downstream from the oil filter when the compressors are running. As a minimum, the air supplied to Class A and B chambers shall meet the requirements of CGA Pamphlet G-7.1, *Commodity Specification for Air*, Grade D.

NOTE 1: Because of the potential for contaminated air from oil-lubricated compressors, the use of oil-lubricated compressors is highly discouraged.

NOTE 2: Air supplied to chambers periodically pressured with pure oxygen may need to meet more stringent requirements with respect to air quality.

19-2.8.7.2 Air, oxygen, or other breathing mixtures from certified commercially supplied flasks shall be randomly sampled to ensure quality control of subject gas.

19-2.8.8 Electrical monitoring equipment used inside the chamber shall comply with the applicable requirements of 19-2.7.

NOTE: It is recommended that information about the status of an anesthetized or otherwise monitored patient be transmitted to the inside chamber attendants via the intercommunications system. As an alternative, the monitor indicators may be placed adjacent to a chamber viewport (or viewports) for direct observation by inside personnel.

19-2.8.9 Closed-circuit TV monitoring of the chamber interior shall be employed for chamber operators who do not have direct visual contact of the chamber interior from their normal operating location.

19-2.9 Other Equipment and Fixtures.

19-2.9.1 All furniture permanently installed in the hyperbaric chamber shall be grounded.

19-2.9.2 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 reentry of exhaust gases into the building, and protected by a grille or fence of at least 2-ft (0.6-m) radius from the exhaust port. A protective grille or fence is not required when the exhaust is above the building height.

19-3 Administration and Maintenance.

19-3.1 General.

19-3.1.1 Purpose. Section 19-3 contains requirements for administration and maintenance that shall be followed as an adjunct to physical precautions specified in Section 19-2.

19-3.1.2 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-19 of this document and shall be reviewed by the safety director. Since Section 19-3 is expected to be used as a text by those responsible for the mitigation of hazards of hyperbaric facilities, the requirements set forth herein are frequently accompanied by explanatory text.

19-3.1.3 Responsibility.

19-3.1.3.1 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.

19-3.1.3.2 A safety director shall be in charge of all hyperbaric equipment. The safety director shall have the authority to restrict potentially hazardous supplies and equipment from the chamber [*see 19-3.1.5.4(c)*].

NOTE: The complexity of hyperbaric chambers is such that one person should be designated chamber operator, such 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.

19-3.1.3.3 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.

19-3.1.3.4 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-19.2 and C-19.3*) 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.

19-3.1.3.5 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 ensure 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 19-3 of this chapter.

19-3.1.4 Rules and Regulations.

19-3.1.4.1 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 assume enforcement. Training and discipline are mandatory.

NOTE: 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.

19-3.1.4.2 All personnel, including those involved in maintenance and repair of the facility, shall become familiar with emergency equipment — its purposes, applications, operation, and limitations.

19-3.1.4.3 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.

19-3.1.4.4 A suggested outline for emergency action in the case of fire is contained in Appendix C-19.2.

19-3.1.4.5 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.

19-3.1.5 General Requirements.

19-3.1.5.1 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, and in the immediate 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.

19-3.1.5.2 Flammable Gases and Liquids. Flammable agents (including devices such as laboratory burners employing bottled or natural gas and cigarette lighters) shall be forbidden inside the chamber and from the proximity of the compressor intake.

Exception: Flammable agents used for patient care, such as alcohol swabs, parenteral alcohol-based pharmaceuticals, and topical creams, shall be permitted in the chamber if the following conditions are met:

(a) Such use is approved by the safety director, or other authority having jurisdiction.

(b) The quantities of such agents are limited so that they are incapable of releasing sufficient flammable vapor into the chamber atmosphere to exceed the LEL for the material. A safety factor shall be included to account for the localized concentrations, stratification, and the absence of ventilation. (See Note 2 for a sample calculation.)

(c) The oxygen monitoring requirement of 19-2.8.5.2 is observed.

NOTE 1: Allowable quantities for the Exception can be determined from the chamber volume, flammable agent vapor density, and lower explosive limit (LEL). Experience

has shown that increased pressure has little effect on LEL for a given flammable gas and oxygen concentration. A safety factor of 10 is recommended. Flammable liquids should be confined to nonbreakable, nonspill containers.

NOTE 2: Example of Limiting Quantity of Flammable Agent Substance: Isopropyl alcohol (2-propanol)

LEL = 2%/vol. (irrespective of chamber pressure)
Vapor density: 2.1 relative to air
Liquid density: 786 g/Liter
Air density: 0.075 lb/cu ft at STP.

The limiting case occurs at the lowest ambient pressure, i.e., 1 atmosphere:

alcohol vapor density at LEL = 0.02 × 2.1 × 0.075
= 0.00315 lb/cu ft
= 1.43 g/cu ft

For a relatively small 500 cu ft chamber, this implies:

1.43 × 500 = 715 g alcohol vapor at LEL.

Using a safety factor of 10 to account for uneven vapor concentrations gives 71.5 g = 91 ml alcohol.

One might conclude that even 90 ml alcohol is more than would be needed for most any medical procedure. The above calculation also does not account for the mitigating effect of ventilation.

NOTE 3: 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.

NOTE 4: 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.

19-3.1.5.3 Personnel.

(a) The number of occupants of the chamber shall be kept to the minimum number necessary to carry out the procedure.

(b) Antistatic procedures as directed by the safety director shall be employed whenever atmospheres containing more than 23.5 percent oxygen by volume are used.

(c) In Class A and Class B chambers with atmospheres containing more than 23.5 percent oxygen by volume, electrical grounding of the patient shall be ensured by the provision of a high-impedance conductive strap in contact with the patient's skin.

(d) Because of the possibility of percussion sparks, shoes having ferrous nails that make contact with the floor shall not be permitted to be worn in Class A chambers.

19-3.1.5.4 Textiles.

(a) Silk, wool, or synthetic textile materials shall not be permitted in Class A or Class B chambers unless the fabric meets the flame resistant requirements of 19-3.1.5.4(d).

(b) Garments fabricated of 100 percent cotton or an antistatic blend of cotton and a polyester fabric shall be permitted in Class A chambers equipped with fire protection as specified in 19.2.5, and in Class B chambers.

(c) Suture material, alloplastic devices, bacterial barriers, surgical dressings, and biologic interfaces of otherwise prohibited materials shall be permitted to 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 Note under 19-3.1.3.2*).

(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.

19-3.1.5.5 All chamber personnel shall wear garments of the overall or jumpsuit type, completely covering all skin areas possible, and as tight-fitting as possible.

19-3.1.5.6 The use of flammable hair sprays, hair oils, and skin oils shall be forbidden for all chamber occupants—patients as well as personnel. 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 19-3.1.5.5. 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.

19-3.1.5.7 All other fabrics used in the chamber such as sheets, drapes, and blankets shall be of inherently flame-resistant materials. Free-hanging drapes shall be minimized.

19-3.2 Equipment.

19-3.2.1 All equipment used in the hyperbaric chamber shall comply with Section 19-2. 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 19-3.1.5.4(c).*]

19-3.2.1.1 Portable X-ray devices, electrocautery equipment, and other similar high-energy devices shall not be operated in the hyperbaric chamber unless approved by the safety director 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.

19-3.2.1.2 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 19-3.1.3.2*).

19-3.2.1.3 The use of paper shall be kept to an absolute minimum in hyperbaric chambers, and any paper brought into the chamber shall be stored in a closed metal container. Containers shall be emptied after each chamber operation.

19-3.2.1.4 No equipment shall be allowed in the chamber that does not meet the temperature requirements of NFPA 70, Article 500-3(a), (b), and (c).

19-3.2.2 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 and impact conditions are applicable. Self-ignition temperatures normally are unknown in special atmospheres.

19-3.2.3 Equipment used inside the chamber requiring lubrication shall be lubricated with oxygen-compatible flame-resistant material.

Exception: Factory-sealed antifriction bearings shall be permitted to be used with standard hydrocarbon lubricants in Class A chambers that do not employ atmospheres of increased oxygen concentration.

19-3.2.4 Equipment of cerium, magnesium, magnesium alloys, and similar manufacture shall be prohibited from the chamber interior. (*See also Note under 19-3.2.2.*)

19-3.2.5 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 1000 parts per million, such radiation equipment shall not be operated until the chamber atmosphere is cleared.

19-3.3 Handling of Gases.

19-3.3.1 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 19-3.1.5.2 and Appendix C-19-1.1.3.2*).

19-3.3.2 Oxygen and other gases shall not be introduced into the chamber in the liquid state.

19-3.3.3 Flammable gases shall not be used or stored in the chamber or in the hyperbaric facility.

19-3.3.4 Quantities of oxygen stored in the chamber shall be kept to a minimum.

NOTE: Pressurized containers of gas may be introduced into the hyperbaric chamber, provided that the container and its contents are approved for such use by the safety director.

19-3.3.5 Nonflammable gases shall be permitted to be piped into the hyperbaric facility. Shutoff valves accessible to facility personnel shall be provided for such piping at the point of entry to the room housing the chamber. Storage and handling of nonflammable gases shall meet the applicable requirements of NFPA 99, Chapter 4, "Gas and Vacuum Systems," and NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites*.

19-3.4 Maintenance.

19-3.4.1 General.

19-3.4.1.1 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.

19-3.4.1.2 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 CGA C-4, *Standard Method of Marking Portable Compressed Gas Containers to Identify the Material Contained.*

19-3.4.1.3 Before piping systems are initially put into use, it shall be ascertained that the gas delivered at the outlet is shown on the outlet label and that proper connecting fittings are checked against their labels, in accordance with Sections 4-3 through 4-6 in Chapter 4.

19-3.4.1.4 The guidelines set forth in Sections 4-3 through 4-6 of Chapter 4, concerning the storage, location, and special precautions required for compressed gases, shall be followed.

19-3.4.1.5 Storage areas for hazardous materials shall not be located in the room (*see 19-2.1*) housing the hyperbaric chamber. Flammable gases, except as provided in 19-3.1.5.2, Exception No. 1, shall not be used or stored in the hyperbaric room.

19-3.4.1.6 All replacement parts and components shall conform to original design specification.

19-3.4.2 Maintenance Logs.

19-3.4.2.1 Installation, repairs, modifications of equipment, etc., related to a chamber shall be evaluated by engineering personnel, tested under pressure, and approved by the safety director. Logs of the various tests shall be maintained.

19-3.4.2.2 Operating equipment logs shall be maintained by engineering personnel. They shall be signed before chamber operation by the person in charge (*see Note under 19-3.1.3.2*).

19-3.4.2.3 Operating equipment logs shall not be taken inside the chamber.

19-3.5 Electrical Safeguards.

19-3.5.1 Electrical equipment shall be installed and operated in accordance with 19-2.7.

19-3.5.1.1 All electrical circuits shall be tested before chamber pressurization. This test shall include a ground fault check to verify that no conductors are grounded to the chamber, as well as a test of normal functioning (*see 19-2.7.2.3*).

19-3.5.1.2 In the event of fire, all nonessential electrical equipment within the chamber shall be deenergized insofar as possible before extinguishing the fire. Smoldering, burning electrical equipment shall be deenergized before extinguishing a localized fire involving only the equipment (*see 19-2.5*).

19-3.6 Electrostatic Safeguards.

19-3.6.1 Administration.

19-3.6.1.1 General. The elimination of static charges is dependent on the vigilance of administrative supervision of materials purchased, maintenance, and periodic inspection and testing.

19-3.6.1.2 Textiles. Textiles used or worn in the hyperbaric chamber shall conform to 19-3.1.5.4 through 19-3.1.5.7.

19-3.6.2 Maintenance.

19-3.6.2.1 Conductive Floors. For chambers containing conductive floors, the requirements of 12-4.1, "Anesthetizing Locations," shall apply.

19-3.6.2.2 Furniture Used in the Chamber.

(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 that 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. Lubricants shall be oxygen compatible and flame resistant.

NOTE: Wheelchairs and gurneys with bearings lubricated and sealed by the manufacturer may be used in Class A chambers where conditions prescribed in 19-2.8.4.1, 19-2.8.5.1, and 19-2.8.5.2 are met.

19-3.6.2.3 Conductive Accessories. Conductive accessories, such as belting, rubber accessories, plastics, covers, and sheeting used inside the chamber, shall meet the conductivity and antistatic requirements of 12-4.1.3.8, "Reduction in Electrostatic Hazard."

19-3.6.3 Testing. Conductive testing, if required, shall be in accordance with requirements in 12-4.1.3, "Requirements for Flammable Anesthetizing Locations."

19-3.6.3.1 Materials containing rubber shall be inspected regularly, especially at points of kinking.

NOTE: Materials containing rubber deteriorate rapidly in oxygen-enriched atmospheres.

19-3.6.4 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.

19-3.6.5 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 20 Referenced Publications

20-1 The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

20-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1990 edition

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1991 edition

NFPA 30, *Flammable and Combustible Liquids Code*, 1990 edition

NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*, 1990 edition

NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, 1991 edition

NFPA 49, *Hazardous Chemicals Data*, 1991 edition

NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites*, 1990 edition

NFPA 50A, *Standard for Gaseous Hydrogen Systems at Consumer Sites*, 1989 edition

NFPA 51, *Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes*, 1992 edition

NFPA 54, *National Fuel Gas Code*, 1992 edition

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, 1992 edition

NFPA 70, *National Electrical Code*, 1993 edition

NFPA 72, *Standard for the Installation, Maintenance, and Use of Protective Signaling Systems*, 1990 edition

NFPA 80, *Standard for Fire Doors and Fire Windows*, 1992 edition

NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, 1993 edition

NFPA 99B, *Standard for Hypobaric Facilities*, 1993 edition

NFPA *101*, *Life Safety Code*, 1991 edition

NFPA 110, *Standard for Emergency and Standby Power Systems*, 1993 edition

NFPA 220, *Standard on Types of Building Construction*, 1992 edition

NFPA 259, *Standard Test Method for Potential Heat of Building Materials*, 1993 edition

NFPA 701, *Standard Methods of Fire Tests for Flame-Resistant Textiles and Films*, 1989 edition

NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*, 1990 edition

20-1.2 Other Publications.

20-1.2.1 AATCC Publication. American Association of Textile Chemists and Colorists, P.O. Box 886, Durham, NC 27701.

AATCC Test Method 76-1989, *Determination of the Electrical Resistivity of Fabrics, included in 1962 Technical Manual* (ANSI/AATCC 76)

20-1.2.2 ANSI Publications. American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

ANSI B120.1-1983, *Pipe Threads, General Purpose*

ANSI B16.22-1989, *Wrought Copper and Copper Alloy Solder - Joint Pressure Fittings*

ANSI B57.1 (See CGA V-1)

ANSI C73-1973, *Plugs and Receptacles*

ANSI C84.1-1989, *Voltage Ratings: Electric Power Systems and Equipment*

ANSI C-4 (See CGA C-4)

ANSI G-7.1 (See CGA G-7.1)

ANSI Z66.1-1964 (R 1972), *Specifications for Paints and Coatings Accessible to Children to Minimize Dry Film Toxicity*

20-1.2.3 ASHRAE Publications. American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329.

ASHRAE Guide and Data Book — Applications Table on Pressure Relationships and Ventilation of Certain Hospital Areas, published annually

ASHRAE Handbook of Fundamentals-1985, Chapter 24

20-1.2.4 ASME Publications. American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ANSI/ASME PVHO-1a-1990, *Safety Standard for Pressure Vessels for Human Occupancy*

ASME *Boiler and Pressure Vessel Code* (1990)

20-1.2.5 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM B88-1992, *Specification for Seamless Copper Water Tube*

ASTM B280-1992, *Specification for Seamless Copper Tubing for Air Conditioning and Refrigeration Field Service*

ASTM B819-1992, *Standard Specification for Seamless Copper Tube for Medical Gas Systems*

ASTM D5-1986, *Test for Penetration of Bituminous Materials*

ASTM D2240-1991, *Test Method for Rubber Property — Durometer Hardness*

ASTM D2863-1991, *Method for Measuring the Minimum Oxygen Concentration to Support Candle-like Combustion of Plastics (Oxygen Index)* (ANSI D2863)

ASTM E136-1982, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*

20-1.2.6 AWS Publications. American Welding Society, Inc., 550 NW Lejune Road, Miami, FL 33135.

ANSI/AWS A5.8-1989, *Specification for Brazing Filler Metal*

AWS B2.2-1985, *Standard for Brazing Procedure and Performance Qualifications*

20-1.2.7 CGA Publications. Compressed Gas Association, Inc., 1725 Jefferson Davis Highway, Arlington, VA 22202.

Pamphlet C-4-1990, *Standard Method of Marking Portable Compressed Gas Containers to Identify the Material Contained*

Pamphlet C-9-1988, *Standard Color-Marking of Compressed Gas Cylinders Intended for Medical Use*

Pamphlet G-4-1987, *Oxygen*

Pamphlet G-4.1-1985, *Cleaning Equipment for Oxygen Service*

Pamphlet G-7.1-1989, *Commodity Specification for Air* (ANSI Z86.1)

Pamphlet G-8.1-1990, *Standard for the Installation of Nitrous Oxide Systems at Consumer Sites*

Pamphlet G-10.1-1991, *Commodity Specification for Nitrogen*

Pamphlet P-2-1989, *Characteristics and Safe Handling of Medical Gases*

Pamphlet P-2.5-1987, *Transfilling of High Pressure Gaseous Oxygen to Be Used for Respiration*

Pamphlet P-2.6-1983, *Transfilling of Low-Pressure Liquid Oxygen to Be Used for Respiration*

Pamphlet P-9-1980, *Inert Gases: Argon, Nitrogen and Helium*

Pamphlet V-1-1987, *Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections* (ANSI B57.1)

Pamphlet V-5-1985, *Diameter-Index Safety System — Non-Interchangeable Low Pressure Connections for Medical Gas Applications*

20-1.2.8 Copper Development Association Publication. Copper Development Assn., 260 Madison Avenue, 16th floor, New York, NY 10016.

Copper Tube Handbook

20-1.2.9 ISA Publication. Instrument Society of America, P.O. Box 12277, Research Triangle Park, NC 27709.

RP 12.6-1987, *Installation of Intrinsically Safe Systems in Hazardous Locations*

20-1.2.10 MSS Publications. Manufacturer's Standardization Society of the Valve and Fittings Industry, Inc., 127 Park Street NE, Vienna, VA 22180.

SP-58 (1988) *Pipe Hangers and Supports — Materials, Design, and Manufacture*

SP-69 (1983) *Pipe Hangers and Supports — Selection and Application*

20-1.2.11 NCCLS Publication. 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*

20-1.2.12 UL Publication. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL Subject 94-1991, *Burning Tests for Plastics*

20-1.2.13 U.S. Government Publications.

20-1.2.13.1 U.S. Government 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 (U.S. 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.)

Commercial Standard 223-59, *Casters, Wheels, and Glides for Hospital Equipment*

20-1.2.13.2 U.S. Dept. of Defense, Naval Publications & Form Center (NPFC 103), 5801 Tabor Avenue, Philadelphia, PA 19120.

MIL-Standard 104B, *Limit for Electrical Insulation Color*

Appendix A

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

NOTE: Sections of Appendix A identified by a dagger (†) indicate text extracted from NFPA 30, *Flammable and Combustible Liquids Code*, 1990 edition. Requests for interpretations or revisions of the extracted text will be referred to the Technical Committee on Flammable and Combustible Liquids.

A-2-2 Atmosphere of Increased Burning Rate. 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, *Standard for Hyperbaric Facilities*, prior to 1982, did not necessarily reflect the increased fire hazard of hyperbaric and hypobaric atmospheres.

The definition of atmosphere of increased burning rate in Chapter 19 and in NFPA 99B, *Standard for Hypobaric Facilities*, defines an oxygen-enriched atmosphere with an increased fire hazard, as it relates 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(a) 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(a).*]

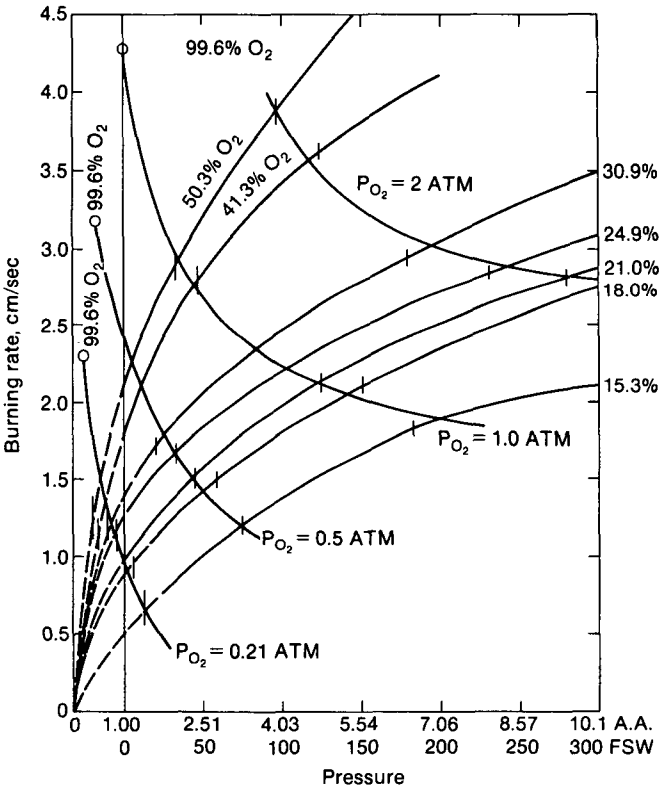


Figure A-2-2(a) Burning rates of filter paper strips at an angle of 45 degrees in N_2-O_2 mixtures. (From Figure 4, Technical Memorandum UCRI-721, *Chamber Fire Safety*, T. C. Schmidt, V. A. Dorr, and R. W. Hamilton, Jr., Ocean Systems, Inc. Research and Development Laboratory, Tarrytown, New York 10591. Work carried out under U.S. Office of Naval Research, Washington, DC, Contract No. N00014-67-A-0214-0013.) (From Cook, G. A., Meierer, R. E., Shields, B. M. *Screening of Flame-Resistant Materials and Comparison of Helium with Nitrogen for Use in Diving Atmospheres*. First summary report under ONR Contract No. 0014-66-C-0149. Tonawanda, NY: Union Carbide, 31 March 1967. DDC No. AD-651583.)

A-2-2 Dental Compressed Air. Dental compressed air for general dentistry, podiatry, and plastic surgery use operates at general line pressures of up to 175 psig (1207 kPa). The individual use points are separately and manually regulated for the individual hand piece and application/use. This is significantly different from a medical compressed air system, which typically operates at pressures of 50 to 55 psig (345-380 kPa).

The dental compressed air system should provide appropriately dehumidified, filtered, oil-free compressed air.

A-2-2 Hazardous Area in a Flammable Anesthetizing Location. The definition in Chapter 2 of this standard is based on 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 1 ft (30 cm) 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 5 ft (152 cm) above the floor as defined in Chapter 2 constitutes a "hazardous area." Because persons entering such anesthetizing locations may have accumulated electrostatic charges, the floors 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 12-4.1.3.1(c) to be provided with conductive floors to equalize static charges. Such rooms, if not used as flammable anesthetizing locations, are not required to be served by explosionproof wiring specified in 3-4.1.2.1(e)(2). Where flammable anesthetizing locations open directly onto a passageway not a part of an operating room or delivery room, the conductive floor should extend 3 m (9.84 ft) from either side of the door frame and out from the frame (into the passageway) for

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, rooms adjacent to flammable anesthetizing locations, and nonflammable anesthetizing locations, should be indicated by prominent signs permanently installed.

(e) Postoperative recovery units that 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 ($CHF_2CCl_2OCH_3$) is partially halogenated and is nonflammable in conditions encountered during clinical anesthesia (if it is heated, its vapor concentration will increase enough to burn). Fluroxene ($CF_3CH_2OCHCH_2$) is halogenated even less; it is flammable in concentrations of 4 percent or greater.

The following agents are considered flammable during conditions of clinical use in anesthesia:

cyclopropane
divinyl ether
ethyl chloride
ethylene
ethyl ether

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 4 percent and are flammable. Maintenance of fluroxene anesthesia may be accomplished with concentrations of less than 4 percent, however.

The following agents are nonflammable during conditions of use in clinical anesthesia:

chloroform
halothane
methoxyflurane
nitrous oxide
trichloroethylene
enflurane

A-2-2 Remote. A gas storage supply system may be remote from the single treatment facility, but all use points must be contiguous within the facility. [*See Figure A-2-2(b).*]

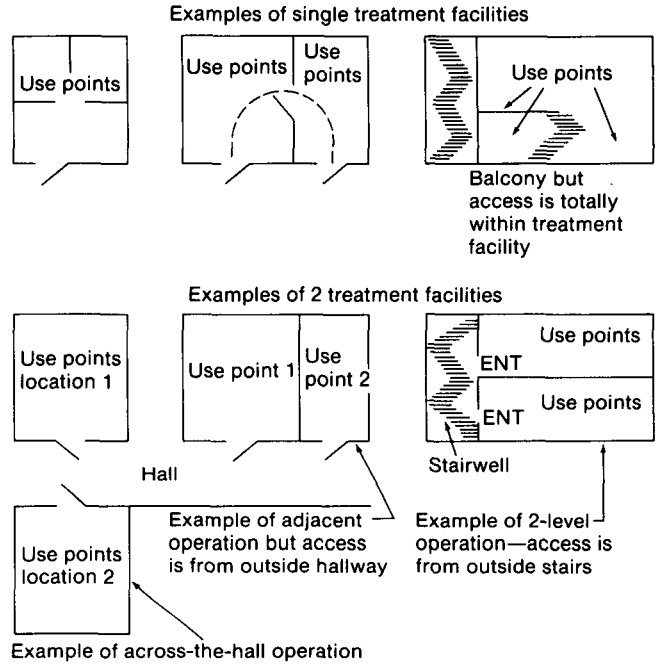


Figure A-2-2(b) Examples of treatment facilities.

A-2-2 Single Treatment Facility. The definition of single treatment facility was established to take into consideration principally single-level installations or those of a practice that could be two-level, but are reached by open stairs within the confines of the single treatment facility.

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-2-2 Surface-Mounted Medical Gas Rail Systems. It is the intent that surface-mounted medical gas rail systems would be permitted in individual patient rooms but would not be allowed to go directly through room walls to adjacent patient rooms. However, it is the intent to allow surface-mounted medical gas rails to be used in a given critical care area where there may be a partition separating certain patient care functions, essentially leaving the system within the given critical care area. As an example, two adjacent patient rooms outside of a critical care unit would not be permitted to have a surface-mounted medical gas rail interconnect between the two rooms through the wall.

However, in a nursery where there may be one or two segregated areas for isolation, a medical gas rail system supplying more than one isolation room, but within the nursery area, would be permitted to be interconnected with the nursery system.

A-3-1 Although 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 document, 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.

A-3-2 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 that increase the risk of serious injury in the event of certain types of electrical failure.

Electricity passing through the body can stimulate excitable tissue causing pain, involuntary muscle contractions, convulsions, or ventricular fibrillation. Also, electricity can cause tissue necrosis due to heat, chemical imbalance, or arcing. The effect of electricity depends upon the applied voltage, the magnitude of the current, the duration of application, whether the current is direct or alternating, the frequency of the current, and the size and location of the electrodes at which the current enters and leaves the body. The conductivity and dielectric strength of the skin is often a factor in determining the outcome of contact with electrified conductors.

Electrocution resulting from contact with equipment connected to ordinary branch circuit (i.e., less than 250 V at about 60 Hz). is usually a consequence of sustained ventricular fibrillation. When applied directly to the heart voltages of less than 100 mV RMS, 60 Hz can cause sustained ventricular fibrillation and death.

A-3-2.2.2 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 member can be shocked. [*See Figure A-3-2.2.2(a).*] There must be:

(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-3-2.2.2(b).*]

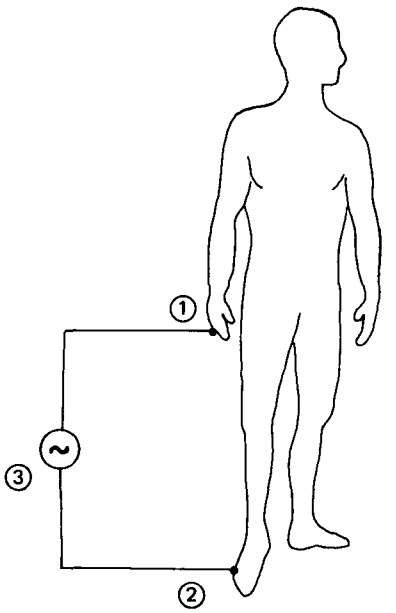


Figure A-3-2.2.2(a) The three basic conditions required to produce an electric shock.

Several separate factors should be analyzed when evaluating a potential electric shock hazard [numbers refer to Points in Figure A-3-2.2.2(b)]:

(1) The likelihood that a piece of line-powered equipment will be within reach of the patient;

(2a) The possibility of direct exposure of a "live" 110-V 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.

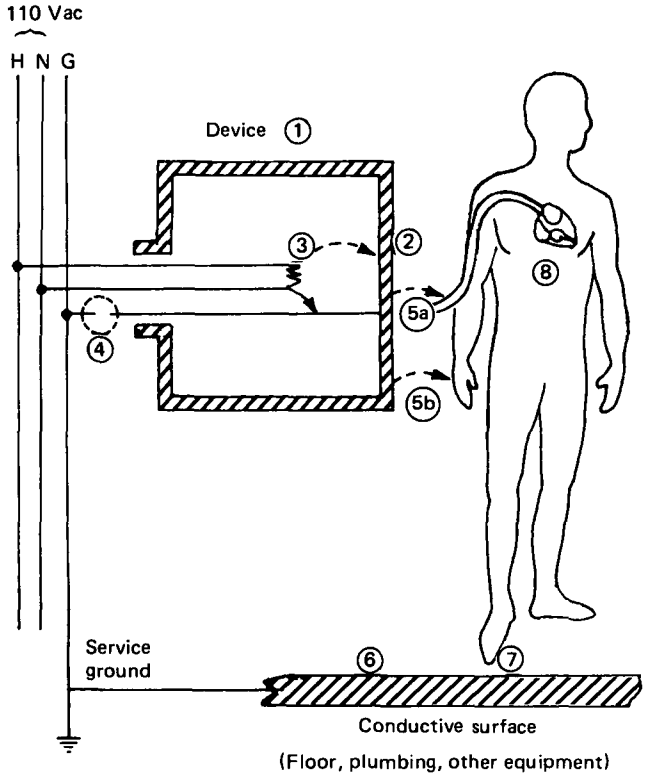


Figure A-3-2.2.2(b) General factors that should be considered when analyzing electrical safety.

The chance of a 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, that 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 provisions 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 when not in protective enclosures, should be insulated by materials suitable to the voltage and environment.

In order to minimize the probability of completing a hazardous circuit, exposed conductive surfaces not likely to be energized from internal sources should not be intentionally grounded. Insulated covering of such surfaces is desirable.

NOTE 1: Past measures recommended by earlier editions of NFPA standards and other standards associated with equipotential grounding and bonding of "dead metal" served to increase likelihood that a patient or staff member 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 for two reasons: to minimize the fraction of the fault current that might flow through an individual during the fault condition, and to operate overcurrent devices in order to minimize the possibility of damage and fire. This grounding 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 care 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 that 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-3-3.2.1.1 Design.

(a) *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 systems will be transferred to the alternate source (generator set) only when both utility services are deenergized, 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 as to problems of synchronization.

(b) *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 (*see Appendix B*).

A-3-3.2.1.11 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 into the reason for a failure to start.

A-3-4.1.2.1 Wiring, Regular Voltage.

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 V dc.

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-3-4.1.2.1(a) Circuits. 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 specific 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-3-4.1.2.1(b)(2) Reliability of Grounding. This requirement is usually met by appropriate mounting hardware, and not by wire jumpers.

A-3-4.1.2.1(c) Grounding Interconnects. 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-3-4.1.2.4(a) 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 the 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-3-4.2.1.4(c) Voltage Sensing. Consideration should be given to monitoring all ungrounded lines of the alternate source of power when conditions warrant.

A-3-4.2.1.4(f) Time Delay on Retransfer to Normal Power. It is recommended that the timer be set for 30 minutes [*see A-3-6.2.4.1(b)(1)*]. Consideration should also be given to an unloaded engine running time after retransfer to permit the engine to cool down before shutdown.

A-3-4.2.1.4(g) Test Switch. To maximize system reliability, it is good engineering practice to locate transfer switches as close as possible to the load that they serve. When transfer switches are installed in remote, infrequently accessed locations, it may be desirable to provide an annunciator at the operating engineer's facility to permit monitoring by a local control station.

A-3-4.2.1.4(h) Indication of Switch Position. To maximize system reliability, it is good engineering practice to locate transfer switches as close as possible to the load that they serve. When transfer switches are installed in remote, infrequently accessed locations, it may be desirable to provide an annunciator at the operating engineer's facility to permit visual indication of transfer switch positions by local indication.

A-3-4.2.1.4(k)† Automatic transfer switches can be provided with accessory controls that provide a signal that may

operate remote motor controls that disconnect motors prior to transfer and reconnect them after transfer when the residual voltage has been substantially reduced. Another method is to provide in-phase monitors within the automatic transfer switch to prevent retransfer to the normal source until both sources are nearly synchronized. A third method is to use a programmed neutral position transfer switch. [110: A-4-2.4.12]

A-3-4.2.1.7(c)† Consideration should be given to the effect that load interruption may have on the load during maintenance and service of the transfer switch. [110: A-4-4.4]

A-3-4.2.2.1 Separation of Wiring on Emergency System in Type I Systems. In principle, Chapter 3 is designed to seek security of electrical function by protection against both internal disruption and the loss of primary power sources. In keeping therewith, Chapter 3 aims to limit the security deterioration that 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 3 must leave details of wiring and overcurrent protection to engineering judgment, in view of wide variations of conditions, the Subcommittee on Electrical Systems's 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-3-4.2.2.2(b)(4), A-3-4.2.2.2(c)(7), and A-3-4.2.3.2(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 that 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-3-4.2.2.2(c) Critical Branch. It is recommended that facility 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-3-4.2.3.3(c) 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 and 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-3-4.3 Isolated Power. 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 No. 12 AWG wire will not exceed 0.2 millivolt, and the voltage across 3 m (9.84 ft) of No. 18 AWG 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 2 millivolts.

The reference grounding point is intended to ensure 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-3-5.2.1.1 Grounding System Testing. 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 purposes here, the load connection point will be considered to be a convenience receptacle, with the grounding conductor terminating 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 that 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 that 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 that 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 condition becomes a fault condition, 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 that 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 that 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 3 ohms or less, of which it is desired that the grounding system contribute 1 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 care vicinity must be considered.

Since all of this fault current flows in the grounding conductor of the defective appliance's power cord, the first effect is to raise the potential of this appliance above that of the receptacle that 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 3 volts or less. This value is not hazardous for casual contacts.

The fault current that enters the grounding system at the grounding contact of any receptacle in the patient care 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 care 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, a direct measure of the effectiveness of the grounding system within the patient care vicinity is obtained. 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 care vicinity that are produced by ground faults in appliances used in that vicinity. This impedance, which characterizes the ability of the grounding system to maintain nearly equipotential conditions within the patient care vicinity, 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 permit 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-3-5.2.1.3 Grounding and Voltage and Leakage Current Measurement Circuits. Effective grounding to safely handle both fault and leakage currents requires following the requirements of both Chapter 3 of NFPA 99 and Article 250 of 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 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 provide most of the effective grounding path of less than 10 milliohms at the receptacle, including plug-to-receptacle impedance. The green grounding wire becomes a backup, 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. 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 3-5.2.1.3 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 that 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 that 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 that 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-3-5.2.1.3(a).

The circuit shown in Figure A-3-5.2.1.3(a) is especially applicable to measurements of leakage current, where the current being measured is derived from a circuit whose 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.

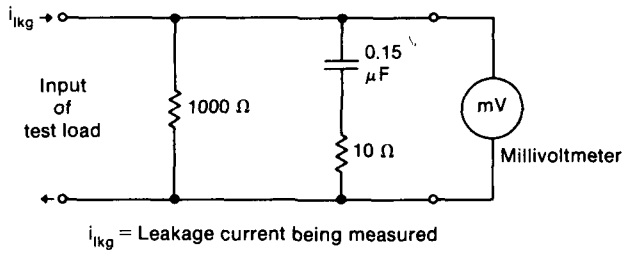


Figure A-3-5.2.1.3(a).

The basic low-frequency sensitivity will be 1 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 in Figure A-3-5.2.1.3(a) can be used for the voltage difference measurements required in Section 3-5, 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-3-5.2.1.3(b).

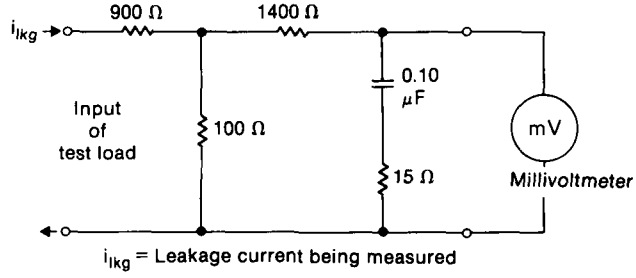


Figure A-3-5.2.1.3(b).

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 1 millivolt of

meter reading for 10 microamperes of leakage current or, on a voltage basis, 1 millivolt of meter reading for 10 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-3-6.2.4.1(b)(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-3-6.2.5.1 and A-7-6.3.1.2 Documentation. While several approaches to documentation exist in hospitals, the minimum acceptable documentation should convey what was tested, when it was tested, and whether 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) that 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-4-3.1.7 The bulk supply system should be installed on a site that has been prepared to meet the requirements of NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites*, or CGA Pamphlet G-8.1, *Standard for the Installation of Nitrous Oxide Systems at Consumer Sites*. Storage unit(s), reserve, pressure regulation, and signal actuating switch(es) are components of the supply system. Shutoff valves, piping from the site, and electric wiring from a signal switch(es) to the master signal panels are components of the piping system.

The bulk supply system is normally installed on the site by the owner of this system. It is the responsibility of the owner or the organization responsible for the operation and maintenance of the bulk supply system to ensure that all components of the supply system — main supply, reserve supply, supply system signal actuating switch(es), and delivery pressure regulation equipment — function properly before the system is put in service.

A-4-3.1.9.8 One method for a decision on Table 4-3.1.9.8 is the following:

(1) Test at the intake and at the sample connection valve.

(2) If the two purities agree within the limits of accuracy of the test, the compressor system may be accepted.

(3) If the air is found to exceed the values in the definition of "medical compressed air" in Section 2-2, the facility may elect to install purification apparatus for the contaminants in question.

A-4-3.2.2 When the storage/supply enclosure is remote from the single treatment facility, it should be locked for security reasons to prevent tampering. Access should be only via authorized staff or fire department. When the enclosure is within the single treatment facility, it is left to the discretion of the single treatment facility management as to whether greater benefit is achieved by immediate access or by security. An enclosure with direct access from a public hallway should be locked. If the door to the enclosure opens onto an exit access corridor, see 4-3.2.2. (*See Figure A-4-3.2.2.*)

A-4-3.2.3.1 The application of dental compressed air is not used for life-support purposes such as respirators, IPPB machines, analgesia, anesthesia, etc. Air discharged into the oral cavity is incidental and not a primary source of air to sustain life. However, if there is a coincident use of dental air for providing respiratory support, the requirements of dental air will be superseded by those of the respiratory support, and the compressed air system must produce the higher-quality medical compressed air as defined in Chapter 2. This may affect the selection of a compressor.

A dental compressed air system should not be used to provide power for an air-powered evacuation system without specific attention paid to the discharge of the evacuated gases and liquids. An open discharge of evacuated gases into the general environment of an operatory may compromise the quality of breathing air in the treatment facility. Air discharge should be vented to the outside of the building through a dedicated vent.

An air power evacuation system may require significant quantities of air to operate. Manufacturers' recommendations should be followed regarding proper sizing of the air compressor. Inadequate sizing can result in overheating, premature compressor failures, and inadequate operating pressures and flows.

A-4-3.2.3.4 Compressed-air quality may be compromised and expected life of system components may be shortened if an undersized system is installed. Manufacturers' recommendations should be followed regarding proper sizing of the air compressor(s).

A-4-3.2.3.6 The environmental air source for the compressor inlet should take into consideration possible contamination by particulates, concentrations of biological waste contaminants, ozone from nearby brush-type electric motors, and exhaust fumes from engines.

Air taken from an outside atmosphere may cause harmful condensation problems in the compressor. Long runs of inlet tube should also be avoided as it will degrade compressor performance. The compressor manufacturer's recommendations should be followed regarding appropriate pipe size to prevent possible degradation of system performance.

A dental air compressor and dental vacuum system may be in the same equipment room as long as the inlet for the dental air compressor does not draw air from a room or space containing an open discharge for the dental vacuum system.

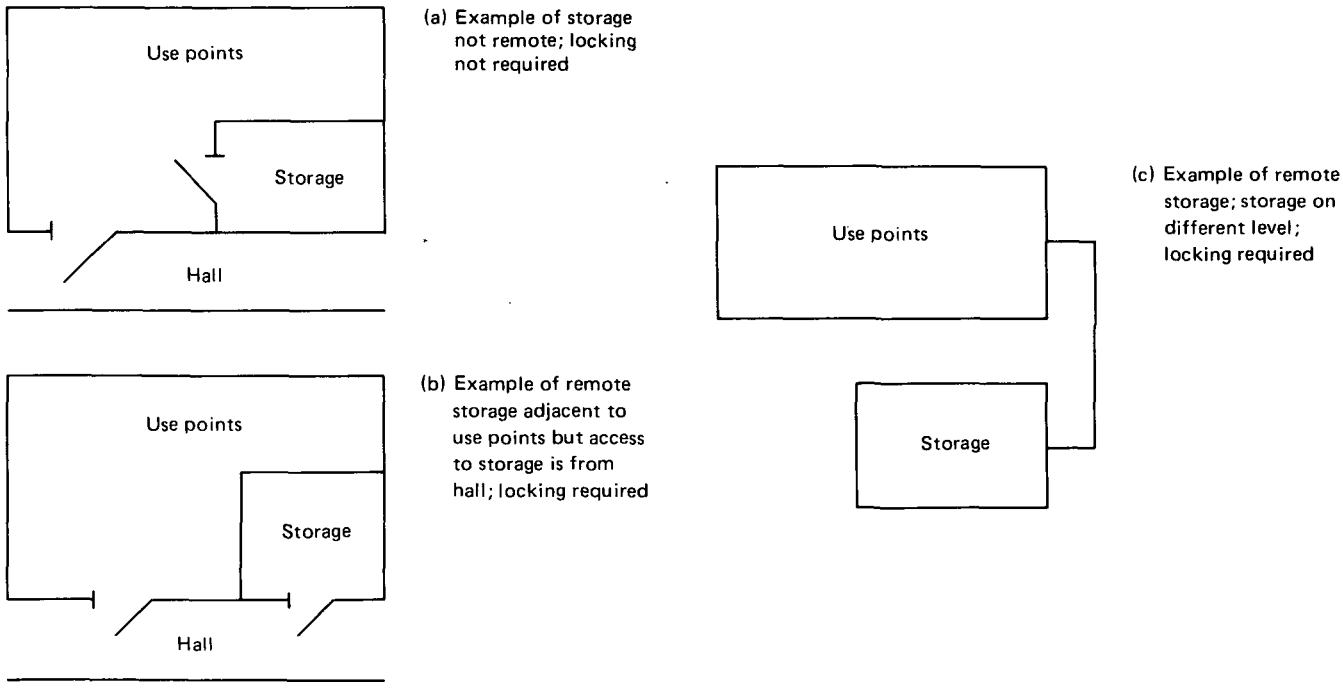


Figure A-4-3.2.2.

Atmospheric air in an operatory may have traces of mercury vapor and other contaminants. A compressor inlet location that would draw its supply directly from an operatory should be avoided.

A-4-3.2.3.8 A color dew point monitor downstream of the receiver indicating the quality of air coming into the receiver is desirable.

A color dew point monitor in the main treatment facility is appropriate to help the staff promptly identify when the system is being degraded with air of dew point higher than is acceptable.

The design of the color monitor should be such that the normal tolerance of variations will limit the maximum moisture at 39°F at 100 psig (3.9°C at 690 kPa) at activation.

A-4-4.1.1.2(d) This signal will be present only if the reserve supply consists of high-pressure cylinders that do not have check valves in the cylinder leads or is provided by a second bulk liquid storage unit.

A-4-4.1.1.3(c) This signal is intended to provide immediate warning for loss of, or increase in, system pressure for all anesthetizing locations supplied from a single branch line — not for each individual operating or delivery room.

A-4-4.1.1.3(d) This signal is intended to provide immediate warning for loss of, or increase in, system pressure for each individual vital life support and critical care area.

A-4-4.1.2.3(e) Typical plating would be nickel plating over copper or brass per Federal Specification QQ-N290, Class I, Type 7.

A-4-4.1.2.4(a) The purpose of the automatic secondary check valve is to shut off the flow of gas when the primary valve is removed for servicing.

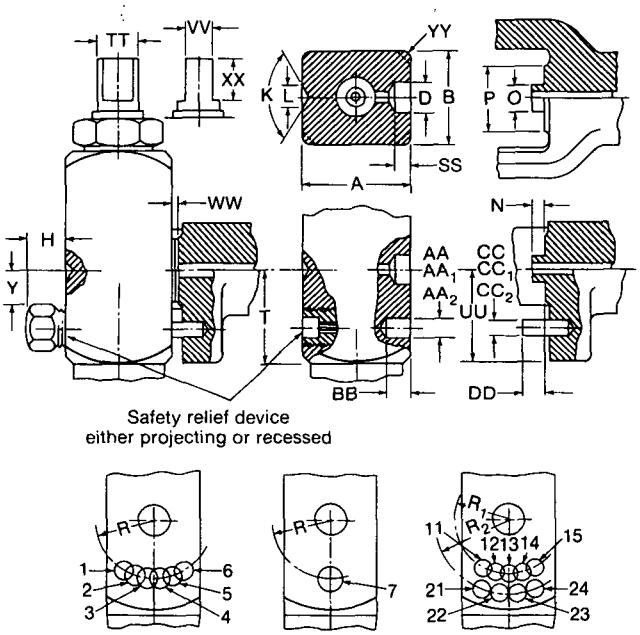
A-4-4.1.3.4 Pin-Index Safety System. The Pin-Index Safety System consists of a combination of two pins projecting from the yoke assembly of the apparatus and so positioned as to fit into matching holes drilled into the cylinder valves. It is intended to provide against the possibility of error in attaching 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-4-4.1.3.5, illustrates the system. Connections No. 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-4-4.1.4 The responsible authority of the facility should ensure that procedures are established to provide for the testing, maintenance, and operation of nonflammable medical gas piping systems.

A-4-4.1.4.3 All brazed joints should have a brazing alloy exhibiting a melting temperature in excess of 1000°F (538°C) to retain the integrity of the piping system in the event of fire exposure.

A-4-4.1.4.3(g) The intent is to provide an oxygen-free atmosphere within the tubing and to prevent the formation of copper oxide scale during brazing. This is accomplished by filling the piping with a low-volume flow of low-pressure inert gas.



DESCRIPTION		INCHES	MM
Major width	A	1 ± 0.015	25 ± 0.2
Minor width	B	0.875 ± 0.015	22.2 $\pm^{0.4}_{0}$
Bore diameter	D	0.275 MIN.	7 MIN.
Projection	**H	0.375 MAX.	9.6 MAX.
C'Sink angle	K	100°-120°	100°-120°
C'Sink diameter	L	0.203-0.250	6 $\pm^{0}_{0.5}$
Distance	T	0.875 MIN.	22 MIN.
Clearance	**Y	0.312 MIN.	8 MIN.
Hole dia. single row	AA	0.187-0.191	4.75 $\pm^{0.1}_{0}$
Single hole dia.	AA_1	0.228-0.232	5.8-5.9
Hole dia. double row	AA_2	0.156-0.160	3.95-4.05
Hole depth	BB	0.219-0.250	5.5 $\pm^{0.5}_{0}$
Bore depth	SS	0.140 MIN.	3.6 MIN.
Stem diameter	TT	0.373-0.356	9.5-9.1
Wrench flats	VV	0.240-0.225	6.1-5.7
Flat length	XX	0.394 MIN.	10 MIN.
Radius or chamfer	†YY	0.062 ± 0.010	1.6 ± 0.25

DESCRIPTION		INCHES	MM
Nose length	N	0.140-0.120	3.6-3.0
Nose diameter	O	0.255-0.235	6.5 $\pm^{0.2}_{0}$
Spotface diameter	P	0.625 MIN.	16 MIN.
Radius, 6 Pins @12°	R	0.562 NOM.	14.3 NOM.
Radius, 5 Pins @13°	R_1	0.516 NOM.	13.1 NOM.
Radius, 4 Pins @13°	R_2	0.703 NOM.	17.9 NOM.
Pin dia. single row	CC	0.157-0.155	4 ± 0.1
Single pin dia.	CC_1	0.213-0.209	5.4-5.3
Pin dia. double row	CC_2	0.126-0.124	3.20-3.15
Pin projection	DD	0.219-0.188	5.5 $\pm^{0}_{0.5}$
Distance	UU	0.866 MAX.	22 MAX.
WASHER			
Protrusion of washer Before compression	WW	0.094 MAX.	2.4 MAX.

Figure and Notes 1 through 13 reprinted with permission of Compressed Gas Assn., Inc.

Figure A-4-4.1.3.5 Compressed Gas Association Drawing No. 860: Pin-Indexed Yoke Connections for Medical Gases. Basic dimensional drawing for Connection Nos. 870 through 965.*

*Letter symbols (A, B, C, etc.) and dimensions in millimeters are as shown in ISO Recommendation R407, "Yoke Type Connections for Small Medical Gas Cylinders Used for Anaesthetic and Resuscitation Purposes," December 1964, except for distance T, which was increased to accommodate the double row of pins. The American National Standard for Connections 870 through 940 was written in inches and when adopted as ISO R407, the translation of inches to mm was handled by ISO. Little attention was paid to possible discrepancies between the inch and mm dimensions until recently. The metric dimensions are being reviewed by CGA with a view to recommending changes to make inch and mm dimensions more compatible. It is intended to confer with ISO countries to determine the most suitable manner of presenting dimensions and symbols for international use. In the meantime, it should be understood that the widest possible tolerances shown for each dimension — whether in metric or inches — is considered in compliance with this (CGA) standard.

Notes to Figure A-4-4.1.3.5

1. Each connection (except No. 965) includes two pins in the yoke and two mating holes in the valve, properly indexed for safety.
2. For precise positions of the pins and holes, see the respective connections that follow.
**3. Dimensions H and Y are applicable only if projecting-type safety relief device is used.
4. The rotary movement of the yoke on the valve must be limited to ± 6 degrees prior to pin engagment.
5. Bore D and countersink L must align within 0.020 in. (0.5 mm) T I R of sides and of each other.
6. Pins in yoke must be made of corrosion-resisting material having a minimum tensile strength of 60,000 psi (42 kg/mm^2).
7. Design must be such that dimension DD cannot be reduced below minimum by force.
8. Face of valve outlet may be grooved and face of yoke washer seating surface may be machined with concentric circles for effective washer seal.
9. A single washer shall be used on the valve outlet or yoke connection to insure a gastight seal. The washer shall be of such thickness that pin engagement of not less than 0.094 in. ($^3/_{32}$ in.) (2.4 mm) is accomplished before washer is compressed.
10. Method of tightening yoke on valve optional except that no pointed object sharper than 100° included angle shall be used as a means to apply tightening pressure at the back of the valve.
11. For non-pin-indexed yoke connections, see 2.1.4 of introduction (of CGA document).
†12. Larger chamfer permitted provided face width is $^5/_8$ in. (16 mm) minimum.
13. These dimensions apply to valves manufactured after January 1, 1977. Valves made prior to this date complying with earlier editions of this standard are acceptable for continuing use.

A-4-4.1.4.4 Where threaded joints are tinned, soft solder should be used. If sealing compound is used, it should be applied sparingly so that excess sealant is not forced inside the system.

A-4-4.2.7 If the supply system is within the confines of a single treatment facility a simple manual transfer is permissible. Only high/low pressure alarms are required. The gases are to be manifolded so a quick manual transfer is possible without life-threatening consequences.

However, if the supply system is remote, a prompt transfer of gases becomes more difficult. It may require transcending one or more flights of stairs and/or going to a remote location on the same floor. Under these situations an automatic system is required.

A-4-4.2.8 The installation of a supply serving more than one single treatment facility creates by its very nature a remote location relative to the other facility. Because more than one practice may be involved, the transfer of oxygen and nitrous oxide gases is to be automatically achieved.

A-4-4.2.11 One of the major concerns is the cross-connection of piping systems of different gases. The problem of cross-connection of oxygen and other gases such as nitrous oxide, air, and nitrogen can readily be recognized/prevented by the use of different sizes of tubing. It is recommended that piping and manifolds for oxygen service be of a different size than the piping intended for other gas services. The piping for other than oxygen may be of a smaller size. Generally, oxygen is installed in $\frac{1}{2}$-in. O.D. tube size and other gases with $\frac{3}{8}$-in. O.D. tube size.

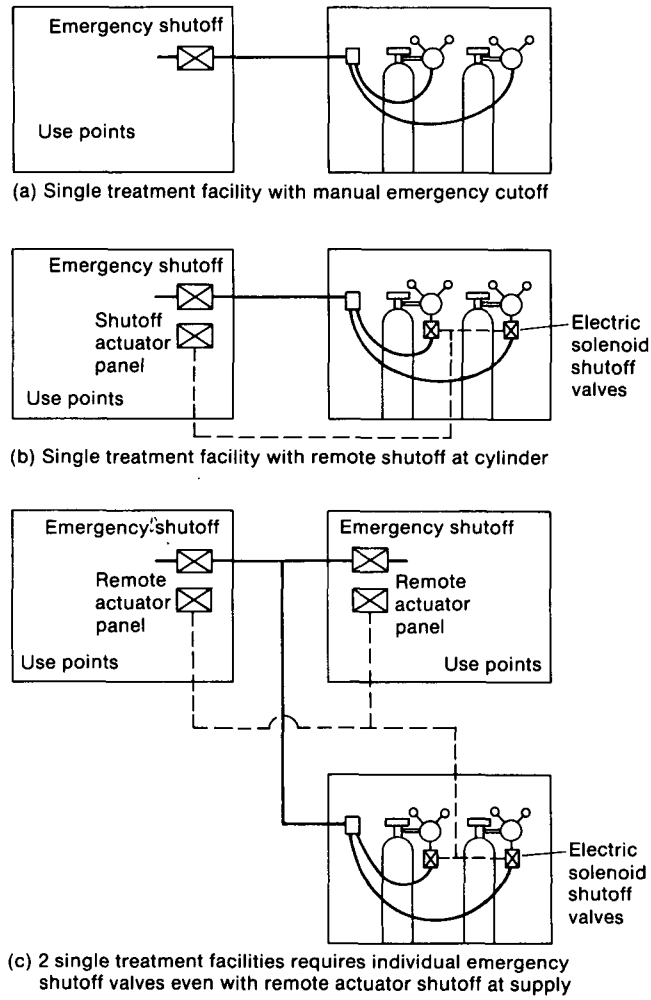
A-4-4.2.12.1 Should a fire occur at night or when the facility is not in use, fire fighters should not be confronted with a potential pressurized gas source that could feed the fire and cause extensive damage and risk of life. Good economics also dictate that when the system is not in use, the leakage of gas through hoses, couplings, etc., can be minimized if the system is shut off and portable equipment disconnected. (*See Figure A-4-4.2.12.1.*)

A-4-4.3.5 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-4-5.1.2.1 This is intended to test those stages of construction that may not be accessible at a later time.

A-4-5.1.2.3 This is the final pressure test of the completely installed system and is intended to locate any leaks that would be more likely to occur at lower pressure — e.g., leaks in station outlet valve seals.

The value of 20 percent above normal operating pressure permits testing without damage to other system components and without activation of any installed pressure relief valves.



(a) Single treatment facility with manual emergency cutoff

(b) Single treatment facility with remote shutoff at cylinder

(c) 2 single treatment facilities requires individual emergency shutoff valves even with remote actuator shutoff at supply

Figure A-4-4.2.12.1 Shutoff valves.

A-4-5.1.3.7 This leak test uses the source gas and the system pressure for which the system is designed in order to avoid contaminating the existing system.

A-4-5.2.5 Testing of all components in accordance with Appendixes C-4.1 and C-4.2 should be conducted as applicable to ensure continued proper operation of the system. Testing devices required to conduct tests in 4-5.1.3 may be available from local hospitals or medical gas suppliers. This test should be recorded in accordance with 4-6.3.1. Experience indicates that this test is often overlooked.

A-4-6.2.1.1 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 be maintained in accordance with regulations of the U.S. Department of Transportation.

A-4-6.2.1.7(a) Handling of Gas Containers. The precautions outlined in CGA 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 cylinders, labeling, withdrawing of cylinder contents, and handling of leaking cylinders. 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 cylinder 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-4-6.2.3.4 Activation of any of the warning signals should immediately be reported to the department of the facility responsible for the medical gas piping system involved. If the medical gas is supplied from a bulk supply system, the owner or the organization responsible for the operation and maintenance of that system, usually the supplier, should also be notified. Provide as much detail as possible.

A-4-6.2.4.1 It is the intent to provide a simple, safe piping system for small facilities. Although the number of use points could be a consideration, it was felt that actual gas use is a more accurate indicator of complexity. Applications involving a storage in excess of 2000 ft^3 (56.6 m^3) would have a complexity warranting installation in accordance with the provisions of Type I patient gas distribution systems.

Although the principle intent is to provide simple installations for single treatment facilities, numerous applications exist where a remote use point creates essentially a second treatment facility or where the supply system may be shared by another health care professional such as another dentist, podiatrist, oral surgeon, or general medicine practioner. The addition of another treatment facility requires incremental safety precautions.

A maximum of two single treatment facilities also approximates the limit with which a 2000 ft^3 (57 m^3) supply system can provide [5000 ft^3 (143 m^3) when liquid oxygen is used].

It is acknowledged that older user analgesia equipment has offered a nitrous oxide lockout device that requires a minimum of 3 L/min oxygen flow. However, a reasonable percentage of older equipment without this safety feature is in daily use. The storage and piping system is based upon the potential use, either initially or subsequently, of one of the older style analgesia equipment in one of the single treatment facilities.

The quantity of 2000 ft^3 (57 m^3), or 5000 ft^3 (143 m^3) if liquid oxygen storage, is to be taken as the total combined storage of gases if there is more than one supply system in the single treatment facility.

A-4-6.3.1 All testing should be completed before putting a new piping system, or an addition to an existing system, into service. Test procedures and the results of all tests should be made part of the permanent records of the facility of which the piping system forms a part. They should show the room and area designations, dates of the tests, and name(s) of persons conducting the tests.

A-4-7.1.2 Number of Station Inlets and Usage Groups. Table 4-7.1.2 sets forth the minimum number of system stations inlets and Table A-4-7.1.2 establishes usage Groups A and B. Table A-4-7.1.2 should be used in conjunction with Figure A-4-7.1.2 and Appendix C-4.4 for determining proper pipe and pump sizing. The Group A classification represents a more critical and more frequently used vacuum station inlet than the Group B classification.

Table A-4-7.1.2 Number of Vacuum Station Inlets without Waste Anesthetic Gas Disposal

	Minimum Number of Station Inlets	Usage Group
Anesthetizing Locations		
Operating Room	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 (Nonanesthetizing Locations)		
Recovery Room	3/bed	A
ICUs (Except Cardiac)	3/bed	A
Special Procedures	2/rm	A
Emergency Rooms	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
Birthing Rooms	2/rm	A
Subacute Care Areas (Nonanesthetizing Locations)		
Nurseries	1/bed	B
Patient Rooms	1/bed	B
Exam and Treatment Rooms	1/bed	B
Respiratory Care	Convenience	
Other		
Autopsy	1/table	B
Central Supply	Convenience	B
Equipment Repair, Calibration, and Teaching	Convenience	B

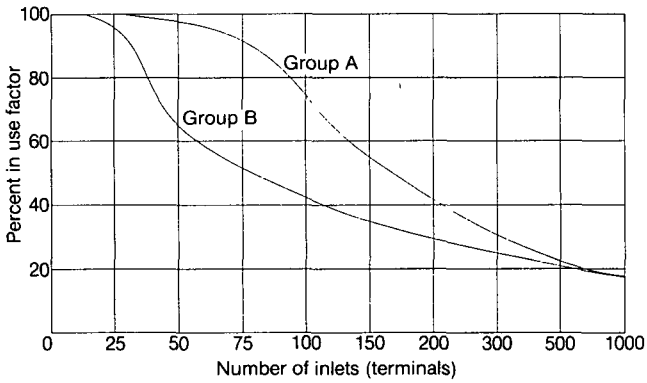


Figure A-4-7.1.2 Simultaneous use curves.

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 4-8.1.2, "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 number of station inlets.

NOTE 2: It should be understood that the percentage in use factors obtained from Figure A-4-7.1.2 represent an average hospital. Hospitals with heavier-than-average use may require higher use factors.

A-4-8.1.1 Recommended Vacuum Source Sizing.

Unweighted System Demand. Pump sizing is based upon first determining the total number of station 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. [*See Table A-4-7.1.2.*]

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 Figure A-4-7.1.2, "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-4-8.1.1(c) One method of indicating the reserved vacuum pump is in use is to activate the alarm from the vacuum switch that starts the reserve vacuum pump.

A-4-8.1.1(h) Vibration can possibly cause motor deterioration and premature piping failures. Excessive noise can interfere with trouble alarms being heard.

A-4-9.1.1.1(b) 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 station inlet served, as described in Table A-4-7.1.2, commencing with the station inlet on the branch farthest from the vacuum source(s), until all of the station inlets in a room have been accommodated. Branch lines serving more than one room should be sized as mains in accordance with the paragraph below. 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 branches.

Mains. Sizing should be on the basis of 0.25 SCFM per station inlet served, as described in Appendix C-4.3, 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 stations 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-4-11.2.1.1 Vacuum systems from station inlets to the exhaust discharge should be considered contaminated unless proven otherwise. Methods exist to disinfect the system or portions thereof.

A-5-4.1 and A-5-4.2 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 to reduce the hazard of infection, which is accomplished by dilution and removal of airborne microbial contamination and dilution of flammable gases. It also contributes to odor control and comfort of personnel.

The Subcommittee on Anesthesia Services recognizes that a hazard may be created by the chronic exposure of anesthesia and other operating room personnel to low concentrations 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. *Anesth. and Analg.* 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. *JAMA* 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, 18 October 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 November 1975. Cytogenic evaluation of spermatogonial cells in the rat following long-term inhalation exposure to nitrous oxide plus halothane. 17 November 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. and 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., 308-323, 1968.

(j) Bruce, D. L., et al. Trace anesthetic effects on perceptual, cognitive and motor skills. *Anesthesiology* 40:453-458, 1973.

(k) Bruce, D. L., and 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., and 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., and Brown, B. W. Comment on the critique. *Anesthesiology* 42:765-766, 1975.

(p) Fink, B. R., and 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 enflurance 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 N_2O in the dental operatory. HEW Publication No. (NIOSH) 77-171. Cincinnati, U.S. 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. *Anesth. and Analg.* 56:769, 1977.

Dealing with Personnel

(a) Lecky, J. H. Notice to employees on the potential health hazards associated with occupational exposure 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, U.S. 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 Z79, 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 dilutes 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 Handbook — 1982 Applications, Chapter 7, "Table on Pressure Relationships and Ventilation of Certain Hospital Areas."*)

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 ASHRAE Standard 52-76, *Method of Testing Air Cleaning Devices Used in General Ventilation for Removing Particulate Matter.* (Summarized in *ASHRAE Handbook* — 1983 Equipment, 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 5-4.2.1. Although the high level of humidity is not sufficiently reliable for complete dissipation of electrostatic charges, this humidity does reduce the hazard of electrostatic spark discharges under many conditions. The control of airborne 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-5-4.3.1 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-5-6.2 Warning signs should include, or reference, information on hazards, and on the changing, handling, and disposal of filters.

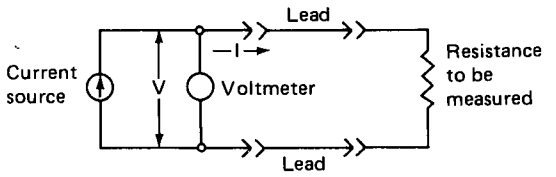
A-7-1 This chapter originated from a concern about electrical safety in the hospital. It resulted in NFPA 76B-1980, *Safe Use of Electricity in Patient Care Areas of Hospitals* (incorporated into NFPA 99 in 1984).

This chapter states the basic electrical safety performance criteria for patient care areas to be followed by personnel. Chapter 9 provides performance criteria for manufacturers of appliances. Chapter 3 provides performance criteria for the installation implementation requirements contained in Article 517, NFPA 70, *National Electrical Code.* The purpose of these chapters is the practical safeguarding of patients and staff from the hazards arising from the use of electricity in medical diagnosis and therapy.

The material in this appendix, as it relates to electrical safety (Sections A-3 and A-7), interprets some of the basic criteria by presenting different methodologies and alternative procedures to achieve the level of safety defined by the criteria.

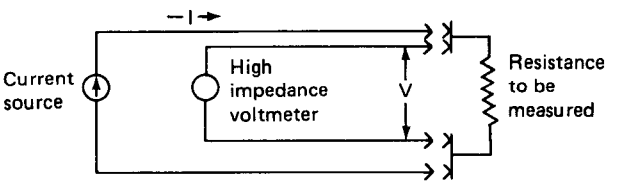
A-7-5.1.3.2 There are several methods for measuring ground-wire resistance accurately. Three examples are described below:

(a) *Two-Wire Resistance Technique.*



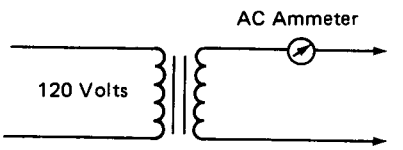
A known current is fed through the unknown resistance. A high-input-impedance voltmeter measures the voltage drop across the resistance and R is calculated as V/I. This technique measures the lead resistance in series with the unknown resistance. When the unknown resistance is a ground wire (less than 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-7-5.1.3.3 and A-9-2.1.13.3 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 7-5.1.3.3 or 9-2.1.13.3.

This "weighting" can be achieved by a frequency-response-shaping network that precedes a flat-response meter, or by a meter whose own frequency response characteristic matches 7-5.1.3.3 or 9-2.1.13.3.

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 that precedes an otherwise flat-response meter, then the input impedance of the network should be 1000 ohms ± 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.

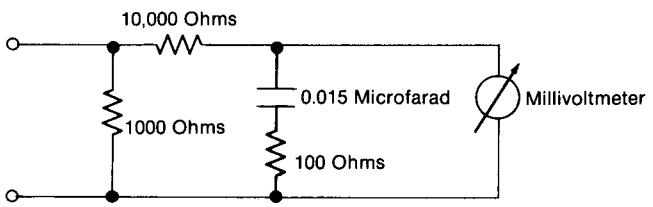


Figure A-7-5.1.3.3/A-9-2.1.13.3 Leakage current measurements (1.0 millivolt meter reading corresponds to input current of 1.0 microampere).

A-7-5.2.2.2 As a guideline, 500 microamperes is recommended as the maximum allowable leakage current limit for laboratory equipment.

A-7-6.2.1.8 Consideration should be given to requiring the vendor to sell parts to the individual or group designated by the hospital to service the equipment following the warranty period.

A-7-6.2.5.1 One reason for requiring testing of all electrical equipment used in the laboratory is to provide minimum assurance against electrical macroshock hazards.

A-7-6.2.5.2 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 that have many personnel and electrical devices and that 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-7-6.3.1.2 Documentation. *(See A-3-6.2.3.1.)*

A-8-1.2 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]

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.[2]

There is a continual need for human diligence in the establishment and maintenance of safe practices for respiratory therapy.

It is essential for personnel having responsibility for respiratory therapy to establish and enforce appropriate programs to fulfill provisions of this chapter.

It is the responsibility of the administrative and professional staff of a hospital, or safety director if one is appointed, to adopt and enforce appropriate regulations for a hospital. In other health care facilities, responsibility may be assigned to a safety director or other responsible person, who is, in turn, responsible to the administration.

In institutions having a respiratory therapy service, it is recommended that this service be directly responsible for the administration of this chapter.

Hazards can be mitigated only when there is continual recognition and understanding.

A-8-5.1.2.1(b) 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.

1. Courtesy of the American Association for Respiratory Therapy, 1720 Regal Row, Dallas, TX 75235.
2. Ibid.

A-8-5.1.2.1(d) 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-8-6.4.2 Signs. Precautionary signs should be at least 8 in. × 11 in. (21 cm × 28 cm) in size.

A-9-2.1.9.1(a) Signal Transmission. This may be accomplished by using a signal transmission system that is isolated from ground or presents a high impedance to ground; that employs a common signal grounding wire between appliances served from the same reference grounding point; that 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 care vicinity due to grounding currents to a safe level.

A-9-2.1.9.2(b)(4) 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 9-2.1.13.5(c), "Isolation Test."

A-9-2.1.13.3 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, e.g., 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. (*See also A-7-5.1.3.3.*)

A-9-2.1.13.4(c) Chassis Leakage Current Limits. The chassis leakage current limits given in 9-2.1.13.4(c) 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 7-5.2.2.1, 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. A., and Scott, J. R., 60 Hz ventricular fibrillation and pump failure thresholds versus electrode area. *IEEE Trans. Biomed. Eng.* BME 23:45-48, 1976.

Watson, A. B., Wright, J. S., and Loughman, J., Electrical thresholds for ventricular fibrillation in man. *Med. J. Australia* 1:1179-1181, 1973.

Weinberg, D. I., et al., Electric shock hazards in cardiac catheterization. *Elec. Eng.* 82:30-35, 1963.

For equipment in the patient care 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 whether 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 9-2.1.12, "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.

A-10-1 Table on Using NFPA Documents for Laboratories in Health Care Facilities. The following are some considerations in determining which document (NFPA 99 or 45) should be consulted first when designing or operating a laboratory in a health care facility (i.e., those laboratories under the jurisdiction of a health care facility as defined in Chapter 2 of NFPA 99). In addition, the following paragraphs should be reviewed in conjunction with this Table: NFPA 45-1991 (1-1.1); NFPA 99-1993 (1-1 and 10-1); and NFPA 101-1991 (12-1.2.1 and 12-1.2.2).

Table A-10-1

Location of Laboratory	Primary Reference Document
1. Laboratory in a bldg. with inpatient	99
2. Laboratory in a bldg. with outpatients incapable of self-preservation	99
3. Laboratory in a bldg. with outpatients capable of self-preservation	45

A-10-1.1 Before a hazardous chemical is ordered, controls should be established to ensure 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 325M, *Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*;

NFPA 491M, *Manual of Hazardous Chemical Reactions*;

Flash Point Index of Trade Name Liquids (NFPA Publ. No. SPP-51) - Out of print.

Class IA and IB flammable liquids in glass containers larger than the 1-quart (0.91-L) size should be transported in suitable containers of sufficient size to hold the contents of the glass containers.

A-10-1.2.1 While NFPA 45 provides basic requirements and guidance for laboratory design, fire separation and sprinkler requirements are more stringent for laboratories in health care facilities. In addition, NFPA 99 has more stringent and realistic limitations of quantities of flammable liquids in laboratories, requires hood discharge above the roof, allows valves on emergency water supplies, encourages laboratory safety program activities, and recommends placement of flammable gas cylinders outside of the laboratory.

A-10-2.1.3.3 Laboratory personnel should be thoroughly indoctrinated in procedures to follow in cases of clothing fires. The single most important instruction, one that 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 or her 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-10-3.1 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 the NFPA *Fire Protection Handbook*. For information on the fire resistance, installation, and maintenance of fire doors, see NFPA 80, *Standard for Fire Doors and Fire Windows*.

A-10-3.1.1 NFPA 45 provides basic requirements and guidance for laboratory design, but fire separation and sprinkler requirements are more stringent for laboratories in health care facilities. In addition, NFPA 99 requires hood discharge above the roof, allows valves on emergency water supplies, and has other specific requirements based on the unique nature of facilities for care of patients who may be incapable of self-preservation.

A-10-3.2.1 A door to an adjoining laboratory work area is considered to be a second access to an exit.

A-10-3.4 Subsection 5-4.3 gives ventilation requirements that are specific for laboratories in health care facilities and are in addition to the basic laboratory ventilation requirements contained in Chapter 6 of NFPA 45.

A-10-4.2.2 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-10-5 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, 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-10-5.1 The hazard level of a laboratory is considered severe if quantities of flammable, combustible, or hazardous materials are present that are capable of sustaining a fire condition of sufficient magnitude to breach a 1-hour fire separation.

To determine the combustible content or heat potential of flammable or combustible materials capable of breaching or penetrating a 1-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 1: 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.

NOTE 2: In 17th edition of the NFPA *Fire Protection Handbook*, see Section 6, Chapter 6, Table 6-6A; and Appendix A, respectively.

The above, it should be noted, is only one of several methods for calculating the hazard level of a laboratory with regard to combustibles breaching a 1-hour fire separation.

The following chart can be used as a guide in making the above determination:

	Hazard	
Wall Rating	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-10-6 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 in areas of hospitals and other health care facilities are likely to dry out if the floors are not wet-mopped regularly, and dry traps can permit passage of gases, vapors, odors, and vermin. Since a floor drain will be of great value if a safety shower is used and several hundred gallons of water are released, it is recommended that floor drains be filled with water regularly, or in new construction that some plumbing be provided to fill the traps manually, automatically, or incidentally by plumbing design.

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-10-7.2 Flammable Liquids. 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-10-7.2.1† Table A-10-7.2.1 is a portion of Table 4-2.3 in NFPA 30, *Flammable and Combustible Liquids Code*. NFPA 45 provides more specific guidance for use of flammable and combustible liquids in laboratories, in addition to basic requirements set forth in NFPA 30.

A-10-7.2.2 The goal is to keep the fuel load to a limit that is as low as is practicable. In no case should excessive amounts be stored. Constant effort must be exerted to prevent the overstocking of hazardous chemicals. The laboratory manager 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

Table A-10-7.2.1 Maximum Allowable Size of Containers and Portable Tanks

	Flammable Liquids			Combustible Liquids	
Container Type	Class 1A	Class 1B	Class 1C	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 = 0.49 L; 1 qt = 0.95 L; 1 gal = 3.8 L.

room, by selecting brands that 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-10-7.2.5 Walk-in Thermal-Controlled Boxes. Procedures likely to result in toxic or flammable atmospheres should be discouraged within "walk-in" refrigerators or other types of 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 that can be released by a person inside the box when the door is locked from the outside; latch and door frames designed to allow actuation under all conditions of freezing; a floor with a nonconductive surface; neoprene matting to insulate up to 10,000 V; a view-window in the door; an independently circuited high-temperature thermostat and alarm (for warm boxes); vaporproof duplex electrical receptacles; an alarm that can be heard throughout the occupied work area and an alarm button at the inside door frame that 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 refrigerated 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 that 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-10-7.5 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; and radioactive, pathogenic, corrosive, or potentially harmful wastes, such as television 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 that are miscible with water in all proportions may be flushed down a drain within a laboratory room in quantities not exceeding 1 pint (0.45 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-10-8 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-10-8.1.4 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 or her own facility.

A-10-8.1.6 Information sources for safe handling, storage, and emergency response to spills or fires in hazardous materials include NFPA 49, *Hazardous Chemicals Data*.

A-10-8.2.1 The identification system of NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*, is encouraged to be used on doors of approved flammable liquid storage cabinetry and on doors of refrigerators.

A-12-4.1.1.4 In determining whether existing construction or equipment does or does not constitute a hazard to life, due consideration should be given to 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-12-4.1.1.5(f) Hazards During Transport of Anesthetized Patients. Transporation 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-12-4.1.3.2 Isolated Power Systems. The ungrounded electrical distribution system specified in 12-4.1.3.2 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 in 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. (*See 12-4.1.3.3 and 12-4.1.3.4.*)

A-12-4.1.3.8(b) 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 12-4.1.3.8(b)(3) and (4).

A-12-4.1.3.8(i) In its requirement for furniture in a flammable anesthetizing location to be constructed of conductive materials, the Subcommittee on Anesthesia Services 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-12-4.1.3.10(a) 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-12-4.1.4.4 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 that increase in resistivity (decrease in conductivity) as they age.

A-12-4.1.5 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-12.3.

A-12-4.2 NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, establishes basic requirements for all laboratories using chemicals, but important additional requirements are contained in Chapter 10 and in Chapters 4, 5, and 7.

A-13-4.2 NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals,* establishes basic requirements for all laboratories using chemicals, but important additional requirements are contained in Chapter 10 and in Chapters 4, 5, and 7.

A-14-4.1 NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals,* establishes basic requirements for all laboratories using chemicals, but important additional requirements are contained in Chapter 10 and in Chapters 4, 5, and 7.

Appendix B Referenced and Informatory Publications

B-1 The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1990 edition

NFPA 30, *Flammable and Combustible Liquids Code*, 1990 edition

NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, 1991 edition

NFPA 49, *Hazardous Chemicals Data*, 1991 edition

NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites*, 1990 edition

NFPA 53M, *Manual on Fire Hazards in Oxygen-Enriched Atmospheres*, 1990 edition

NFPA 54, *National Fuel Gas Code*, 1992 edition

NFPA 70, *National Electrical Code*, 1993 edition

NFPA 75, *Standard for the Protection of Electronic Computer/Data Processing Equipment*, 1992 edition

NFPA 80, *Standard for Fire Doors and Fire Windows*, 1992 edition

NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, 1993 edition

NFPA 90B, *Standard for the Installation of Warm Air Heating and Air Conditioning Systems*, 1993 edition

NFPA 99B, *Standard for Hypobaric Facilities*, 1993 edition

NFPA 220, *Standard on Types of Building Construction*, 1992 edition

NFPA 325M, *Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*, 1991 edition

NFPA 491M, *Manual of Hazardous Chemical Reactions*, 1991 edition

NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*, 1990 edition

NFPA 780, *Lightning Protection Code*, 1992 edition

NFPA 801, *Recommended Fire Protection Practice for Facilities Handling Radioactive Materials*, 1991 edition

Flash Point Index of Trade Name Liquids

NFPA *Fire Protection Handbook*, 17th edition, 1991

NFPA FR 61-1, "Occupancy Fire Record — Hospitals"

B-1.2 Other Publications. The following publications are available from the addresses listed.

B-1.2.1 ASHRAE Publications. American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc., 1791 Tullie Circle, NE, Atlanta, GA 30329.

ASHRAE Guide and Data Book (Annual)

ASHRAE Handbook on Equipment, 1988 (Chap 10, Steam Systems, 1992)

ASHRAE Handbook on HVAC Applications, 1991 (Chap 7, Health Care Facilities, 1991)

B-1.2.2 ASME Publication. American Society of Mechanical Engineers, United Engineering Center, 345 E. 47th Street, New York, NY 10017.

ASME *Boiler and Pressure Vessel Code*, Section IX, Welding and Brazing Qualifications

B-1.2.3 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D56-1987, *Test Method for Flash Point by Tag Closed Tester* (ANSI)

ASTM D93-1990, *Test Methods for Flash Point by Pensky-Martens Closed Tester* (ANSI)

B-1.2.4 CGA Publications. Compressed Gas Association, Inc., 1725 Jefferson Davis Highway, Arlington, VA 22202.

CGA Pamphlet G-8.1-1990, *Standard for the Installation of Nitrous Oxide Systems at Consumer Sites*

CGA Pamphlet P-1-1991, *Safe Handling of Compressed Gases*

CGA Pamphlet P-2-1989, *Characteristics of Safe Handling of Medical Gases*

CGA Pamphlet V-1-1987, *Compressed Gas Cylinder Valve Outlet and Inlet Connections* (ANSI B57.1)

B-1.2.5 JCAH Publication. Joint Commission on the Accreditation of Hospitals, 875 N. Michigan Avenue, Chicago, IL 60611.

Accreditation Manual for Hospitals

B-1.2.6 NCCLS Publication. 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-1.2.7 Ocean Systems Publication. Ocean Systems, Inc. Research and Development Laboratory, Tarrytown, NY 10591. Work carried out under U.S. Office of Naval Research, Washington, DC, Contract No. N00014-67-A-0214-0013.

Technical Memorandum UCR1-721, *Chamber Fire Safety*

B-1.2.8 U.S. Government Publications. U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20025.

Code of Federal Regulations, Title 49

NRC Publication 1132, *Diesel Engines for Use with Generators to Supply Emergency and Short Term Electric Power* (Also available as Order No. O.P.52870 from University Microfilms, P.O. Box 1366, Ann Arbor, MI 48106.)

B-1.2.9 U.S. Pharmacopia Publication. U.S. Pharmacopia, 12601 Twinbrook Parkway, Rockville, MD 20852.

USP *Standard for Compressed Air*, Document No. XXII/NFXVII

B-2 Published Articles on Fire Involving Respiratory Therapy Equipment, and Related Incidents.

Benson, D. M., and Wecht, C. H. Conflagraton in an ambulance oxygen system. *Journal of Trauma*, vol. 15, no. 6:536-649, 1975

Dillon, J. J. Cry fire! *Respiratory Care*, vol. 21, no. 11: 1139-1140, 1976

Gjerde, G. E., and Kraemer, R. An oxygen therapy fire. *Respiratory Care*, vol. 25, no. 3:362-363, 1980

Walter, C. W. Fire in an oxygen-powered respirator. *JAMA* 197:44-46, 1960

Webre, D. E., Leon, R., and Larson, N.W. Case History; Fire in a nebulizer. *Anes. and Analg.* 52:843-848, 1973

B-3 Addresses of Some Other Organizations Publishing Standards or Guidelines.

American Industial 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 Boulevard, Skokie, IL 60077

Scientific Apparatus Makers Assoc., 1101 16th Street, NW, Washington, DC 20036

Appendix C Additional Explanatory Notes to Chapters 1-19

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

NOTE: Sections of Appendix C identified by a dagger (†) include text extracted from NFPA 30, *Flammable and Combustible Liquids Code*, and NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*. Requests for interpretations or revisions of the extracted text will be referred to the Technical Committee on General Storage of Flammable Liquids and the Technical Committee on Fire Hazards of Materials, respectively.

C-3 Additional Information on Chapter 3.

Appendix C-3 consists of the following:

C-3.1 Typical Hospital Wiring Arrangement;

C-3.2 Maintenance Guide for an Essential Electrical System;

C-3.3 Suggested Format for Listing Functions to be served by the Essential Electrical System in a Hospital.

C-3.1 Typical Hospital Wiring Arrangement.

C-3.2 Maintenance Guide for an Essential Electrical System.

This generalized maintenance guide is provided to assist administrative, supervisory, and operating personnel in establishing and evaluating maintenance programs for emergency electric generating systems.

Monthly:

(1) Testing of generator sets and transfer switches under load and operating temperature conditions at least every 30 days. A 30-minute exercise period is an absolute minimum, or the engine manufacturer's recommendations should be followed.

(2) Permanently record all available instrument readings during the monthly test.

(3) During the monthly test, check the following system or systems applicable to your installation:

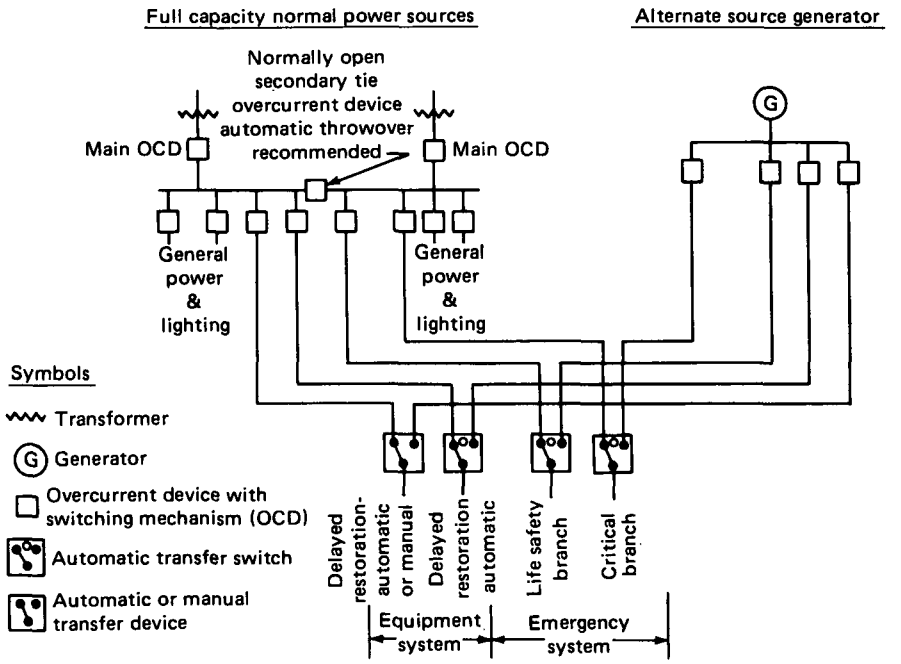
Natural Gas or Liquid Petroleum Gas System:
- Operation of solenoids and regulators
- Condition of all hoses and pipes
- Fuel quantity

Gasoline Fuel System:
- Main tank fuel level
- Operation of system

Diesel Fuel System:
- Main tank fuel level
- Day tank fuel level
- Operation of fuel supply pump and controls

Turbine Prime Movers:
- Follow manufacturer's recommended maintenance procedure

Engine Cooling System:
- Coolant level
- Rust inhibitor in coolant



Separate transfer switches for each branch, as shown, are required only if dictated by load considerations. Smaller facilities may be served by a single transfer switch.

Figure C-3.1 Typical hospital wiring arrangement.

Antifreeze in coolant (if applicable)
Adequate cooling water to heat exchangers
Adequate fresh air to engine and radiators
Condition of fan and alternator belts
Squeeze and check condition of hoses and connections
Functioning of coolant heater (if installed)

Engine Lubricating System:
Lubricating oil level
Crankcase breather not restricted
Appearance of lubricating oil
Correct lubricating oil available to replenish or change
Operation of lubricating oil heater (if installed)
Oil pressure correct

Engine Electrical Starting System:
Battery terminals clean and tight
Add distilled water to maintain proper electrolyte level
Battery charging rate
Battery trickle charging circuit operating properly
Spare batteries charged if provided

Engine Compressed Air Starting System:
Air compressor operating properly
Air compressor lubricating oil level
Spare compressed air tanks full
Main compressed air tanks full
Drain water from compressed air tanks

Engine Exhaust System:
Condensate trap drained
No exhaust leaks
Exhaust not restricted
All connections tight

Transfer Switch:
Inside clean and free of foreign matter
No unusual sounds
Terminals and connectors normal color
Condition of all wiring insulation
All covers tight
Doors securely closed

General:
Any unusual condition of vibration, deterioration, leakage, or high surface temperatures or noise
Maintenance manuals, service log, basic service tools, jumpers, and supplies readily available
Check and record the time intervals of the various increments of the automatic start-up and shutdown sequences
Overall cleanliness of room
No unnecessary items in room

(4) After the monthly test:
Take prompt action to correct all improper conditions indicated during test
Check that the standby system is set for automatic start and load transfer

Quarterly:

(1) On generator sets:

Engine Electrical Starting System:
Check battery electrolyte specific gravity
Check battery cap vents

Engine Lubricating System:
Check lubricating oil (or have analyzed if part of an engineered lube oil program)

(2) Fuel System:
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 Liquefied 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:
Reevaluate the settings of the voltage sensing and time delay relays

(2) Main Switchgear and Generator Switchgear:

Determine whether 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-3.3 Suggested Format for Listing Functions to Be Served by the Essential Electrical System in a Hospital.

ESSENTIAL ELECTRICAL SYSTEMS

Hospital _____ Date _____

Room No.	Room Name	Function Served*	EMERGENCY SYSTEM		EQUIPMENT SYSTEM		NON-ESSENTIAL
			Life Safety Branch	Critical Branch	Delayed Auto.**	Delayed Manual	

* Indicate precise lighting, receptacles and/or equipment. Use a separate line for each function.
** Indicate time interval.

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 ensure 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 reenergized 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 attention. It may be that the hospital engineer or the reviewing authority will wish to keep on file a final copy of the list, which would be the basis for the electrical engineer's detailed engineering design.

Although this suggested format is intended for use by a hospital it may, with suitable changes, be useful for other health care facilities.

C-4 Additional Information on Chapter 4.

Appendix C-4 consists of the following:

C-4.1 Initial Testing of Nonflammable Medical Piped Gas Systems;

C-4.2 Retesting and Maintenance of Nonflammable Medical Piped Gas Systems;

C-4.3 Examples, Medical-Surgical Vacuum System Sizing;

C-4.4 Vacuum Flow Chart and Formulas;

C-4.5 Metric Conversion Factors;

C-4.6 Comments on Derivation of Design Parameters for Medical-Surgical Vacuum Systems.

C-4.1 Initial Testing of Nonflammable Medical Piped Gas Systems.

NOTE: Numbers in brackets refer to paragraphs in Chapter 4 of text.

C-4.1.1 [4-3.1.8.5] The pressure relief valve, set at 50 percent above normal line pressure, should be tested to assure proper function prior to use of the system for patient care.

C-4.1.2 [4-3.1.9.6] The proper functioning of the safety valve, automatic drain, pressure gauge, and high-water-level sensor should be verified before the system is put into service.

C-4.1.3 [4-4.1.1.2(b)] Changeover Warning Signal — Manifold or Alternating Bulk Supply — 4-3.1.5.1, 4-3.1.6.1(b), and 4-3.1.7.1(b).

(1) Start a flow of gas from an outlet of the piping system.

(2) Close the shutoff valve or cylinder valves on the number 1 bank (Figure 4-3.1.5), the primary supply of the manifold (Figure 4-3.1.6), or the primary unit of the alternating bulk supply to simulate its depletion. Changeover should be made to the Number 2 bank, secondary supply, or the alternate bulk unit.

(3) Check main-line pressure gauge to ensure maintenance of the desired pressure.

(4) Check signal panels for activation of the proper changeover signal.

(5) Silence the audible signal; visual signal should remain.

(6) Open the valves closed in Step 2. Close the valve on the Number 2 bank, secondary supply, or alternate bulk unit. When changeover back to original primary supply has occured, reopen the valve. This will reinstate system to its original status.

(7) Check signal panels for deactivation of warning signals.

(8) Stop flow of gas from the piping system.

C-4.1.4 [4-4.1.1.2(c)] Reserve-In-Use Warning Signal — 4-3.1.6.1(c), 4-3.1.6.3, and 4-3.1.7.1.

(1) Start a flow of gas from the piping system.

(2) Close the proper shutoff valves to simulate depletion of the operating supply. Reserve should begin to supply the piping system.

(3) Check the main-line pressure gauge. Pressure should remain at the desired level.

(4) Check the master signal panels to determine that the reserve-in-use signals have been activated.

(5) Silence the audible signal. Visual signal should remain.

(6) Open the shutoff valves closed in Step 2.

(7) Check master signal panels for deactivation of the warning signals.

(8) Stop the flow of gas from the piping system.

C-4.1.5 [4-4.1.1.2(d) and (f)] Reserve Supply Low (Down to an average one-day supply) — 4-3.1.6.2 and 4-3.1.7.2(b) and (c).

High-Pressure Cylinder Reserve.

(1) Start a flow of gas from the piping system.

(2) Close all operating supply shutoff valves. (To use pressure from the reserve.)

(3) Close the reserve supply shutoff valve or, if necessary, the reserve cylinder valves, depending on the exact location of the actuating switch (to reduce pressure on the actuating switch, simulating loss of reserve).

(4) Open the operating supply valves closed in Step 2 (so that only the "reserve low" signal should be activated).

(5) Check the master signal panels for activation of the proper signal.

(6) Silence the audible signal. Visual signal should remain.

(7) Open reserve supply valve or cylinder valves closed in Step 3.

(8) Check master signal panels for deactivation of the warning signals.

(9) Stop flow of gas from the piping system.

Liquid Bulk Unit Reserve.

This type of reserve requires an actuating switch on the contents gauge and another actuating switch for the gas pressure being maintained in the reserve unit. Reduced contents or gas pressure in the reserve unit would indicate less than a day's supply in reserve.

Simulation of these conditions requires the assistance of the owner or the organization responsible for the operation and maintenance of the supply system as it will vary for different styles of storage units.

C-4.1.6 [4-4.1.1.2(f)] High or Low Pressure in Piping System.

Initial test of the area alarms covered in 4-5.1.3.4(d) can be done at the same time.

(1) Increase the pressure in the piping system to the high-pressure signal point (20 percent above normal pressure).

(2) Check all master signal panels (and area signals) to ensure that the properly labeled warning signal is activated; also check main-line pressure gauge and area gauges to ensure their function.

(3) Silence the audible signal. Visual signal should remain.

(4) Reduce piping system pressure to the normal. A flow from the system is required to lower the pressure and permit readjustment of the line regulator.

(5) Check all signal panels for deactivation of the signals.

(6) Close main-line shutoff valve.

(7) Continue the flow from the system until pressure is reduced to the low-pressure signal point (20 percent below normal).

(8) Check all signal panels for activation of the properly labeled warning signal; also check main-line gauge and area pressure gauges to ensure their function.

(9) Silence the audible signal. Visual signal should remain.

(10) Open main-line shutoff valve.

(11) Check main-line gauge for proper line pressure.

(12) Check all signal panels for deactivation of warning signals.

C-4.1.7 [4-4.1.1.3(a)] This signal should be initially tested at the time the tests of C-4.1.4 are performed.

C-4.2 Retesting and Maintenance of Nonflammable Medical Piped Gas Systems (formerly Appendix C in NFPA 56F-1983).

NOTE: Numbers in brackets refer to paragraphs in Chapter 4 of text.

C-4.2.1 [4-3.1.5] These systems should be checked daily to assure that proper pressure is maintained and that the changeover signal has not malfunctioned. Periodic retesting of the routine changeover signal is not necessary as it will normally be activated on a regular basis.

C-4.2.2 [4-3.1.6] These systems should be checked daily to assure that proper pressure is maintained and that the changeover signal has not malfunctioned. Periodic retesting of the routine changeover signal is not required. Annual retesting of the operation of the reserve and activation of the reserve-in-use signal should be performed.

C-4.2.3 [4-3.1.6.2] If the system has an actuating switch and signal to monitor the contents of the reserve, it should be retested annually.

C-4.2.4 [4-3.1.7] Maintenance and periodic testing of the bulk system is the responsibility of the owner or the organization responsible for the operation and maintenance of that system. The staff of the facility should check the supply system daily to ensure that medical gas is ordered when the contents gauge drops to the reorder level designated by the supplier. Piping system pressure gauges and other gauges designated by the supplier should be checked regularly, and gradual variation, either increases or decreases, from the normal range should be reported to the supplier. These variations may indicate the need for corrective action.

Periodic testing of the master signal panel system, other than the routine changeover signal, should be performed. Request assistance from the supplier or detailed instruction if readjustment of bulk supply controls is necessary to complete these tests.

C-4.2.5 [4-3.1.8.3] The main-line pressure gauge should be checked daily to ensure the continued presence of the desired pressure. Variation, either increases or decreases, should be investigated and corrected.

C-4.2.6 [4-3.1.9.2] Quarterly rechecking of the location of the air intake should be made to ensure that it continues to be a satisfactory source for medical compressed air.

C-4.2.7 [4-3.1.9.6] Proper functioning of the pressure gauge and high-water-level sensor should be checked at least annually. Check the receiver drain daily to determine if an excessive quantity of condensed water has accumulated in the receiver.

C-4.2.8 [4-3.1.9.7] An important item required for operation of any medical compressed air supply system is a comprehensive preventive maintenance program. Worn parts on reciprocating compressors can cause high discharge temperatures resulting in an increase of contaminants in the discharge gas. Adsorber beds, if not changed at specified time intervals, can become saturated and lose their effectiveness. It is important that all components of the system be maintained in accordance with the manufacturer's recommendations. It is important that any instrumentation, including analytical equipment, be calibrated routinely and maintained in operating order. Proper functioning of the dew point sensor should be checked at least annually.

C-4.2.9 [4-4.1.1.1(b)] When test buttons are provided with signal panels, activation of the audible and visual signals should be performed on a regular basis (monthly).

C-4.2.10 [4-4.1.1.2(b)] Changeover Warning Signal — Manifold or Alternating Supply — 4-3.1.5.1, 4-3.1.6.1(b), and 4-3.1.7.1(b).

As this is a routine signal that is activated and deactivated at frequent intervals, there is no need for retesting UNLESS it fails. If the reserve-in-use signal is activated because both units of the operating supply are depleted without the prior activation of the changeover signal, it should be repaired and retested.

C-4.2.11 [4-4.1.1.2(c)] Reserve-In-Use Warning Signal — 4-3.1.6.1(c), 4-3.1.6.3, and 4-3.1.7.1.

All components of this warning signal system should be retested annually in accordance with steps 2 through 7 of the procedure given in Appendix C-4.1.4. Audible and visual signals should be tested periodically during the year (monthly).

C-4.2.12 [4-4.1.1.2(d)] Reserve Supply Low (Down to an average one-day supply) — 4-3.1.6.2 and 4-3.1.7.2(b) and (c).

High-Pressure Cylinder or Liquid Reserve.

All components of these signal warning systems should be retested annually in accordance with Steps 2 through 8 of the procedure given in Appendix C-4.1.5. If test buttons are provided, audible and visual signals should be periodically tested throughout the year (monthly).

C-4.2.13 [4-4.1.1.2(g)] The medical compressed air system alarms in 4-5.1.4.2(a) should be checked at least annually.

C-4.2.14 [4-4.1.1.4(a)] This pressure gauge should be checked on a daily basis to ensure proper piping system pressure. A change, increase or decrease, if noted, may give evidence that maintenance may be required on the line pressure regulator and could thus avoid a problem.

C-4.2.15 [4-4.1.1.4(b)] This pressure gauge should be checked on a daily basis to ensure proper system pressure. A gradual change, increase or decrease, if noted, will give an indication of a developing problem that could be avoided by preventive maintenance.

C-4.2.16 [4-5.1.3.4] Annual retesting of all components of warning systems, if it can be done without changing piping system line pressure, should be performed.

C-4.2.17 [4-5.1.3.4(b)] If test buttons are provided, the retesting of audible and visual alarm indicators should be performed monthly.

C-4.2.18 [4-4.1.2.2] Shutoff valves should be periodically checked for external leakage by means of a test solution or other equally effective means of leak detection safe for use with oxygen.

C-4.2.19 [4-4.1.2.4] Station outlets should be periodically checked for leakage and flow. Instructions of the manufacturer should be followed in making this examination.

C-4.3 Examples, Medical-Surgical Vacuum System Sizing.

C-4.3.1 Example 1. Vacuum Source Sizing Example. Calculate the required vacuum pump capacity to meet the demands of a hypothetical hospital with rooms and station inlets quantities described below:

Pump Sizing for 3 in. Hg

Piping Pressure Drop:

Minimum allowable system vacuum	12 in. Hg Vac.
Design pressure drop (Appendix C-4.2)	3 in. Hg Vac.
Minimum operating vacuum at receiver	15 in. Hg Vac.

Table C-4.3.1(a) Hospital Parameters

Room Designation	Number of Rooms or Beds	Number of Station Inlets	Type/Usage Group *[See Table A-4-7.1.2]*
Operating Rooms	6	18	A
Cystoscopy Rooms	2	6	A
Delivery Rooms	4	12	A
Recovery Rooms	13	39	A
ICUs	24	72	A
Emergency Rooms	10	10	A
Emergency Rooms— Major Trauma	2	6	A
Patient Rooms	385	385	B
Nurseries	30	30	B
Treatment and Examination Rooms	20	20	B
Autopsy	1	1	B
Respiratory Care	1	1	B
Dialysis Unit	4	2	B

Table C-4.3.1(b) Calculations

Type of Room	No. of Station Inlets	SCFM	Use Factor*	Adjusted SCFM
Type A	163	163 × 0.25 = 41	0.52	21
Type B	439	439 × 0.25 = 110	0.22	24
Operating Rooms	6	6 × 1.5 = 9	1.0	9
				54**

*Per Table A-4-7.1.2.
**Does not include waste anesthetic gas evacuation.

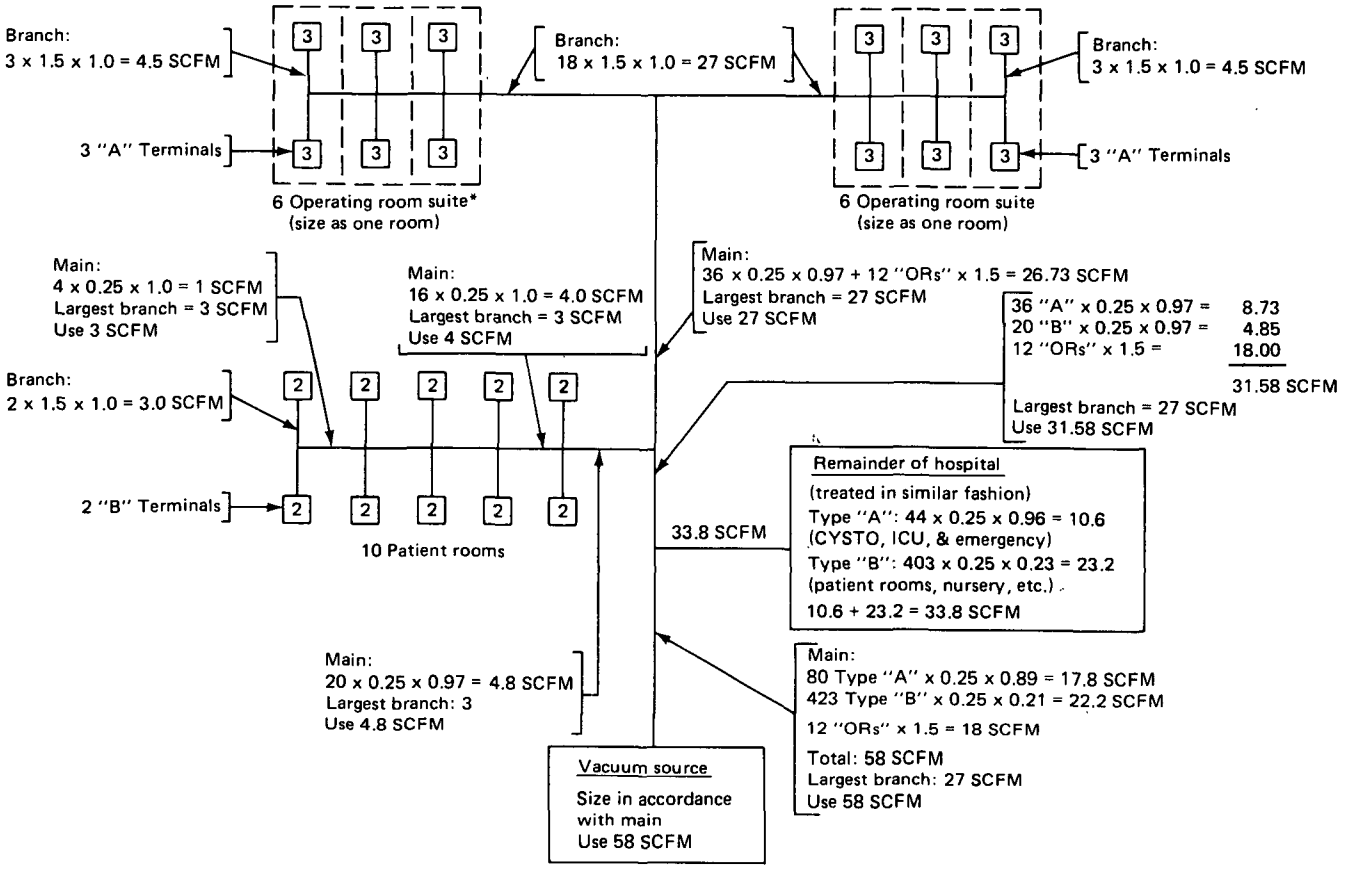
To maintain the minimum operating vacuum at the receiver, typical control settings for a duplex vacuum pump installation might be as follows (assuming pumps are located at the receiver):

	Start	Stop
Lead Switch	16 in. Hg Vac.	19 in. Hg Vac.
Lag Swtich	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.

C-4.3.2 Example 2. Pipe Sizing Example (Not Related to Examples 1 and 3). See Figure C-4.3(a).

C-4.3.3 Example 3. Pipe Sizing Example (Not Related to Examples 1 and 2). See Figure C-4.3(b).



*In the event of a branch line serving more than six (6) operating rooms, or the like, only the first six should be considered as one room. The branch sizing for the remaining rooms should use the same procedure as for other branch lines. See Figure C-4.3(b).

Figure C-4.3(a) Typical branch and main sizing.

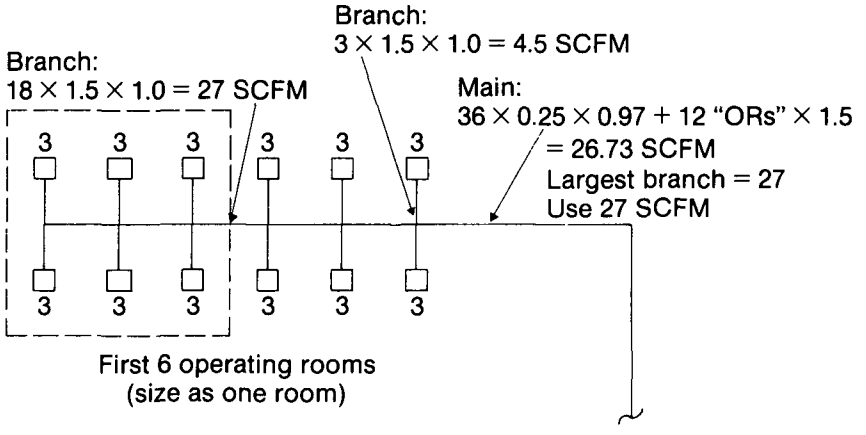
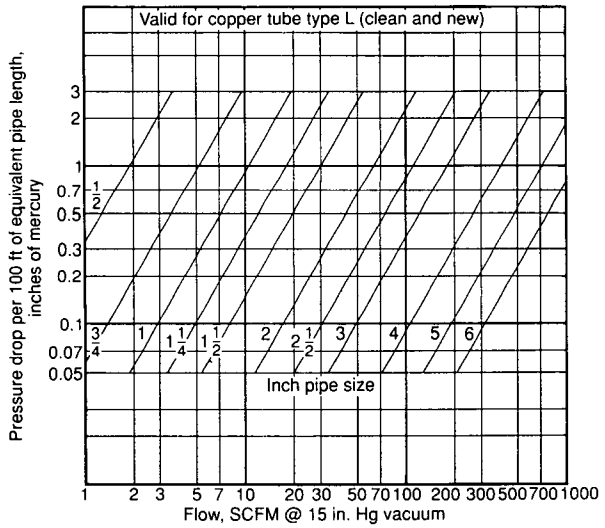


Figure C-4.3(b) Sizing branch lines serving large operating suites.

C-4.4 Vacuum Flow Chart and Formulas.



NOTE: Pressure drops at other vacuum levels may be closely approximated by dividing the pressure drop found from the chart (for a given SCFM and pipe size) by the ratio:

$$\frac{30 - \text{new vacuum level}}{15}$$

Formulas for Calculating Pressure Drop for Other Types and Sizes of Pipe

(Eq. 1) Darcy's Formula:

$$P = 0.01414\, f \left(\frac{L}{D}\right) \times \frac{\rho V^2}{2g}$$

where:

P = pressure drop in. Hg abx.
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/ft^3
V = velocity of air at upstream pressure, ft/sec
g = gravitation constant, 32.2 ft/sec^2.

For clean, new copper tube K, L, or M, the friction factor may be closely approximated by the following relation:

(Eq. 2) $$f = \frac{0.184}{(Re_N)^{0.2}}$$

where:

Re_N = Reynold's Number, $\frac{\rho VD}{\mu}$

μ = absolute (dynamic) viscosity, $\frac{lb}{sec\ ft}$.

Friction factors of commercial steel pipe are higher.

C-4.5 Metric Conversion Factors.

1 in. = 2.540 cm
1 ft = 30.48 cm
1 atm = 29.92 in. Hg = 760 mm Hg
1 lb per sq in. = 4.882 kg per sq m
1 cu ft per min = 28.32 L per min

C-4.6 Comments on Derivation of Design Parameters for Medical-Surgical Vacuum Systems.

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 station inlets needed for various types of rooms or functional areas of a health care facility [Table A-4-7.1.2] and, second, the number of station inlets that are in simultaneous operation at any given time [Figure A-4-7.1.2].

The reasons for this empiricism are obvious. The number of station inlets needed for any particular room depends not only on the medical needs of the patients being treated, but also upon the location of those station inlets within each room and the individual characteristics of each vacuum device attached to the station inlets. The number of station inlets 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 station inlets 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 station inlets and pumps. One design approach would be to assume a "worst-case" situation (such as all installed station inlets 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 then NFPA Sectional Committee on Medical-Surgical Vacuum Systems[1] examined representative samples of suction apparatus to determine the design requirements (i.e., flow rates and vacuum) for the associated station inlets. "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 Sectional 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 flow rate given in 4-10.1.1.3 and minimum vacuum given in 4-10.1.1.1 are based on these measurements. Periodic review of these 1974 measurements indicated that they were still valid as of 1980.

[1] In 1974, the Sectional 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. In 1985, the Health Care Facilities Project was reorganized, with the Technical Committee on Medical-Surgical Vacuum Systems becoming the Standing Subcommittee on Vacuum Systems and Equipment.

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 station inlets, the number of station inlets in use throughout the day, and total demand on the vacuum source(s) as the various station inlets were used. These hospitals ranged in size from 100 beds to 1200 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-4-7.1.2 and Figure A-4-7.1.2 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-4-7.1.2 and Figure A-4-7.1.2.

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 Technical Committee on Medical-Surgical Vacuum Systems, and by the American Society for Hospital Engineering. Hospital sizes varied from 40 to 1200 beds and constituted a broader representation than before.

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 operating rooms 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 operating room. 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 2½ 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 4 and its associated Appendixes A-4 and C-4. These systems have continued to perform as intended.

C-8 Additional Information on Chapter 8.

Appendix C-8 consists of the following:

C-8.1 Medical Safeguards, Respiratory Therapy;
C-8.2 Glossary of Respiratory Therapy Terminology;
C-8.3 Suggested Fire Reponse, Respiratory Therapy;
C-8.4 Typical Gas Cylinders.

C-8.1 Medical Safeguards, Respiratory Therapy.

C-8.1.1 General.

C-8.1.1.1 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-8.1.1.2 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 — cleanup and sterilization, repair, and storage and reissue.

C-8.1.1.3 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 ensure ready availability of equipment.

C-8.1.1.4 Personnel must be aware of the exact location of equipment in storage to facilitate emergency use.

C-8.1.2 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 that might be toxic to the patient and no residual bacteria that might cause cross-infection.

C-8.1.2.1 Mechanical cleansing and sterilization should be carried out after each patient application.

C-8.1.2.2 Mechanical cleansing should be sufficiently thorough to remove blood, saliva, mucus, residual adhesive tape, and other debris.

C-8.1.2.3 Use of improper combinations of medication in therapy equipment should be avoided.

C-8.1.3 Tracheotomy and Endotracheal Tube Connection.

C-8.1.3.1 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-8.1.3.2 A tracheotomy collar should not obstruct movement of gas through the tracheotomy tube.

C-8.1.3.3 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-8.1.4 Suction Equipment for Respiratory Care.

C-8.1.4.1 Equipment employed for patient suction includes the source of suction, the interconnecting tubing, and 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-8.1.4.2 Suction equipment should be set up and applied only by qualified individuals.

C-8.1.4.3 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 bodily fluids from open wounds.

C-8.1.4.4 Suction regulators should be serviced by qualified individuals. Defective regulators should not be employed.

C-8.1.4.5 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-8.1.4.5.1 Trap bottles should be utilized between collection bottles and the source of suction to prevent spillage (*see C-8.1.4.1 and C-8.1.4.5*).

C-8.1.4.5.2 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-8.1.4.5.3 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-8.1.4.5.4 The overflow-preventive mechanism of the trap bottle should be cleaned each time the bottle is emptied and should be tested periodically to ensure proper functioning.

C-8.1.4.6 Suction tips or tubes with the largest practical internal diameter should be employed.

C-8.1.4.7 Tubing employed for connection of the various components of the suction system should possess an internal diameter of at least 0.25 in. (6.4 mm). The wall thickness of the tubing should be sufficient to prevent collapse during all conditions of use.

C-8.1.4.8 Suction tubing employed in a hazardous location is to be electrically conductive.

C-8.2 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.

CPAP. Continuous positive airway pressure.

CPR. Cardiopulmonary 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 mucus 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.

IMV. Intermittent mandatory ventilation.

IPPB. Intermittent positive pressure breathing.

PEEP. Positive end expiratory pressure.

Respiration. The exchange by diffusion of gases between the alveoli, the blood, and the tissue.

RLF. 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 that 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 nonbreathing or inadequately breathing patient.

C-8.3 Suggested Fire Response, Respiratory Therapy.

Suggested procedure in the event of fire involving respiratory therapy apparatus.

C-8.3.1 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-8.3.2 Steps to Take in Event of Fire.

C-8.3.2.1 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-8.3.4 and C-8.3.5.*)

(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-8.3.3.*)

(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-8.3.4*),

(4) Direct fire fighters to the site of the fire,

(5) Take whatever steps necessary to protect or evacuate patients in adjacent areas.

C-8.3.3 Closing Off of Oxygen Supply.

C-8.3.3.1 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-8.3.3.1.1 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-8.3.3.2 In the case 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-8.3.4 Extinguishment or Containment of Fire.

C-8.3.4.1 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-8.3.4.1.1 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-V circuits.

C-8.3.4.1.2 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 deenergized at the circuit panel.

C-8.3.4.1.3 If such deenergization cannot be accomplished, water should not be employed. (*See C-8.3.4.2.*)

C-8.3.4.2 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 for Portable Fire Extinguishers.*

NOTE: Chemical extinguishers are not effective against fires in oxygen-enriched atmospheres unless the source of oxygen is shut off. See C-8.3.3 for closing off oxygen supply.

C-8.3.5 Protection of Patients and Personnel.

C-8.3.5.1 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-8.3.5.2 The large quantities of noxious gases produced constitute a threat to life from asphyxia, beyond the thermal burn problem.

C-8.3.5.2.1 Personnel are cautioned not to remain in the fire area after patients are evacuated if quantities of gaseous combustion products are present.

C-8.3.6 Indoctrination of Personnel.

C-8.3.6.1 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 fire safety, 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 is accomplished most expeditiously. Reference should be made to the facility'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-8.4 Typical Gas Cylinders. See Table C-12.5, "Typical Gas Cylinders."

C-10 Additional Information on Chapter 10.

Appendix C-10 consists of the following:

C-10.1 Fire Incidents in Laboratories;

C-10.2 Related Definitions, Laboratories.

C-10.1 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 p.m. to 7 a.m., a tissue processor was suspected of causing $200,000 damage because the incident occurred after 11 p.m. 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 that 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 that 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 that 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 that 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 that 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 10-7.2.5.*)

Pressure Filter Fire. At an eastern hospital pharmacy, a fire-conscious technician prepared for pressure filtering of 50 gal (220 L) 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 that 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 (220 L) 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 that in themselves seem almost too insignificant to worry about.)

Ampuls Explode. An ampul 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 ampul through pinhole imperfections. As the ampul 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 2500 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 overtemperature 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, with oxygen and subsequently charged with cyclopropane. The valve, regulator, and fittings were unsuitable for oxygen, thus providing the conditions for a classic organic-oxidizer explosion. (From NFPA Quarterly, January, 1964, page 222.) (*See 4-4.3.5.*)

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 7-6.2.4.1.*)

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 and 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 4-6.2.1.7(c).*]

Steam Bath Flash. Flammable vapors from a batch of solvent that 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 that produce hazardous exhaust should be slowed down or stopped.

C-10.2 Related Definitions, Laboratories. The following definitions are taken from other NFPA documents and are critical to the understanding of Chapter 10.

C-10.2.1† 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. (absolute) (2,068 mm Hg) 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 IIIA liquids shall include those having flash points at or above 140°F (60°C) and below 200°F (93.4°C).

(3) Class IIIB liquids shall include those having flash points at or above 200°F (93.4°C).

C-10.2.2† 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 D56-1982, *Standard Test Method for Flash Point by 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 D93-1980, *Test Methods for Flash Point by Pensky-Martens Closed Tester.*

C-10.2.3† The following definitions are based on NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials.*

C-10.2.3.1 Health Hazard. A health hazard is any property of a material that, either directly or indirectly, can cause injury or incapacitation, either temporary or permanent, from exposure by contact, inhalation, or ingestion.

C-10.2.3.1.1 Degrees of Health Hazard.

4 — Materials that on very short exposure could cause death or major residual injury even though prompt medical treatment was given, including those that are too dangerous to be approached without specialized protective equipment. This degree should include:

(a) Materials that can penetrate ordinary rubber protective clothing;

(b) Materials that under normal conditions or under fire conditions give off gases that are extremely hazardous (i.e., toxic or corrosive) through inhalation or through contact with or absorption through the skin.

3 — Materials that on short exposure could cause serious temporary or residual injury even though prompt medical treatment was 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.

2 — Materials that on intense or continued exposure could cause temporary incapacitation or possible residual injury unless prompt medical treatment was 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 that either under normal conditions or under fire conditions give off toxic vapors lacking warning properties.

1 — Materials that on exposure would cause irritation but only minor residual injury even if no treatment is given, including those that require use of an approved canister-type gas mask. This degree should include:

(a) Materials that under fire conditions would give off irritating combustion products;

(b) Materials that on the skin could cause irritation without destruction of tissue.

0 — Materials that on exposure under fire conditions would offer no hazard beyond that of ordinary combustible material.

C-10.2.3.2 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-10.2.3.2.1 Degree of Flammability Hazard.

4 — Materials that will rapidly or completely vaporize at atmospheric pressure and normal ambient temperature or that are readily dispersed in air and that will burn readily. This degree should include:

(a) Gases;

(b) Cryogenic materials;

(c) Any liquid or gaseous material that 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 that on account of their physical form or environmental conditions can form explosive mixtures with air and that are readily dispersed in air, such as dusts of combustible solids and mists of flammable or combustible liquid droplets.

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 that may burn rapidly but that generally do not form explosive atmospheres with air;

(c) Solid materials in a fibrous or shredded form that may burn rapidly and create flash fire hazards, such as cotton, sisal, and hemp;

(d) Materials that burn with extreme rapidity, usually by reason of self-contained oxygen (e.g., dry nitrocellulose and many organic peroxides);

(e) Materials that ignite spontaneously when exposed to air.

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 that readily give off flammable vapors.

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 that will burn in air when exposed to a temperature of 1500°F (816°C) for a period of 5 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.

0 — Materials that will not burn. This degree should include any material that will not burn in air when exposed to a temperature of 1500°F (816°C) for a period of 5 minutes.

C-10.2.3.3 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 that, 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-10.2.3.3.1 Degree of Reactivity (Instability) Hazard.

4 — Materials that in themselves are readily capable of detonation or of explosive decomposition or explosive reaction at normal temperatures and pressures. This degree should include materials that are sensitive to mechanical or localized thermal shock at normal temperatures and pressures.

3 — Materials that in themselves are capable of detonation or of explosive decomposition or explosive reaction but that require a strong initiating source or that must be heated under confinement before initiation. This degree should include materials that are sensitive to thermal or mechanical shock at elevated temperatures and pressures or that react explosively with water without requiring heat or confinement.

2 — Materials that in themselves are normally unstable and readily undergo violent chemical change but do not detonate. This degree should include materials that can undergo chemical change with rapid release of energy at normal temperatures and pressures or that can undergo violent chemical change at elevated temperatures and pressures. It should also include those materials that may react violently with water or that may form potentially explosive mixtures with water.

1 — Materials that in themselves are normally stable, but that can become unstable at elevated temperatures and pressures or that may react with water with some release of energy, but not violently.

0 — Materials that in themselves are normally stable, even under fire exposure conditions, and that are not reactive with water.

C-12 Additional Information on Chapter 12.

Appendix C-12 consists of the following:

C-12.1 Nature of Hazards, Anesthetizing Locations;

C-12.2 Related Hazards and Safeguards, Anesthetizing Locations;

C-12.3 Text of Suggested Signs and Posters for Inhalation Anesthetizing Locations;

C-12.4 Suggested Procedures in Event of a Fire or Explosion, Anesthetizing Locations;

C-12.5 Cylinder Table.

C-12.1 Nature of Hazards, Anesthetizing Locations.

C-12.1.1 General. The environment of the modern operating room poses numerous hazards, even in those rooms in which flammable agents are prohibited.

C-12.1.2 Hazards Present in All Anesthetizing Locations.

C-12.1.2.1 Electric Shock and Spark Hazards — High-Frequency Burn.

C-12.1.2.1.1 When a human body becomes the connecting link between two points of an electric system that 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. If a conductive material bridges two points of an electric system that 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-12.1.2.1.2 Electric equipment that 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-12.1.2.1.3 Improper use of the high-frequency electrosurgical 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 Annex 2, "Safe Use of High-Frequency Electricity in Health Care Facilities."*)

C-12.1.2.2 Toxicologic Hazards.

C-12-1.2.2.1 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-5-4.1/A-5-4.2*).

C-12.1.2.3 Mechanical Hazards.

C-12.1.2.3.1 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-12.1.2.3.2 A hazard exists when hospital personnel attempt to transfer the contents of one compressed gas cylinder into another.

C-12.1.3 Hazards Related to the Use of Flammable Substances.

C-12.1.3.1 Flammable Anesthetic Agents.

C-12.1.3.1.1 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-12.1.3.1.2 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°C to 3000°C (1093°F 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 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 isofluorane, 7.0 percent and 5.25 percent.[2]

[1]Brown, T. A. and Morris, G. The ignition risk with mixtures of oxygen and nitrous oxide with halothane. *Brit. J. Anaesth.* 38:164-173, 1966.

[2]Cruice, 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, 5 March 1974.

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-12.1.3.1.3 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-12.1.3.2 Flammable Medicaments, Including Aerosol Products.

C-12.1.3.2.1 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-12.1.3.2.2 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-12.1.3.2.1*), since the liquid remaining on the skin or vapors pocketed within the surgical drapes may be ignited.

C-12.1.3.3 Sources of Ignition.

C-12.1.3.3.1 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, and (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 (8-3.1.8), and ignition from improper handling of oxygen cylinders (4-6.2.1.2).

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 780, *Lightning Protection Code*.

C-12.1.3.3.2 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 that 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-12.1.3.3.3 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-12.1.3.3.4 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-12.1.3.1.2 is that of diethyl 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 sources of flames and hot objects into the anesthetizing locations (*see 12-4.1.2.3*).

C-12.1.4 Hazards that May Be Present in Nonflammable Anesthetizing Locations.

C-12.1.4.1 Electrostatic Hazard.

C-12.1.4.1.1 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-12.1.4.2 Hazard of Flammable Substances.

C-12.1.4.2.1 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-12.1.3.2*).

C-12.1.5 Hazards that May Be Present in Mixed Facilities.

C-12.1.5.1 Mixed facilities contain both flammable and nonflammable anesthetizing locations. Movable furniture, portable equipment, and conductive accessories intended for 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-12.1.5.2 Personnel working in mixed facilities may not take the proper precautions in reference to wearing