NFPA®

45

Standard on Fire Protection for Laboratories Using Chemicals

2019

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NFPA® 45

Standard on

Fire Protection for Laboratories Using Chemicals

2019 Edition

This edition of NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, was prepared by the Technical Committee on Laboratories Using Chemicals. It was issued by the Standards Council on November 5, 2018, with an effective date of November 25, 2018, and supersedes all previous editions.

This edition of NFPA 45 was approved as an American National Standard on November 25, 2018.

Origin and Development of NFPA 45

The first edition of NFPA 45 was developed by the Technical Committee on Chemistry Laboratories. It was tentatively adopted at the 1974 NFPA Annual Meeting and was officially adopted at the 1975 NFPA Fall Meeting. The committee wishes to acknowledge that NFPA 45 is due in large part to the leadership and efforts of the late Russell H. Scott, who served as chairman of the committee during the planning and drafting stages of the first edition of NFPA 45. After the document had been in use for two years, the technical committee began an exhaustive review of the text; amendments were adopted for the 1982, 1986, and 1991 editions.

The 1996 edition of NFPA 45 included clarification on the scope and application of the standard as it applied to various types of educational, industrial, and medical laboratory facilities. Clarification of objectives was made to ensure a fire is contained to the room of origin. The requirements for maximum quantities of flammable and combustible liquids, construction, and fire protection in laboratory units were separated into two tables, one for sprinklered laboratory units and the other for nonsprinklered laboratory units. In addition, the committee revised the fire hazard classifications to recognize that clinical laboratories were using this standard as directed by NFPA 99, *Standard for Health Care Facilities*, and to identify that NFPA *101*®, *Life Safety Code*®, no longer addresses laboratory occupancies.

The 2000 edition of NFPA 45 included modified laboratory separation requirements, and nonsprinklered laboratories of Class A or B and Class C [over 929 m^2 (10,000 ft^2)] were prohibited. Expanded requirements and advisory information for compressed and liquefied gases were added. Additional changes included modified laboratory ventilating systems and hood requirements. Average face velocity is used to determine the safe operating levels for hood exhaust systems. Changes were made to address the current industry trend in the utilization of variable air volume (VAV) laboratory ventilation systems, which provide clear requirements for the containment of contaminants within the hood. The language was clarified regarding multiple or manifold exhaust ducts within buildings.

The 2004 edition of NFPA 45 included a new requirement that all new laboratories must be protected with automatic extinguishing systems. Pressurized liquid dispensing containers not previously recognized but indirectly prohibited because of quantity restrictions were defined, addressed, and regulated. Clarification of the scope was provided for labs containing the minimum quantity of either flammable and combustible liquids or gas that would qualify the lab for coverage under NFPA 45. Clarification was also made that the minimum quantity of gas does not include low-pressure utility gas in accordance with NFPA 54, *National Fuel Gas Code*.

The 2004 edition included expanded advisory material on biological safety cabinets and recognition of listed Class II, Type B2 biological safety cabinets in lieu of chemical fume hoods under certain circumstances. All flammable and combustible liquids requirements were consolidated into one chapter. Requirements were incorporated to limit hazchem storage spill scenarios to less than 20 L (5 gal). Expanded requirements and advisory information were created for compressed and liquefied gases. Maximum quantity requirements were clarified for outside cylinder storage.

The 2011 edition of NFPA 45 included major modifications to Chapters 4, 5, 9, 10, and 11 to modify the design, construction, and operational requirements for laboratories located in buildings over 1 story in height. Height restrictions were added for Class A and B laboratory units. The fire resistance rating of laboratory units, height restrictions, and quantities of hazardous materials were modified for laboratory units depending upon the height of the building containing the laboratories. Laboratories located in health care facilities previously covered by NFPA 99 were added to NFPA 45. Hazardous materials in storage or use in a laboratory work area that could present an explosion hazard were quantified. Requirements for the management of time-sensitive chemicals were clarified.

The 2015 edition of NFPA 45 included a new chapter on educational and instructional laboratories. The standard applies to all educational and instructional laboratories, independent of the quantity of chemicals present. Requirements for Class A, B, C, and D laboratory units permitted below grade were clarified in Chapter 5, and requirements for fire-retardant clothing, inert atmosphere glove boxes, handling pyrophoric reagents and water reactive materials, and open flame operations were added in Chapters 6, 7, and 11. Supplementary information on laboratory units was expanded to provide additional guidance. Because explosion hazard protection is no longer within the scope of NFPA 45, the chapter by that title was removed and the information was relocated to Annex C.

The 2019 edition of NFPA 45 adds definitions for *use*, *closed system use*, and *open system use* as the terms are found throughout the standard. The 2019 edition also incorporates requirements for laboratory units in health care facilities, particularly flammable and combustible liquid quantity limitations; lab unit classifications; fire separation; and specific provisions for distillation and solvent recycling equipment and tissue processors. Area limitations for lab units have been removed, because the quantity of flammable liquids is limited by the volume and density limits. Language has been revised to clarify that curbing of laboratory floors can be used to prevent liquids from migrating to lower floor levels, and new annex text has been added to list other preventative means. Requirements for exit doors have been revised to clarify that the methods need to also comply with NFPA *101* egress requirements. The section on emergency lighting has been revised to require emergency lighting in all laboratory work areas, not only those that require a second means of access to an exit. Requirements for Class I wet standpipe systems have been clarified, and requirements for manual fire alarm systems have been revised to include all buildings with laboratory units. Terminology related to flame-resistant clothing has been revised to align with NFPA 2112. Requirements for laboratory exhaust systems have been expanded to prohibit sound attenuation devices within them. Laboratory exhaust ducts, dampers, and exhaust ducting through fire barriers has been addressed to clarify the installation of exhaust ducts through fire-rated barriers and to align with the current editions of NFPA 90A and 91. Inspection, testing, and maintenance of fire-extinguishing systems in ductwork or chemical fume hoods has been revised from a specified time interval to a schedule appropriate for the type of system. A new retroactivity clause has been added to clarify that the chapter on chemical storage, handling, and waste disposal contains operational requirements that need to be applied to existing laboratories, not only new construction. Hazardous chemical containers stored and handled in laboratory work areas are now limited to 20 L (5 gal), where previous language about limiting spill scenarios was ambiguous. A minimum inspection frequency of 1 year has been added for chemical storage. Annex material has been added to reinforce the need to evaluate the effects of any mixing of wastes, to clarify the process of dispensing Class I liquids in a ventilated area, to explain why pyrophoric reagents and water-reactive materials in glove boxes need to be sealed in airtight containers when not in use, to describe flame-jetting hazards, and to explain the need for hazard evaluations and risk assessments before new or changed experiments. Language has been added to reference NFPA 30 for quantities of flammable and combustible liquids within inside liquid storage areas, and requirements for gas cylinders have been aligned with NFPA 55. Requirements for emergency gas shutoffs and overpressure protection have been clarified, and new language has been added to address the potential explosion hazards associated with mixing flammable and oxidizing materials. The sections on heating operations and heating equipment have been combined into one section for consistency, and new requirements to perform hazard analysis and risk assessment before use of pressure containing equipment have been added.

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Committee Scope: This Committee shall have primary responsibility for documents for the prevention of loss of life and damage to property from fire and explosion in chemical laboratories.

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Standard on

Fire Protection for Laboratories Using Chemicals

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

A reference in brackets [ ] following a section or paragraph indicates material that has been extracted from another NFPA document. As an aid to the user, the complete title and edition of the source documents for extracts in mandatory sections of the document are given in Chapter 2 and those for extracts in informational sections are given in Annex G. Extracted text may be edited for consistency and style and may include the revision of internal paragraph references and other references as appropriate. Requests for interpretations or revisions of extracted text shall be sent to the technical committee responsible for the source document.

Information on referenced publications can be found in Chapter 2 and Annex G.

Chapter 1 Administration

1.1 Scope.

1.1.1* This standard shall apply to laboratory buildings, laboratory units, and laboratory work areas whether located above or below grade in which chemicals, as defined in NFPA 704 with one or more of the following hazard ratings are handled or stored: health — 2, 3, or 4; flammability — 2, 3, or 4; or instability — 2, 3, or 4. *(See also Section B.2.)*

Δ **1.1.2** This standard shall apply to all educational laboratory units and instructional laboratory units in which any quantity of chemicals, as defined in NFPA 704 with one or more of the following hazard ratings, is handled or stored: health — 2, 3, or 4; flammability — 2, 3, or 4; or instability — 2, 3, or 4. *(See also Section B.2.)*

1.1.3 With the exception of 1.1.2, this standard shall not apply to the following:

(1)* Laboratories for which the following conditions apply:
   (a) Laboratory units that contain less than or equal to 4 L (1 gal) of flammable or combustible liquid
   (b) Laboratory units that contain less than 2.2 standard m^3 (75 scf) of flammable gas, not including piped-in low-pressure utility gas installed in accordance with NFPA 54
(2)* Pilot plants
(3) Laboratories that handle only chemicals with a hazard rating of 0 or 1 for all of the following: health, flammability, and instability, as defined by NFPA 704
(4) Laboratories that are primarily manufacturing plants
(5) Incidental testing facilities
(6) Physical, electronic, instrument, laser, or similar laboratories that use chemicals only for incidental purposes, such as cleaning
(7)* Hazards associated with radioactive materials, as covered by NFPA 801
(8) Laboratories that work only with explosive material, as covered by NFPA 495
(9)* A laboratory work area containing an explosion hazard great enough to cause property damage outside that laboratory work area or injury outside that laboratory work area requiring medical treatment beyond first aid

Δ **1.1.4*** A laboratory work area contains an explosion hazard if an explosion of quantities or concentrations of reactive materials could result in serious or fatal injuries to personnel within that laboratory work area.

N **1.1.4.1** Quantities or concentrations that pose an explosion hazard include, but are not limited to, the following:

(1) Storage of more than 0.45 kg (1 lb) of materials with an instability hazard rating of 4 *(see Table B.2.5)*
(2) Use or formation of more than 0.11 kg (0.25 lb) of materials with an instability hazard rating of 4 *(see Table B.2.5)*
(3)* Presence of highly exothermic reactions in glass or open reaction vessels involving more than 10 g (0.35 oz) of materials such as polymerizations, oxidations, nitrations, peroxidations, hydrogenations, or organo-metallic reactions
(4) Use or formation in glass or open reaction vessels involving more than 10 g (0.35 oz) of materials whose chemical structures indicate a potential hazard, but whose properties have not been established, such as salts of alkenes, triple bonds, epoxy radicals, nitro and nitroso compounds, and peroxides
(5) Other explosion hazards as determined by a qualified person

N **1.1.4.2** In such cases where a laboratory work area contains an explosion hazard, NFPA 45, supplemented by appropriate shielding, handling, and similar protective measures, does apply.

1.1.5 A laboratory work area contains an explosion hazard if an explosion of quantities or concentrations of flammable gases or vapors or other explosion hazards as determined by a qualified person could result in serious or fatal injuries to personnel within that laboratory work area — in which case, NFPA 45 shall apply.

1.1.6 This standard contains requirements, but not all-inclusive requirements, for handling and storage of chemicals where laboratory-scale operations are conducted and shall not cover the following:

(1) The special fire protection required when handling explosive materials *(See NFPA 495.)*
(2) The special fire protection required when handling radioactive materials

1.2 Purpose.

1.2.1 The purpose of this standard shall be to provide basic requirements for the protection of life and property through prevention and control of fires and explosions involving the use of chemicals in laboratory-scale operations.

1.2.2 This standard is designed to control hazards and protect personnel from the toxic, corrosive, or other harmful effects of chemicals to which personnel might be exposed as a result of fire or explosion.

1.2.3 The goal of this standard shall be to achieve a comprehensive laboratory fire prevention and protection program to prevent injury or death to occupants and emergency response personnel.

1.2.4 The objectives of this standard shall be as follows:

(1) Limit injury to the occupants at the point of fire origin
(2) Limit injury to emergency response personnel
(3) Limit property loss to a maximum of a single laboratory unit

Δ **1.2.5** It is not the objective of this standard to address financial losses such as business interruption or property loss of a laboratory unit.

1.3* Application.

1.3.1 The provisions of this document shall be considered necessary to provide a reasonable level of protection from loss of life and property from fire and explosion. They reflect situations and the state of the art prevalent at the time the standard was issued.

1.3.2 When interface with existing NFPA or other consensus codes and standards occurs, reference shall be made to the appropriate source in the text.

1.3.3 Due to the special nature of laboratories using chemicals, this standard modifies and supplements existing codes and standards so as to apply more specifically to buildings or portions of buildings devoted to laboratory-scale operations.

1.3.4 Where a construction or protection requirement of a governmental agency having jurisdiction is more stringent than a requirement in this standard, the more stringent requirement shall apply.

1.4 Retroactivity. The provisions of this standard reflect a consensus of what is necessary to provide an acceptable degree of protection from the hazards addressed in this standard at the time the standard was issued.

1.4.1 Unless otherwise specified, the provisions of this standard shall not apply to facilities, equipment, structures, or installations that existed or were approved for construction or installation prior to the effective date of the standard. Where specified, the provisions of this standard shall be retroactive.

1.4.2 In those cases where the authority having jurisdiction determines that the existing situation presents an unacceptable degree of risk, the authority having jurisdiction shall be permitted to apply retroactively any portions of this standard deemed appropriate.

1.4.3 The retroactive requirements of this standard shall be permitted to be modified if their application clearly would be impractical in the judgment of the authority having jurisdiction, and only where it is clearly evident that a reasonable degree of safety is provided.

1.5 Equivalency. Nothing in this standard is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this standard.

1.5.1 Technical documentation shall be submitted to the authority having jurisdiction to demonstrate equivalency.

1.5.2 The system, method, or device shall be approved for the intended purpose by the authority having jurisdiction.

Chapter 2 Referenced Publications

2.1 General. The documents referenced in this chapter are referenced within this standard and shall be considered part of the requirements of this standard, and the following shall also apply:

(1)* Documents referenced in this chapter, or portion of such documents, shall only be applicable to the extent called for within other chapters of this standard.
(2) Where the requirements of a referenced code or standard differ from the requirements of this standard, the requirements of this standard shall govern.
(3)* Existing buildings or installations that do not comply with the provisions of the codes or standards referenced in this chapter shall be permitted to be continued in service, provided that the lack of conformity with these documents does not present a serious hazard to the occupants as determined by the authority having jurisdiction.

2.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 1, *Fire Code,*2018 edition.
NFPA 10, *Standard for Portable Fire Extinguishers,* 2018 edition.
NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam,* 2016 edition.
NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems,* 2018 edition.
NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems,* 2018 edition.
NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2019 edition.
NFPA 14, *Standard for the Installation of Standpipe and Hose Systems,* 2019 edition.
NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection,* 2017 edition.
NFPA 17, *Standard for Dry Chemical Extinguishing Systems,* 2017 edition.
NFPA 17A, *Standard for Wet Chemical Extinguishing Systems,* 2017 edition.
NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems,* 2017 edition.

NFPA 30, *Flammable and Combustible Liquids Code,* 2018 edition.

NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials,*2018 edition.

NFPA 54, *National Fuel Gas Code,* 2018 edition.

NFPA 55, *Compressed Gases and Cryogenic Fluids Code,* 2016 edition.

NFPA 69, *Standard on Explosion Prevention Systems,* 2019 edition.

NFPA 70®, National Electrical Code®, 2017 edition.

NFPA 72®, National Fire Alarm and Signaling Code, 2019 edition.

NFPA 80, *Standard for Fire Doors and Other Opening Protectives,* 2019 edition.

NFPA 86, *Standard for Ovens and Furnaces,* 2019 edition.

NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems,*2018 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Particulate Solids,* 2015 edition.

NFPA *101®, Life Safety Code®,* 2018 edition.

NFPA 400, *Hazardous Materials Code,* 2019 edition.

NFPA 495, *Explosive Materials Code,* 2018 edition.

NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment,*2017 edition.

NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response,* 2017 edition.

NFPA 750, *Standard on Water Mist Fire Protection Systems,* 2019 edition.

NFPA 801, *Standard for Fire Protection for Facilities Handling Radioactive Materials,*2019 edition.

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems,* 2018 edition.

NFPA 2112, *Standard on Flame-Resistant Clothing for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire,* 2018 edition.

2.3 Other Publications.

2.3.1 ANSI Publications. American National Standards Institute, Inc., 25 West 43rd Street, 4th Floor, New York, NY 10036.

ANSI/AIHA Z9.5, *Laboratory Ventilation*, 2012.

ANSI Z535.1, *Safety Colors*, 2017.

ANSI Z535.2, *Environmental and Facility Safety Signs*, 2017.

ANSI Z535.3, *Criteria for Safety Symbols*, 2017.

ANSI Z535.4, *Product Safety Signs and Labels*, 2017.

2.3.2 ASME Publications. ASME International, Two Park Avenue, New York, NY 10016-5990.

ASME *Boiler and Pressure Vessel Code*, Section VIII, 2017.

2.3.3 ASTM Publications. ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.

ASTM D5/D5M, *Standard Test Method of Penetration of Bituminous Materials*, 2013.

ASTM D4359, *Standard Test for Determining Whether a Material is a Liquid or a Solid*, 2012.

ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, 2017a.

Δ **2.3.4 NSF Publications.** NSF International, P.O. Box 130140, 789 N. Dixboro Road, Ann Arbor, MI 48113-0140.

NSF/ANSI 49, *Biosafety Cabinetry: Design, Construction, Performance, and Field Certification*, 2016.

2.3.5 UL Publications. Underwriters Laboratories, Inc. 333 Pfingsten Road, Northbrook, IL 60062-2096.

ANSI/UL 723, *Standard for Test for Surface Burning Characteristics of Building Materials*, 2008, revised 2017.

UL 1275, *Standard for Flammable Liquid Cabinets*, 2014.

UL 1805, *Standard for Laboratory Hoods and Cabinets*, 2006, revised 2007.

2.3.6 Other Publications.

Merriam-Webster's Collegiate Dictionary, 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

2.4 References for Extracts in Mandatory Sections.

NFPA 30, *Flammable and Combustible Liquids Code,* 2018 edition.

NFPA 54, *National Fuel Gas Code,* 2018 edition.

NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems,* 2018 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Particulate Solids,* 2015 edition.

NFPA 99, *Health Care Facilities Code,* 2018 edition.

NFPA *101®, Life Safety Code®,* 2018 edition.

NFPA 400, *Hazardous Materials Code,* 2019 edition.

NFPA 801, *Standard for Fire Protection for Facilities Handling Radioactive Materials,* 2014 edition.

NFPA 5000®, Building Construction and Safety Code®, 2018 edition.

Chapter 3 Definitions

3.1 Definitions. The definitions contained in this chapter shall apply to the terms used in this standard. Where terms are not defined in this chapter or within another chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary*, 11th edition, shall be the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

3.2.3 Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is 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.

3.2.4* Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

3.2.5 Shall. Indicates a mandatory requirement.

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

3.2.7 Standard. An NFPA Standard, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and that is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions are not to be considered a part of the requirements of a standard and shall be located in an appendix, annex, footnote, informational note, or other means as permitted in the NFPA Manuals of Style. When used in a generic sense, such as in the phrase "standards development process" or "standards development activities," the term "standards" includes all NFPA Standards, including Codes, Standards, Recommended Practices, and Guides.

3.3 General Definitions.

3.3.1 Apparatus. Furniture, chemical fume hoods, centrifuges, refrigerators, and commercial or made-on-site equipment used in a laboratory.

3.3.2 Auxiliary Air. Supply or supplemental air delivered near the outside face of a chemical fume hood to reduce room air consumption.

3.3.3 Baffle. An object placed in an appliance to change the direction of or to retard the flow of air, air–gas mixtures, or flue gases. [**54,** 2018]

3.3.4* Biological Safety Cabinet. A ventilated cabinet for personnel, product, and environmental protection having an open front with inward airflow for personnel protection, downward HEPA-filtered laminar airflow for product protection, and HEPA-filtered exhausted air for environmental protection.

3.3.5 Business Occupancy. See 3.3.46.1.

3.3.6 Bypass. An airflow-compensating opening that maintains a relatively constant volume exhaust through a chemical fume hood regardless of sash position, serving to limit the maximum face velocity as the sash is lowered.

3.3.7* Canopy Hood. A suspended ventilating device used only to exhaust heat, water vapor, odors, and other nonhazardous materials.

3.3.8* Chemical Fume Hood. A ventilated enclosure designed to contain and exhaust fumes, gases, vapors, mists, and particulate matter generated within the hood interior.

3.3.9 Combustible Liquid. A liquid that has a closed-cup flash point at or above 37.8°C (100°F).

3.3.10 Compressed Gas Cylinder. Any portable pressure vessel of 45.4 kg (100 lb) water capacity or less designed to contain a gas or liquid that is authorized for use at gauge pressures over 276 kPa (40 psi) at 21°C (70°F) by the U.S. Department of Transportation (DOT) or Transport Canada (T.C.).

3.3.11* Cryogenic Fluid. Substance that exists only in the vapor phase above −73°C (−99°F) at one atmosphere pressure and that is handled, stored, and used in the liquid state at temperatures at or below −73°C (−99°F) while at any pressure.

3.3.12 Deflector Vane. An airfoil-shaped vane along the bottom of the hood face that directs incoming air across the work surface to the lower baffle opening. The opening between the work surface and the deflector vane is open even with the sash fully closed.

3.3.13 Educational Laboratory Unit. A laboratory unit that is under direct supervision of an instructor and used for educational purposes for students through the twelfth grade.

3.3.14 Educational Occupancy. See 3.3.46.2.

3.3.15 Exit Access Corridor. A corridor used as exit access that leads to an exit that is separated from other parts of the building by walls.

3.3.16 Explosive Material. Any explosive, blasting agent, emulsion explosive, water gel, or detonator.

3.3.17* Face (of hood). The hood opening or the plane of the inside surface of the sash.

3.3.18 Face Velocity. The rate of flow or velocity of air moving into the chemical fume hood entrance or face, as measured at the plane of the chemical fume hood face.

3.3.19 Fire Separation. A horizontal or vertical fire resistance–rated assembly of materials that have protected openings and are designed to restrict the spread of fire.

3.3.20 Flammable Gas. Any substance that exists in the gaseous state at normal atmospheric temperature and pressure and is capable of being ignited and burned when mixed with the proper proportions of air, oxygen, or other oxidizers. [**99,** 2018]

3.3.21 Flammable Liquid. A liquid that has a closed-cup flash point that is below 37.8°C (100°F) and a maximum vapor pressure of 2068 mm Hg (absolute pressure of 40 psi) at 37.8°C (100°F).

3.3.22* Flammable Solid. A solid, other than a blasting agent or explosive, that is liable to cause fire through friction, absorption of moisture, spontaneous chemical change, or retained heat from manufacturing or processing, or that can be ignited readily and when ignited, burns so vigorously and persistently as to create a serious hazard.

3.3.23 Flash Point. The minimum temperature at which a liquid or a solid emits vapor sufficient to form an ignitible mixture with air near the surface of the liquid or the solid.

3.3.24 Glove Box. A sealed enclosure in which items inside the box are handled exclusively using long gloves sealed to ports in the walls of the enclosure. [**801,** 2014]

3.3.25* Health Care Facilities. Buildings, portions of buildings, or mobile enclosures in which medical, dental, psychiatric, nursing, obstetrical, or surgical care is provided. (FUN) [**99,** 2018]

3.3.26 Health Care Occupancy. See 3.3.46.3.

3.3.27 Hood Interior. The volume enclosed by the side, back, and top enclosure panels, the work surface, the access opening (called the face), the sash or sashes, and the exhaust plenum, including the baffle system for airflow distribution.

3.3.28 Incidental Testing Facility. An area within a production facility set aside for the purpose of conducting in-process control tests that are related to the production process.

3.3.29 Industrial Occupancy. See 3.3.46.4.

3.3.30* Inside Liquid Storage Area. A room or building used for the storage of liquids in containers or portable tanks, separated from other types of occupancies.

3.3.31 Instructional Laboratory Unit. A laboratory unit under the direct supervision of an instructor that is used for purposes of instruction for students beyond the twelfth grade.

3.3.32 Instructor. A person whose job includes teaching or instructing students in educational or instructional laboratories. This can include science teachers, professors, assistant professors, associate professors, lecturers, substitute teachers, and teaching assistants.

3.3.33 Laboratory. A facility where the containers used for reactions, transfers, and other handling of chemicals are designed to be easily and safely manipulated by one person. A laboratory is a workplace where chemicals are used or synthesized on a nonproduction basis.

3.3.34 Laboratory Building. A structure consisting wholly or principally of one or more laboratory units.

3.3.35 Laboratory Equipment. See 3.3.1, Apparatus.

3.3.36 Laboratory Scale. Work with chemicals in which the containers used for reactions, transfers, and other handling of chemicals are designed to be easily and safely manipulated by one person.

3.3.37* Laboratory Unit. An enclosed space used for experiments or tests.

3.3.38 Laboratory Unit Separation. All walls, partitions, floors, and ceilings, including openings in them, that separate a laboratory unit from adjoining areas.

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

3.3.40 Laminar Flow Cabinet. A ventilated, partially enclosed cabinet primarily intended to provide filtered airflow over the work surface by use of laminar airflow methods.

3.3.41 Lecture Bottle. A small compressed gas cylinder up to a size of approximately 5 cm × 33 cm (2 in. × 13 in.).

3.3.42 Liquefied Gas Cylinder. A compressed gas cylinder used for liquefied gas.

3.3.43 Liquid. Any material that has a fluidity greater than that of 300 penetration asphalt when tested in accordance with ASTM D5/D5M, *Standard Test Method of Penetration of Bituminous Materials*, and is a viscous substance for which a specific melting point cannot be determined but that is determined to be a liquid in accordance with ASTM D4359, *Standard Test for Determining Whether a Material Is a Liquid or a Solid*. Unless otherwise specified, the term *liquid* includes both flammable and combustible liquids.

3.3.44 Maximum Allowable Working Pressure. The maximum gauge pressure permissible at the top of completed equipment, a container, or a vessel in its operating position for a design temperature.

3.3.45 Nonlaboratory Area. Any space within a building not included in a laboratory unit. *(See also 3.3.37.)*

3.3.46 Occupancy.

3.3.46.1 ***Business Occupancy.*** An occupancy used for the transaction of business other than mercantile. [**5000,** 2018]

3.3.46.2* ***Educational Occupancy.*** An occupancy used for educational purposes through the 12th grade by six or more persons for 4 or more hours per day or more than 12 hours per week.

3.3.46.3 ***Health Care Occupancy.*** An occupancy used to provide medical or other treatment or care simultaneously to four or more patients, on an inpatient basis, where such occupants are mostly incapable of self-preservation due to age, physical or mental disability, or because of security measures not under the occupants' control. [**5000,** 2018]

3.3.46.4* ***Industrial Occupancy.*** An occupancy in which products are manufactured or in which processing, assembling, mixing, packaging, finishing, decorating, or repair operations are conducted. [**5000,** 2018]

3.3.47 Open Plan Building. A building having rooms, spaces, and corridors delineated by tables, chairs, desks, bookcases, counters, low-height partitions, floor patterns, or any similar finishes or furnishings.

3.3.48 Organic Peroxide. Any organic compound having a double oxygen or peroxy (-O-O-) group in its chemical structure.

3.3.49* Oxidizer. Any material that readily yields oxygen or other oxidizing gas, or that readily reacts to promote or initiate combustion of combustible materials.

3.3.50 Pilot Plant. An experimental assembly of equipment for exploring process variables or for producing semicommercial quantities of materials.

3.3.51 Pressurized Liquid Dispensing Container (PLDC). DOT-, United Nations- (UN-), or ASME-approved containers which are designed for the pressure dispensing of liquids at the specified maximum allowable working pressure of the container.

3.3.52 Pyrophoric Gas. A gas that will spontaneously ignite in air at or below a temperature of 54.4°C (130°F).

3.3.53* Pyrophoric Reagent. A solid or liquid substance that ignites at 54°C (130°F) or below on exposure to water vapor in air-producing flammable gas and heat.

3.3.54 Qualified Person. A person who, by possession of a recognized degree, certificate, professional standing, or skill, and who, by knowledge, training, and experience, has demonstrated the ability to deal with problems relating to a particular subject matter, work, or project.

3.3.55 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 B.2.5 for definitions of Instability 2, 3, or 4.)*

3.3.56 Refrigerating Equipment. Any mechanically operated equipment used for storing materials below normal ambient temperature, including refrigerators, freezers, and similar equipment. *(See 11.3.2 and A.11.3.2.2.)*

3.3.57 Safety Can. A listed container, of not more than 5.3 gal (20L) capacity, having a screen or strainer in each fill and pour opening and having a spring-closing lid and spout cover designed to safely relieve internal pressure when exposed to fire. [**30,** 2018]

3.3.58 Sash. A movable panel or panels set in the hood entrance. *(See C.6.1.)*

3.3.59 Street Floor. A story or floor level accessible from the street or from outside the building at the finished ground level, with the floor level at the main entrance located not more than three risers above or below the finished ground level, and arranged and utilized to qualify as the main floor. [***101,*** 2018]

3.3.60* 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.

N **3.3.61 Use.** To place a material, including solids, liquids, and gases, into action. [**400,** 2019]

N **3.3.61.1*** ***Closed System Use.*** Use of a solid or liquid hazardous material in a closed vessel or system that remains closed during normal operations where vapors emitted by the product are not liberated outside of the vessel or system and the product is not exposed to the atmosphere during normal operations and all uses of compressed gases. [**400,** 2019]

N **3.3.61.2** ***Open System Use.*** Use of a solid or liquid hazardous material in a vessel or system that is continuously open to the atmosphere during normal operations and where vapors are liberated or the product is exposed to the atmosphere during normal operations. [**400,** 2019]

Chapter 4 Laboratory Unit Hazard Classification

4.1 General. This chapter shall classify laboratory units based on the amount of flammable and combustible liquids in use within the unit.

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4.2 Laboratory Unit Fire Hazard Classification.

4.2.1* Classifications. Laboratory units shall be classified as Class A (high fire hazard), Class B (moderate fire hazard), Class C (low fire hazard), or Class D (minimal fire hazard), according to the quantities of flammable and combustible liquids specified in Table 9.1.1(a) and Table 9.1.1(b).

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4.2.2 Additional Requirements for Educational and Instructional Laboratory Units.

4.2.2.1 Instructional laboratory units shall be classified as Class C or Class D laboratory units.

4.2.2.2 Educational laboratory units shall be classified as Class D or shall be limited to 50 percent of the flammable and combustible liquids quantity for Class C laboratory units presented in Table 9.1.1(a) and Table 9.1.1(b).

N **4.2.3 Additional Requirements for Laboratory Units in Health Care Facilities.**

N **4.2.3.1** Laboratory units in health care facilities shall be classified as Class C or D.

N **4.2.3.2** Class C laboratory units in health care facilities shall be limited to 50 percent of the flammable and combustible liquid quantity for Class C laboratory units presented in Table 9.1.1(a) and Table 9.1.1(b).

Chapter 5 Laboratory Unit Design and Construction

5.1 Laboratory Unit Enclosure.

Δ **5.1.1** The required construction of laboratory units shall be in accordance with Table 5.1.1.

5.1.2 A single Class C or Class D laboratory unit on a floor shall not be required to have fire separation.

5.1.3 Regardless of the construction and fire protection requirements for laboratory units that are specified in Table 5.1.1, laboratory units in educational occupancies or Class C laboratory units in health care facilities shall be separated from nonlaboratory areas by 1-hour construction.

5.1.4* Penetrations through fire-rated floor/ceiling, floor, and wall assemblies shall be protected in accordance with NFPA *101* and the applicable fire code or building code.

5.1.5* Floors, Floor Openings, Floor Penetrations, and Floor Firestop Systems.

N **5.1.5.1** Floors, floor openings, floor penetrations, and floor firestop systems shall be sealed or curbed to prevent liquid leakage to lower floors.

N **5.1.5.2** The sealing material shall be compatible with the chemicals being stored or used in the laboratory, or a program shall be in place to inspect and repair, if necessary, after exposure to leakage.

Δ **Table 5.1.1 Separation Requirements and Height Allowances for Laboratory Units**

Laboratory Unit[a]	Permitted Stories Above Grade	Permitted Stories Below Grade	Fire Separation[b]
A	1–3	Not permitted	2 hours
B	1–3 4–6	1	1 hour 2 hours
C	1–6 Over 6	1–2	1 hour[c] 2 hours
D	No limit	No limit	1 hour[c]

[a]Refer to Table 9.1.1 for laboratory unit classification.
[b]Separation in this table refers to fire separation from laboratory unit(s) to nonlaboratory areas or fire separations from laboratory unit(s) of equal or lower hazard classification.
[c]See 5.1.2.

5.1.6 Door assemblies in required 1-hour-rated fire separations shall be ¾-hour rated. Door assemblies in required 2-hour-rated fire separations shall be 1 ½-hour rated.

5.1.7 Window assemblies shall be permitted in fire-rated wall assemblies having a required fire resistance rating of 1 hour or less.

5.1.7.1 Window assemblies shall be of an approved type and shall have a fire protection rating in accordance with NFPA *101*.

5.1.7.2 Fire window assemblies shall be installed in accordance with NFPA 80.

• **5.2 Requirements for Life Safety.** Life safety features for laboratory buildings, laboratory units, and laboratory work areas shall comply with NFPA *101* unless otherwise modified by other provisions of this standard.

5.2.1 Class A, B, and C laboratory units shall be classified as industrial occupancies in accordance with NFPA *101*.

5.2.2 Educational laboratory units shall be classified as educational occupancies in accordance with NFPA *101*.

5.2.3 Class D laboratories located in facilities classified as business occupancies shall be in accordance with the requirements for business occupancies of NFPA *101*.

5.3 Means of Access to an Exit.

5.3.1* A second means of access to an exit shall be provided from a laboratory work area if any of the following situations exist:

(1) A laboratory work area contains an explosion hazard located so that an incident would block escape from or access to the laboratory work area.
(2) A laboratory work area within a Class A laboratory unit exceeds 46.5 m^2 (500 ft^2).
(3) A laboratory work area within a Class B, Class C, or Class D laboratory unit exceeds 93 m^2 (1000 ft^2).
(4) A hood in a laboratory work area is located adjacent to the means of exit access.
(5) A compressed gas cylinder larger than lecture bottle size [approximately 5 cm × 33 cm (2 in. × 13 in.)] is located so that it could prevent safe egress in the event of accidental release of cylinder contents.
(6) A cryogenic container is located so that it could prevent safe egress in the event of accidental release of container contents.

5.3.2 The required exit access doors of all laboratory work areas within Class A or Class B laboratory units shall swing in the direction of exit travel.

5.3.3* The required exit access doors of all laboratory work areas within Class C or Class D laboratory units shall be allowed to be installed in accordance with one of the following if permitted by the egress provisions of NFPA *101*:

(1) Swing in the direction of exit travel
(2) Swing against the direction of exit travel
(3) A horizontal sliding door

5.4* Furniture, Casework, and Equipment. Furniture, casework, and equipment in laboratory units shall be arranged so that means of access to an exit can be reached easily from any point.

5.5 Electrical Installation. All electrical installations, including wiring and appurtenances, apparatus, lighting, signal systems, alarm systems, remote control systems, or parts thereof, shall comply with *NFPA 70*.

5.5.1* Electrical receptacles, switches, and controls shall be located so as not to be subject to liquid spills.

5.5.2* Laboratory work areas, laboratory units, and chemical fume hood interiors shall be considered as unclassified electrically with respect to Article 500 of *NFPA 70* unless operations are determined to cause a hazardous atmosphere. *(See 9.5.5 and 11.3.2.2.)*

N **5.5.3 Emergency Lighting.**

Δ **5.5.3.1** Emergency lighting shall be provided for laboratory work areas.

Δ **5.5.3.2** Emergency lighting shall be installed in accordance with Section 7.9 of NFPA *101*.

Chapter 6 Fire Protection

6.1 Automatic Fire Extinguishing Systems.

6.1.1 Automatic Sprinkler Systems.

6.1.1.1 Automatic sprinkler system protection shall be required for all new laboratories in accordance with the following:

(1) Automatic sprinkler system protection for Class A and Class B laboratories shall be in accordance with NFPA 13 for ordinary hazard (Group 2) occupancies.
(2) Automatic sprinkler system protection for Class C and Class D laboratories shall be in accordance with NFPA 13 for ordinary hazard (Group 1) occupancies.

6.1.1.2* Fire sprinklers in laboratory units shall be the quick-response (QR) sprinkler type installed in accordance with NFPA 13.

6.1.1.3 Automatic sprinkler systems shall be regularly inspected, tested, and maintained in accordance with NFPA 25.

6.1.2* Other Automatic Extinguishing Systems.

N **6.1.2.1** Where water will create a serious fire or personnel hazard, a suitable nonwater automatic extinguishing system shall be permitted to be an acceptable substitute for sprinklers.

N **6.1.2.2** Where required or used in place of automatic sprinkler systems, special hazard extinguishing systems and nonwater automatic extinguishing systems shall be designed, installed, and maintained in accordance with NFPA 11, NFPA 12, NFPA 12A, NFPA 15, NFPA 17, NFPA 17A, NFPA 69, NFPA 750, and NFPA 2001, as applicable.

• **6.2 Standpipe and Hose Systems.**

6.2.1* Class I wet standpipe systems shall be installed in laboratory buildings where the floor level of the highest story is located more than 9.14 m (30 ft) above the lowest level of fire department vehicle access, or where the floor level of the lowest story is located more than 9.14 m (30 ft) below the highest level of fire department vehicle access in accordance with NFPA 14.

6.2.2 Standpipe systems shall be regularly inspected, tested, and maintained in accordance with NFPA 25.

6.3 Portable Fire Extinguishers.

6.3.1 Portable fire extinguishers shall be installed, located, and maintained in accordance with NFPA 10.

Δ **6.3.2** For purposes of sizing and placement of fire extinguishers for Class B fires *(see Table 6.3.1.1 of NFPA 10)*, Class A laboratory units shall be rated as extra hazard, and Class B, Class C, and Class D laboratory units shall be rated as ordinary hazard.

6.4 Fire Alarm Systems.

6.4.1 Buildings with laboratory units shall have a manual fire alarm system installed and maintained in accordance with *NFPA 72*.

6.4.2 Automatic fire sprinkler or other extinguishing systems shall activate the fire alarm system.

6.4.3* The fire alarm system shall activate fire alarm notification appliances and notify the fire department.

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6.5 Fire Prevention.

6.5.1 Fire Prevention Procedures.

6.5.1.1 Fire prevention procedures shall be established for all new and existing laboratories.

6.5.1.2 Fire prevention procedures shall include, but not be limited to, the following:

(1) Handling and storage of chemicals, flammable and combustible liquids, pyrophoric and other reactive compounds, and compressed gases
(2) Open flame and spark-producing equipment work permit system
(3) Arrangements and use of portable electrical cords
(4) Smoking area controls

6.5.2* Maintenance Procedures. Maintenance procedures shall be established for all new and existing laboratories.

6.5.3* Emergency Plans.

6.5.3.1 Provisions Within the Emergency Action Plan. Plans for laboratory emergencies shall be established for all new and existing laboratories. The emergency action plan shall include the following procedures in the event of a chemical emergency, fire, or explosion:

(1) Procedures for sounding the alarm
(2) Procedures for notifying and coordinating with the fire department, governmental agencies, or other emergency responders or contacts, as required
(3) Procedures for evacuating and accounting for personnel, as applicable
(4) Procedures for establishing requirements for rescue and medical duties for those requiring or performing these duties
(5) Procedures and schedules for conducting drills
(6) Procedures for shutting down and isolating equipment under emergency conditions to include the assignment of personnel responsible for maintaining critical functions or for shutdown of process operations
(7) Appointment and training of personnel to carry out assigned duties, including steps to be taken at the time of initial assignment, as responsibilities or response actions change, and at the time anticipated duties change
(8) Alternative measures for occupant safety, when applicable
(9) Aisles designated as necessary for movement of personnel and emergency response
(10) Maintenance of fire protection equipment
(11) Safe procedures for startup to be taken following the abatement of an emergency

[**400:** 7.2.3.2]

6.5.3.2* Procedures for extinguishing clothing fires shall be established for all new and existing laboratories.

6.5.3.3* All laboratory users, including, but not limited to, instructors and students, shall be trained prior to laboratory use and at least annually thereafter on the emergency plan.

6.6 Flame-Resistant Clothing.

6.6.1 The provisions of 6.6.2 through 6.6.5 shall apply to all new and existing laboratories.

6.6.2* Flame-resistant lab coats shall be worn where pyrophoric reagents are used outside the inert atmosphere of a glovebox.

6.6.3* Flame-resistant gloves shall be worn whenever possible where pyrophoric reagents are used outside the inert atmosphere of a glovebox.

6.6.4* Natural-fiber clothing shall be worn under flame-resistant lab coats and on the legs and feet where pyrophoric reagents are used outside the inert atmosphere of a glovebox.

6.6.5 Flame-resistant clothing shall meet the requirements of NFPA 2112.

Chapter 7 Laboratory Ventilating Systems and Hood Requirements

7.1* General.

7.1.1 This chapter shall apply to laboratory exhaust systems, including chemical fume hoods, local ventilated enclosures, fume arms, special local exhaust devices, and other systems for exhausting air from laboratory work areas in which flammable gases, vapors, or particulate matter are released.

7.1.2 This chapter shall apply to laboratory air supply systems and shall provide requirements for identification, inspection, and maintenance of laboratory ventilation systems and hoods.

7.2 Basic Requirements.

7.2.1* Laboratory ventilation systems shall be designed to ensure that fire hazards and risks are minimized.

7.2.2 Continuous Ventilation.

N **7.2.2.1*** Laboratory units and laboratory hoods in which chemicals are present shall be continuously ventilated under normal operating conditions.

7.2.2.2 If laboratory exhaust ventilation is out of service or inoperable, all laboratory operations shall be suspended until the deficiency is corrected. All hazardous materials shall be secured in a safe condition or removed from the laboratory during the time that the deficiency exists.

7.2.3* Chemical fume hoods shall not be relied upon to provide explosion (blast) protection unless specifically designed to do so. *(See also C.6.4 and C.6.5 for further information on explosion-resistant hoods and shields.)*

7.2.4 Chemical fume hoods using perchloric acid shall be in accordance with Section 7.12.

7.2.5 Exhaust and supply systems shall be designed to prevent a pressure differential that would impede egress or ingress when either system fails or during a fire or emergency scenario. This design includes reduced operational modes or shutdown of either the supply or the exhaust ventilation system.

7.2.6 The release of chemical vapors into the laboratory shall be controlled by enclosure(s) or captured to prevent any flammable and/or combustible concentrations of vapors from reaching any source of ignition.

7.3 Supply Systems.

7.3.1* Laboratory ventilation systems shall be designed to ensure that chemical fumes, vapors, or gases originating from the laboratory shall not be recirculated. *(See also 7.4.2.)*

7.3.2* The location and configuration of fresh air intakes shall be chosen so as to avoid drawing in chemicals or products of combustion coming either from the laboratory building itself or from other structures and devices.

7.3.3 The air pressure in the laboratory work areas shall be negative with respect to corridors and nonlaboratory areas of the laboratory unit except in the following instances:

(1) Where operations such as those requiring clean rooms preclude a negative pressure relative to surrounding areas, alternate means shall be provided to prevent escape of the atmosphere in the laboratory work area or unit to the surrounding spaces.
(2) The desired static pressure level with respect to corridors and nonlaboratory areas shall be permitted to undergo momentary variations as the ventilation system components respond to door openings, changes in chemical fume hood sash positions, and other activities that can for a short term affect the static pressure level and its negative relationship.
(3) Laboratory work areas located within a designated electrically classified hazardous area with a positive air pressure system as described in NFPA 496 in accordance with Chapter 7, Pressurized Control Rooms, shall be permitted to be positive with respect to adjacent corridors.

7.3.4* The location of air supply diffusion devices shall be chosen so as to avoid air currents that would adversely affect the performance of chemical fume hoods, exhaust systems, and fire detection or fire-extinguishing systems. *(See Sections 6.1, and 6.4, and 7.9.1.)*

N **7.3.5*** Openings in fire-rated floor/ceiling and wall assemblies for supply air-handling ducts shall be protected in accordance with NFPA 90A.

7.4 Exhaust Air Discharge.

7.4.1* Air exhausted from chemical fume hoods and other special local exhaust systems shall not be recirculated. *(See also 7.3.1.)*

7.4.2* Energy Conservation Devices.

7.4.2.1 If energy conservation devices are used, they shall be designed in accordance with 7.3.1 and 7.3.2.

Δ **7.4.2.2*** Energy conservation devices shall only be used in a laboratory ventilation system when evaluated and approved by a qualified person. These systems must meet, or exceed, the criteria established by Section 5.4.7 and Section 5.4.7.1 of ANSI/AIHA Z9.5, *Laboratory Ventilation*. Systems that recirculate within their respective laboratory work area, such as fan coil units for sensible heat loads, are exempt from these requirements.

7.4.2.3* Energy conservation devices shall be designed and installed in a manner that safely facilitates anticipated service and maintenance requirements and does not adversely impact the proper operation of the exhaust system.

7.4.3 Air exhausted from laboratory work areas shall not pass unducted through other areas.

7.4.4* Air from laboratory units and laboratory work areas in which chemicals are present shall be continuously discharged through duct systems maintained at a negative pressure relative to the pressure of normally occupied areas of the building.

7.4.5 Positive pressure portions of the lab hood exhaust systems (e.g., fans, coils, flexible connections, and ductwork) located within the laboratory building shall be sealed airtight or located in a continuously mechanically ventilated room.

7.4.6 Chemical fume hood face velocities and exhaust volumes shall be sufficient to contain contaminants generated within the hood and exhaust them outside of the laboratory building.

7.4.7* The hood shall provide containment of the possible hazards and protection for personnel at all times when chemicals are present in the hood.

7.4.8 Special local exhaust systems, such as snorkels or "elephant trunks," shall have sufficient capture velocities to entrain the chemical being released.

7.4.9* Canopy hoods, laminar flow cabinets, and ductless enclosures shall not be used in lieu of chemical fume hoods.

Δ **7.4.10** Only Class II, Type B2 biological safety cabinets listed by a nationally recognized testing laboratory as meeting NSF/ANSI 49, *Biosafety Cabinetry: Design, Construction, Performance, and Field Certification*, shall be permitted to be used in lieu of chemical fume hoods, as determined by a qualified person.

7.4.11* Air exhausted from chemical fume hoods and special exhaust systems shall be discharged above the roof at a location, height, and velocity sufficient to prevent re-entry of chemicals and to prevent exposures to personnel.

7.5 Duct Construction for Hoods and Local Exhaust Systems.

7.5.1 Ducts from chemical fume hoods and from local exhaust systems shall be constructed entirely of noncombustible materials except in the following cases:

(1) Flexible ducts of combustible construction shall be permitted to be used for special local exhaust systems within a laboratory work area. *(See 7.5.2.)*
(2) Combustible ducts shall be permitted to be used if enclosed in a shaft of noncombustible or limited-combustible construction where they pass through nonlaboratory areas or through laboratory units other than the one they serve. *(See 7.5.2.)*
(3) Combustible ducts shall be permitted to be used if all areas through which they pass are protected with an

approved automatic fire-extinguishing system, as described in Chapter 6. *(See 7.5.2.)*

7.5.2 Combustible ducts or duct linings shall have a flame spread index of 25 or less when tested in accordance with ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, or ANSI/UL 723, *Standard for Test for Surface Burning Characteristics of Building Materials*. Test specimens shall be of the minimum thickness used in the construction of the duct or duct lining.

7.5.3 Sound attenuation devices, linings, and coatings containing such fill as fiberglass, mineral wool, foam, or other similar material that could accumulate chemical deposits shall not be permitted within laboratory exhaust systems.

7.5.4 Duct systems for perchloric acid hoods shall be constructed in accordance with Section 7.12.

7.5.5 Ducts shall be of adequate strength and rigidity to meet the conditions of service and installation requirements and shall be protected against mechanical damage.

7.5.6 Materials used for vibration isolation connectors shall comply with 7.5.2.

7.5.7 Flexible connectors containing pockets in which conveyed material can collect shall not be used in any concealed space or where strong oxidizing chemicals (e.g., perchloric acid) are used.

7.5.8 Hand holes, where installed for damper, sprinkler, or fusible link inspection or resetting and for residue clean-out purposes, shall be equipped with tight-fitting covers provided with substantial fasteners.

7.5.9 Manifolding of Chemical Fume Hood and Ducts.

7.5.9.1 Exhaust ducts from each laboratory unit shall be separately ducted to a point outside the building, to a mechanical room, or to a shaft. *(See 5.1.4 and 7.5.10.)*

7.5.9.2 Connection to a common chemical fume hood exhaust duct system shall be permitted to occur within a building only in the following locations:

(1) A mechanical room, not connected to a shaft, shall be protected in accordance with Table 5.1.1
(2) A shaft or a mechanical room connected to a shaft, shall be protected in accordance with the chapter on protection of vertical openings of NFPA *101*
(3) A point outside the building

7.5.9.3 Exhaust ducts from chemical fume hoods and other exhaust systems within the same laboratory unit shall be permitted to be combined within that laboratory unit. *(See 7.4.1.)*

Δ **7.5.10*** The design and installation of laboratory exhaust ducts shall be in accordance with NFPA 91 except that the requirements in 7.5.10.1 through 7.5.12 shall take precedence.

7.5.10.1 Dampers.

N **7.5.10.1.1** Controls and dampers, where required for balancing or control of the exhaust system, shall be of a type that, in the event of failure, will fail open to ensure continuous draft.

7.5.10.1.2* Automatic fire dampers shall not be used in laboratory exhaust systems.

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N **7.5.10.2 Ductwork.**

N **7.5.10.2.1** A duct conveying laboratory exhaust that passes through a fire barrier shall provide an alternative means of protection equal to or greater than the rating through which the duct passes by one of the following or in accordance with 7.5.10.2.2:

(1) Wrapped or encased with listed or approved materials having a fire resistance rating equal to the fire barrier for 10 ft (3 m) of the duct on each side of the fire barrier including duct supports within this span [**91:**4.2.12(1)]
(2) Constructed of materials and supports having a minimum fire resistance rating equal to the fire barrier [**91:**4.2.12(2)]
(3) Enclosed with a shaft that is constructed of material having a fire resistance rating equal to the fire barrier for 10 ft (3 m) of the duct on each side of the fire barrier with no inlets to the duct within this distance, and the duct entry into and exit from the shaft is protected in accordance with 4.2.13 of NFPA 91 [**91:**4.2.12(3)]

N **7.5.10.2.2** If not protected in accordance with 7.5.10.2.1, when an exhaust duct enters an exhaust shaft, the penetration shall be protected by all of the following:

(1) Branch ducts connect to enclosed exhaust risers meeting the requirements of 5.3.4.1 or 5.3.4.4 of NFPA 90A. [**90A:** 5.3.4.6.2(1)]
(2) The airflow moves upward. [**90A:**5.3.4.6.2(2)]
(3)* Steel subducts at least 560 mm (22 in.) in length are carried up inside the riser from each inlet. [**90A:** 5.3.4.6.2(3)]
(4) The riser is appropriately sized to accommodate the flow restriction created by the subduct. [**90A:**5.3.4.6.2(4)]

7.5.11 Fire detection and alarm systems shall not be interlocked to automatically shut down laboratory exhaust fans.

7.5.12 Door operation for egress shall be maintained when the supply system shuts down and the lab exhaust system operates, creating a pressure differential.

7.6* Duct Velocities. Duct velocities of laboratory exhaust systems shall be high enough to minimize the deposition of liquids or condensable solids in the exhaust systems during normal operations in the chemical fume hood.

7.6.1 If dirt, dust, or particulate generation in significant amounts is expected in a hood, then other measures such as separate dust filtration systems shall be required.

7.6.2 If significant amounts of condensable vapors are generated in the hood, then other measures such as condensing systems for condensate traps shall be provided.

7.7 Exhausters (Fans), Controls, Velocities, and Discharge.

7.7.1 Fans shall be selected to meet requirements for fire, explosion, and corrosion.

7.7.2 Fans conveying both corrosive and flammable or combustible materials shall be permitted to be lined with or constructed of corrosion-resistant materials having a flame spread index of 25 or less when tested in accordance with ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, or ANSI/UL 723, *Standard for Test for Surface Burning Characteristics of Building Materials.*

7.7.3 Fans shall be located and arranged so as to afford ready access for repairs, cleaning, inspection, and maintenance.

7.7.4* Where flammable gases, flammable vapors, or combustible dusts are passed through the fans, the rotating element shall be of nonferrous or spark-resistant construction; alternatively, the casing shall be constructed of or lined with such material.

7.7.4.1 Where there is the possibility of solid material passing through the fan that would produce a spark, both the rotating element and the casing shall be constructed of such material.

7.7.4.2 Nonferrous or spark-resistant materials shall have a flame spread index of 25 or less when tested in accordance with ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, or ANSI/UL 723, *Standard for Test for Surface Burning Characteristics of Building Materials*.

7.7.5 Motors and their controls shall be located outside the location where flammable or combustible vapors or combustible dusts are generated or conveyed, unless specifically approved for that location and use.

7.7.6* Fans shall be marked with an arrow or other means to indicate direction of rotation and with the location of chemical fume hoods and exhaust systems served.

7.8 Chemical Fume Hood Requirements.

7.8.1 Chemical Fume Hood Interiors.

7.8.1.1* Materials of construction used for the interiors of new chemical fume hoods or for the modification of the interiors of existing chemical fume hoods shall have a flame spread index of 25 or less when tested in accordance with ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, or ANSI/UL 723, *Standard for Test for Surface Burning Characteristics of Building Materials*, unless the interior of the hood is provided with automatic fire protection in accordance with 7.10.2.

7.8.1.2 Chemical fume hoods shall meet the requirements of UL 1805, *Standard for Safety Laboratory Hoods and Cabinets*, or other approved standards.

7.8.1.3* Baffles shall be constructed so that they are unable to be adjusted to materially restrict the volume of air exhausted through the chemical fume hood.

7.8.1.4* Chemical fume hoods shall be provided with a means of preventing overflow of a spill of 2 L (0.5 gal) of liquid.

7.8.2* Chemical Fume Hood Sash Glazing. The sash, if provided, shall be glazed with material that will provide protection to the operator against the hazards associated with the use of the hood. *(See also Annex C and the sash requirements of UL 1805, Standard for Laboratory Hoods and Cabinets.)*

7.8.3* Chemical Fume Hood Sash Closure.

7.8.3.1 Chemical fume hood sashes shall be kept closed whenever possible.

7.8.3.2* Where a fume hood is unattended, its sash shall remain fully closed.

7.8.4* Electrical Devices.

7.8.4.1 In installations where services and controls are within the hood, additional electrical disconnects shall be located within 15 m (50 ft) of the hood and shall be accessible and clearly marked.

7.8.4.2 If electrical receptacles are located external to the hood, no additional electrical disconnect shall be required. *(See 5.5.1.)*

7.8.5 Other Hood Services.

7.8.5.1 For new installations or modifications of existing installations, controls for chemical fume hood services (gas, air, water, etc.) shall be located external to the hood and within easy reach.

7.8.5.2 In existing installations where service controls are within the hood, additional shutoffs shall be located within 15 m (50 ft) of the hood and shall be accessible and clearly marked.

7.8.6 Auxiliary Air. For auxiliary air hoods, auxiliary air shall be introduced exterior to the hood face in such a manner that the airflow does not compromise the protection provided by the hood and so that an imbalance of auxiliary air to exhaust air will not pressurize the hood interior.

N **7.8.7 Hood Proper Function Alarm.**

N **7.8.7.1*** A measuring device for indicating that the hood airflow remains within safe design limits shall be provided on each chemical fume hood.

7.8.7.2* The measuring device for hood airflow shall be a permanently installed device and shall provide continuous indication to the hood user of adequate airflow and alert inadequate hood airflow by a combination of an audible and visual alarm. Where an audible alarm could compromise the safety of the user or the research, alternative means of alarm shall be considered.

7.9 Chemical Fume Hood Location.

7.9.1* Chemical fume hoods shall be located in areas of minimum air turbulence.

7.9.2 Chemical fume hoods shall not be located adjacent to a single means of access to an exit or to high-traffic areas.

7.9.3* Work stations not directly related to the chemical fume hood activity shall not be located directly in front of chemical fume hood openings.

7.10 Chemical Fume Hood Fire Protection.

7.10.1* Automatic fire extinguishing systems shall be provided in chemical fume hoods in the following cases:

(1) Existing hoods having interiors with a flame spread index greater than 25 in which flammable liquids are handled
(2) If a hazard assessment determines that an automatic extinguishing system is required for the chemical fume hood, then the applicable automatic fire protection system standard shall be followed.

7.10.2 Automatic Fire Protection Systems.

N **7.10.2.1*** Automatic fire protection systems, where provided, shall comply with NFPA 11, NFPA 12, NFPA 12A, NFPA 13, NFPA 15, NFPA 17, NFPA 17A, NFPA 69, NFPA 750, and NFPA 2001, as applicable.

7.10.2.2 The fire extinguishing system shall be designed to extinguish fires within the chemical fume hood under the anticipated conditions of use.

7.10.3 Chemical fume hoods equipped with control systems that vary the hood exhaust airflow as the sash opening varies and/or in conjunction with whether the laboratory room is in use (occupied or unoccupied) shall be equipped with a user-accessible means to attain maximum exhaust hood airflow regardless of sash position when necessary or desirable to ensure containment and removal of a potential hazard within the hood.

7.10.4* Chemical fume hoods shall be installed in a manner that prevents fire or smoke from a fire in the chemical fume hood from spreading into the voids above the ceiling.

7.11* Inert Atmosphere Glove Boxes.

7.11.1* Glove boxes shall be designed and operated in accordance with Section 4.1 of ANSI/AIHA Z9.5, *Laboratory Ventilation.*

7.11.2 Glove boxes that are vented shall be vented to the chemical exhaust system.

7.11.3 Glove boxes shall be operated at a positive pressure to keep air and water vapor out of the glove box.

7.11.4 Glove boxes shall be provided with pressure control to limit the pressure inside them.

7.11.5 Pressure relief shall be provided for glove boxes. Reliance on component failure, such as glove blowout, is not considered pressure relief.

7.12 Perchloric Acid Hoods.

7.12.1 Chemical Fume Hood Design.

N **7.12.1.1*** Perchloric acid heated above ambient temperatures shall only be used in a chemical fume hood specifically designed for its use and identified as follows:

FOR PERCHLORIC ACID OPERATIONS

7.12.1.2* Perchloric acid shall be permitted to be used in a chemical fume hood that is not specifically designed for perchloric acid operations where the vapors are trapped and scrubbed before they are released into the hood.

7.12.2 Perchloric acid hoods and exhaust ductwork shall be constructed of materials that are acid resistant, nonreactive, and impervious to perchloric acid.

7.12.3 The exhaust fan shall be acid resistant and spark resistant.

7.12.4 The exhaust fan motor shall not be located within the ductwork.

7.12.5 Drive belts shall be conductive and shall not be located within the ductwork.

7.12.6 Ductwork for perchloric acid hoods and exhaust systems shall take the shortest and straightest path to the outside of the building and shall not be manifolded with other exhaust systems.

7.12.6.1 Horizontal runs shall be as short as possible, with no sharp turns or bends.

7.12.6.2 The ductwork shall provide a positive drainage slope back into the hood.

7.12.6.3 Ductwork shall consist of sealed sections.

7.12.6.4 Flexible connectors shall not be used.

7.12.7 Sealants, gaskets, and lubricants used with perchloric acid hoods, ductwork, and exhaust systems shall be acid resistant and nonreactive with perchloric acid.

7.12.8* A water spray system shall be provided for washing down the hood interior behind the baffle and the entire exhaust system.

7.12.8.1 The hood work surface shall be watertight with a minimum depression of 13 mm (½ in.) at the front and sides.

7.12.8.2 An integral trough shall be provided at the rear of the hood to collect washdown water.

7.12.9 The hood baffle shall be removable for inspection and cleaning.

7.12.10* If a chemical fume hood or exhaust system was used for perchloric acid heated above ambient temperature, tests shall be conducted for explosive perchlorates before any inspection, cleaning, maintenance, or any other work is done on any part of the exhaust system or hood interior.

7.12.11 Prior to using a perchloric acid hood for any purpose, the hood shall be water-washed and shall be tested according to 7.12.9 to ensure residual perchlorates are not present.

7.13 Identification of Chemical Fume Hood Systems.

7.13.1* Special-use chemical fume hoods and special-use local exhaust systems shall be identified to indicate their intended use.

7.13.2 A sign containing the following information from the last inspection shall be affixed to each hood, or a properly maintained log of all hoods providing the following information shall be maintained:

(1) Inspection interval
(2) Last inspection date
(3) Average face velocity
(4) Location of fan that serves hood
(5) Inspector's name

7.14 Inspection, Testing, and Maintenance.

7.14.1* When installed or modified and at least annually thereafter, chemical fume hoods, chemical fume hood exhaust systems, and laboratory special exhaust systems shall be inspected and tested as applicable, as follows:

(1) Visual inspection of the physical condition of the hood interior, sash, and ductwork *(see C.2.6.3)*
(2) Measuring device for hood airflow
(3) Low airflow and loss-of-airflow alarms at each alarm location
(4) Face velocity
(5) Verification of inward airflow over the entire hood face
(6) Changes in work area conditions that might affect hood performance

7.14.2 Deficiencies in hood performance shall result in immediate suspension of all activities inside the hood until the deficiencies are corrected.

7.14.3 Chemical fume hood face velocity profile or hood exhaust air quantity shall be checked after any adjustment to the ventilation system balance.

7.14.4 Detectors and Alarms.

7.14.4.1 Air system flow detectors, if installed, shall be inspected and tested annually.

7.14.4.2 Where potentially corrosive or obstructive conditions exist, the inspection and test frequency shall be increased.

7.14.5 Fans and Motors.

7.14.5.1* Air supply and exhaust fans, motors, and components shall be inspected at least annually.

7.14.5.2 Where airflow detectors are not provided or airflow-rate tests are not made, fan belts shall be inspected quarterly; double sheaves and belts shall be permitted to be inspected semiannually.

7.14.5.3 Frayed or broken belts shall be replaced promptly.

7.14.6 Fixed fire-extinguishing systems within ductwork or chemical fume hoods shall be inspected, tested, and maintained according to the applicable standard.

Chapter 8 Chemical Storage, Handling, and Waste Disposal

N **8.1 General.** This chapter shall apply to new and existing laboratories.

8.2* Ordering Procedures.

8.2.1 When a chemical is ordered, steps shall be taken to determine its hazards and to transmit that information to those who will receive, store, use, or dispose of the chemical.

8.2.2 Restrictions imposed by governmental regulations and in-house rules shall be followed.

8.3 Handling and Storage.

8.3.1 Chemical Inventories. Handling and storage of chemicals shall be in accordance with NFPA 400, except as specifically modified in Chapters 8 and 9.

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8.3.2 Facilities.

8.3.2.1 Chemicals shall not be brought into a laboratory work area unless the design, construction, and fire protection of receiving and storage facilities are commensurate with the quantities and hazards of chemicals involved.

8.3.2.2 Safe storage facilities shall be provided for materials that have unique physical or hazardous properties, such as temperature sensitivity, water reactivity, or explosibility. *(See A.8.2 for sources of additional information.)*

8.3.2.3 Hazardous chemical containers stored and handled in laboratory work areas shall not exceed 20 L (5 gal).

8.3.3 Handling.

8.3.3.1* Receiving, transporting, unpacking, and dispensing of chemicals and other hazardous materials shall be carried out by trained personnel in such locations and in such a manner as to minimize hazards from flammable, reactive, or toxic materials.

8.3.3.2* Materials of construction for ducts, piping, and vessels shall be compatible with materials to be transferred or handled.

8.3.3.3 Before a chemical material is used, the user shall determine that information and facilities are available for safe disposal of hazardous materials and waste products.

8.3.3.4 Class I liquids shall not be transferred from one vessel to another in any exit access corridor.

8.3.3.5 Pressurized liquid dispensing containers containing chemicals shall be in accordance with Section 9.4.

8.3.3.6 Chemical quantities outside of storage shall be maintained at the lowest possible level necessary for the work performed.

8.3.3.7 Handling and storage of chemicals shall conform to the manufacturers' recommendations and safety data sheet (SDS).

8.3.4 Storage.

8.3.4.1* Chemical inventories in each laboratory unit shall be maintained within the maximum allowable quantities specified in the applicable fire code or building code except as modified in Chapter 9 for buildings with more than three stories.

8.3.4.1.1 Maximum allowable quantities shall be reduced by 50 percent for Class B laboratory units located above the third floor.

8.3.4.1.2 Maximum allowable quantities shall be reduced by 25 percent for Class C and Class D laboratory units located on the fourth through sixth floors of a building.

8.3.4.1.3 Maximum allowable quantities shall be reduced by 50 percent for Class C and Class D laboratory units located above the sixth floor.

8.3.4.2* Incompatible materials shall be segregated to prevent accidental contact with one another.

8.3.4.3* Class I flammable liquids and Class II combustible liquids that are not in use inside of laboratory units shall be stored in safety cans; in approved storage cabinets constructed in accordance with NFPA 30, ANSI/UL 1275, *Standard for Flammable Liquid Cabinets*, or other approved standards; or in an inside liquid storage area.

8.3.4.4* Containers of materials that might become hazardous (i.e., time sensitive) during prolonged storage shall be dated when first opened, and properly managed.

8.3.4.4.1* Proper management shall consist of the following elements:

(1) Defining those materials present that are time sensitive
(2) Defining each time-sensitive material's inspection frequency
(3) Defining proper or approved inspection methodologies to determine the relative hazard of the time-sensitive material
(4) Defining pass/fail criteria for inspection results

8.3.4.4.2 Time-sensitive materials that pass inspection shall be permitted to be redated and retained for an additional defined inspection period.

8.3.4.4.3 All other material shall be safely discarded.

8.3.4.5* Storage cabinets used in laboratories shall not be required to be vented for fire protection purposes.

Δ **8.3.4.6** Chemical storage shall be inspected at least annually to ensure compliance with the provisions of Chapter 8.

8.3.4.7 Storage of chemicals in the fume hood shall be prohibited.

8.4 Waste Handling and Disposal.

8.4.1 Waste Chemicals.

N **8.4.1.1** Waste chemicals shall be handled and stored according to the requirements in Section 8.3 and NFPA 400.

Δ **8.4.1.2** Combustible waste materials and refuse as defined in NFPA 1 *(see 3.3.62 and 3.3.63)*, and NFPA 400 *(see 3.3.91)*, shall be handled in accordance with Chapter 19 of NFPA 1.

8.4.2* Waste chemicals shall not be combined or mixed with other waste chemicals unless they have been evaluated for compatibility by a qualified person.

8.4.3 Chemical waste containers shall be labeled with the hazards of the waste chemicals.

8.4.4 Liquid waste containers stored in laboratory work areas shall not exceed 20 L (5 gal).

8.4.5 Waste quantities shall be subject to the maximum container sizes and type in accordance with Table 9.1.2.

8.4.6 Waste quantities shall be subject to the maximum allowable quantity for the laboratory unit.

Chapter 9 Flammable and Combustible Liquids

9.1 Quantity Limitations.

9.1.1 The density and total amount of flammable and combustible liquids, including waste, in laboratory work areas and in the laboratory unit outside of flammable liquid storage rooms shall not exceed the quantities presented in Table 9.1.1(a) and Table 9.1.1(b) for the respective class of laboratory.

9.1.2* Container types and maximum capacities for flammable and combustible liquids shall comply with Table 9.1.2 except as follows:

(1) Glass containers as large as 4 L (1 gal) shall be permitted to be used if all the following conditions are present:
   (a) Excessive corrosion or degradation of a metal or an approved plastic container would result.
   (b) The glass container size allowed in Table 9.1.2 is not available.
   (c) The glass containers are required for purity purposes.
(2) Containers of not more than 227 L (60 gal) capacity shall be permitted in a separate area inside the building if the inside area meets the requirements of NFPA 30.
(3) In educational and instructional laboratory work areas, containers for Class I or Class II liquids shall not exceed the following capacity:
   (a) Safety cans of 8 L (2.1 gal)
   (b) Other containers of 4 L (1 gal)

Δ **Table 9.1.1(a) Maximum Quantities of Flammable and Combustible Liquids in Laboratory Units Outside of Inside Liquid Storage Areas (Metric)**

Laboratory Unit Fire Hazard Class	Flammable and Combustible Liquid Class[a]	Quantities in Use[a]		Quantities in Use and Storage[a]	
		Maximum Quantity[b] per 9.3 m^2 of Laboratory Unit[c] (L)	Maximum Quantity[b] per Laboratory Unit (L)	Maximum Quantity[b] per 9.3 m^2 of Laboratory Unit[c] (L)	Maximum Quantity[b] per Laboratory Unit (L)
A (high fire hazard)	I	38	1820	76	1820
	I, II, and IIIA	76	3028	150	6060
B[d] (moderate fire hazard)	I	20	1136	38	1820
	I, II, and IIIA	38	1515	76	3028
C[e] (low fire hazard)	I	7.5	570	15	1136
	I, II, and IIIA	15	757	30	1515
D[e] (minimal fire hazard)	I	4	284	7.5	570
	I, II, and IIIA	4	284	7.5	570

Note: For maximum container sizes, see Table 9.1.2.
[a]The maximum amount in use in open systems is limited to 10 percent of the quantities listed. Flammable and combustible liquid in a safety can or approved storage cabinet and not physically connected to equipment is considered to be in storage; otherwise the liquids are considered to be in use. PLDCs are always considered to be in use.
[b]See Section 4.2 for additional requirements for educational and instructional laboratory units, and laboratory units in health care facilities.
[c]The quantities per 9.3 m^2 do not imply the quantities must be within that 9.3 m^2 area; the quantities per 9.3 m^2 are for calculation purposes to determine the total quantity allowed per laboratory work area and the total amount overall in the laboratory unit.
[d]Reduce quantities by 50 percent for B laboratory units located above the 3rd floor.
[e]Reduce quantities by 25 percent for C and D laboratory units located on the 4th–6th floors of a building, and reduce quantities by 50 percent for C and D laboratory units located above the 6th floor.

Δ Table 9.1.1(b) Maximum Quantities of Flammable and Combustible Liquids in Laboratory Units Outside of Inside Liquid Storage Areas (U.S. Customary Units)

		Quantities in Use[a]		Quantities in Use and Storage[a]	
Laboratory Unit Fire Hazard Class	Flammable and Combustible Liquid Class[a]	Maximum Quantity[b] per 100 ft^2 of Laboratory Unit[c] (gal)	Maximum Quantity[b] per Laboratory Unit (gal)	Maximum Quantity[b] per 100 ft^2 of Laboratory Unit[c] (gal)	Maximum Quantity[b] per Laboratory Unit (gal)
A	I	10	480	20	480
(high fire hazard)	I, II, and IIIA	20	800	40	1600
B[d]	I	5	300	10	480
(moderate fire hazard)	I, II, and IIIA	10	400	20	800
C[e]	I	2	150	4	300
(low fire hazard)	I, II, and IIIA	4	200	8	400
D[e]	I	1	75	2	150
(minimal fire hazard)	I, II, and IIIA	1	75	2	150

Note: For maximum container sizes, see Table 9.1.2.
[a]The maximum amount in use in open systems is limited to 10 percent of the quantities listed. Flammable and combustible liquid in a safety can or approved storage cabinet and not physically connected to equipment is considered to be in storage; otherwise the liquids are considered to be in use. PLDCs are always considered to be in use.
[b]See Section 4.2 for additional requirements for educational and instructional laboratory units, and laboratory units in health care facilities.
[c]The quantities per 100 ft^2 do not imply the quantities must be within that 100 ft^2 area; the quantities per 100 ft^2 are for calculation purposes to determine the total quantity allowed per laboratory work area and the total amount overall in the laboratory unit.
[d]Reduce quantities by 50 percent for B laboratory units located above the 3rd floor.
[e]Reduce quantities by 25 percent for C and D laboratory units located on the 4th–6th floors of a building, and reduce quantities by 50 percent for C and D laboratory units located above the 6th floor.

Table 9.1.2 Maximum Allowable Container Capacity

	Flammable Liquids[a]			Combustible Liquids[a]	
Container Type	IA	IB	IC	II	IIIA
Glass	500 mL (1 pt)[b]	1 L (1 qt)[b]	4 L (1 gal)	4 L (1 gal)	20 L (5 gal)
Metal (other than DOT/UN drums) or approved plastic	4 L (1 gal)	20 L (5 gal)[c]	20 L (5 gal)[c]	20 L (5 gal)[c]	20 L (5 gal)
Safety cans	10 L (2.6 gal)[c]	20 L (5 gal)[c]	20 L (5 gal)[c]	20 L (5 gal)[c]	20 L (5 gal)
Metal container (DOT/UN specification)	4 L (1 gal)	20 L (5 gal)[c]	20 L (5 gal)[c]	227 L (60 gal)[c]	227 L (60 gal)
Polyethylene (DOT Specification 34, UN 1H1, or as authorized by DOT special permit)	4 L (1 gal)	20 L (5 gal)[c]	20 L (5 gal)[c]	227 L (60 gal)[c]	227 L (60 gal)
Pressurized liquid dispensing container	20 L (5 gal)	227 L (60 gal)	227 L (60 gal)	227 L (60 gal)	227 L (60 gal)

Note: This table is based on Table 9.4.3 of NFPA 30, except for allowable quantities of flammable liquids in metal (DOT/UN specification) drums and pressurized liquid dispensing containers.
[a]See B.1 for definitions of the various classes of flammable and combustible liquids.
[b]See 9.1.2(1) and A.9.1.2.
[c]See 9.1.2(3).

N **9.1.3** Inside liquid storage areas shall be in accordance with Chapter 9 of NFPA 30.

9.2 Supply Piping. Supply piping for flammable and combustible liquid supply systems shall comply with NFPA 30.

9.3 Liquid Dispensing.

9.3.1* Dispensing of Class I liquids to or from containers less than or equal to 20 L (5 gal) in capacity shall be performed in one of the following locations:

(1) In a chemical fume hood
(2)* In an area provided with ventilation adequate to prevent accumulations of flammable vapor/air mixtures from exceeding 25 percent of the lower flammable limit
(3) Inside liquid storage areas specifically designed and protected for dispensing Class I flammable liquids that meet the requirements of NFPA 30

9.3.2* Except for pressurized liquid dispensing containers meeting the requirements of Section 9.4, dispensing of Class I liquids to or from containers greater than 20 L (5 gal) shall be performed in one of the following locations:

(1) In a separate area outside the building
(2) Inside liquid storage areas specifically designed and protected for dispensing Class I flammable liquids that meet the requirements of NFPA 30

9.3.3* Class I liquids shall not be transferred between conductive containers of greater than 4 L (1 gal) capacity unless the containers are electrically interconnected by direct bonding or by indirect bonding through a common grounding system.

9.3.4 When dispensing Class I liquids involves nonconductive containers larger than 4 L (1 gal), which can be difficult to bond or ground, special dispensing procedures commensurate with the electrical characteristics of the liquid shall be developed and implemented.

9.4 Pressurized Liquid Dispensing Containers (PLDC).

9.4.1 Pressurized liquid dispensing containers used for flammable and combustible liquids shall be listed or labeled for their intended use by a nationally recognized testing laboratory.

9.4.2 Nonmetallic containers larger than 4 L (1 gal) shall not be used.

9.4.3* Relief devices shall discharge to a safe location, in accordance with the manufacturer's recommendation.

9.4.4 The piping/hose between the container and the use point shall be rated for the pressure, compatible with the materials being transferred, and not subject to mechanical damage.

9.4.5 Prior to pressurizing the system, all fittings and connections shall be secure and leak free.

9.4.6* A readily accessible means to stop the flow of liquid from the container shall be provided.

9.4.7 Containers shall be pressurized only with nitrogen or inert gas; air shall not be used.

9.4.8 A means to prevent backflow into the gas supply system shall be provided.

9.5 Equipment.

9.5.1 Storage cabinets used for the storage of flammable and combustible liquids shall be constructed in accordance with NFPA 30.

9.5.2 Flammable liquids stored in refrigerated equipment shall be stored in closed containers. *(See 11.3.2.)*

9.5.3* Laboratory heating equipment such as ovens, furnaces, environmental chambers, and other heated enclosures shall not be used to heat, store, or test flammable or combustible liquids or aerosols containing flammable gases unless the equipment is designed by the manufacturer for that purpose or modified by a qualified person to prevent internal explosion.

9.5.4 Baths handling flammable liquids or combustible liquids heated to their flash points shall be placed in a chemical fume hood or shall be vented to a safe location to control vapors.

9.5.5 Electric motors shall be suitable for Class I, Division 2, locations when flammable and combustible liquids or flammable gas concentrations can produce hazardous concentrations of flammable mixtures.

9.5.6 Electric motors that are located in chemical hoods or provided with special ventilation that will prevent flammable concentrations of gases or vapors from reaching the motor shall not be required to be listed or labeled for Class I, Division 2, hazardous locations.

Chapter 10 Compressed and Liquefied Gases

10.1 Compressed and Liquefied Gases in Cylinders.

10.1.1 Cylinders shall be handled only by trained personnel. *(See Annex E and Annex F.)*

10.1.2* Cylinders, except nominal 0.5 kg (1 lb) propane cylinders made for consumer use, that are not necessary for current laboratory requirements shall be stored outside the laboratory unit in accordance with NFPA 55.

10.1.3* Any compressed gas cylinder or container used at gauge pressures over 103 kPa (15 psi) shall be fabricated to the specifications of or authorized for use by the U.S. DOT, T.C., or Section VIII of the ASME *Boiler and Pressure Vessel Code.*

10.1.3.1 The container shall be marked to show the authorizing code and its working pressure at 21°C (70°F).

10.1.3.2 Vessels whose physical size, operating pressure, or both, are outside the scope of the referenced code(s) shall be designed and constructed in accordance with the philosophy and guidance of the ASME *Boiler and Pressure Vessel Code* by a qualified person and shall not require marking.

10.1.4 Special Ventilation Requirements for Gas Cylinders.

10.1.4.1 Cylinders of the following gases located in laboratory units shall be kept in NFPA 55–compliant gas rooms, approved gas cabinets, or exhausted enclosures:

(1) All gases that are classified as toxic or highly toxic by NFPA 55
(2) Pyrophoric gases
(3) Carbon monoxide

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N **10.1.4.2*** Lecture bottle cylinders of any gas shall be permitted to be kept in chemical fume hoods.

Δ **10.1.4.3** Cylinders of pyrophoric gases that are greater than lecture bottle size that are located in laboratory units shall be kept in approved sprinklered gas cabinets.

10.1.5 Cylinder Safety.

10.1.5.1* Cylinders shall be secured from tipping over by holders designed for that service.

10.1.5.2 Cylinders in the laboratory shall be equipped with a pressure regulator designed for the specific gas and marked for its maximum cylinder pressure.

10.1.5.2.1 The regulator system shall be equipped with two gauges, either on the regulator or remote from the regulator, installed so as to show both the cylinder pressure and the outlet pressure.

10.1.5.2.2 Where the source cylinder is outside of the laboratory work area, a station regulator and inlet pressure gauge shall be installed at the point of use.

10.1.5.3 Cylinders shall have a manual shutoff valve. A quick connect shall not be used in place of a shutoff valve.

10.1.6 Cylinders in Use.

10.1.6.1 Cylinders, when in use, shall be connected to gas delivery systems designed by a qualified person.

10.1.6.2 Cylinders shall be attached to an instrument for use by means of a regulator.

10.1.6.3 A compressed gas cylinder shall be considered to be "in use" if it is in compliance with one of the following:

(1) Connected through a regulator to deliver gas to a laboratory operation
(2) Connected to a manifold being used to deliver gas to a laboratory operation
(3) A single cylinder secured alongside the cylinder described in 10.1.6.3(1) as the reserve cylinder for the cylinder described in 10.1.6.3(1)

10.1.6.4 Cylinders not "in use" shall not be stored in the laboratory unit.

10.1.6.5 The quantity of compressed and liquefied gases in Class A, Class B, and Class C laboratory units shall be in accordance with the amounts listed in Table 6.3.1.1 of NFPA 55.

10.1.6.6 The quantity of compressed and liquefied gases in lecture bottle cylinders in Class A, Class B, and Class C laboratory units shall be limited to 50 percent of the amounts listed in Table 6.3.1.1 of NFPA 55.

10.1.6.7 The quantity of compressed and liquefied gases in Class D laboratory units shall be limited to 50 percent of the amounts listed in Table 6.3.1.1 of NFPA 55.

Δ **10.1.6.8** In instructional laboratory units, the quantity of compressed and liquefied gases shall be limited to 10 percent of the amounts listed in Table 6.3.1.1 of NFPA 55.

10.1.6.9 In educational laboratory work areas, the quantity of compressed and liquefied gases shall be limited as follows:

(1) The maximum quantity of flammable gas shall not exceed 2.8 m^3 (100 ft^3).
(2) The maximum quantity of oxidizing gas shall not exceed 2.8 m^3 (100 ft^3).
(3) A maximum of two 0.5 kg (1 lb) liquefied flammable gas cylinders shall be permitted.
(4) Gases classified as toxic or highly toxic in accordance with NFPA 55 shall not be permitted.

10.2 Storage and Piping Systems.

Δ **10.2.1*** The method of storage and piping systems for compressed and liquefied gases shall comply with the applicable requirements of NFPA standards, including NFPA 54 and NFPA 55.

10.2.2 Systems for other compressed gases and for cryogenic materials shall comply with the manufacturer's design and specifications.

10.2.3* Each point of use shall have an accessible manual shutoff valve.

10.2.3.1 The manual shutoff valve at the point of use shall be located away from the potential hazards and be located within 1.8 m (6 ft) of the point of use.

10.2.3.2 Where the cylinder valve is located within 1.8 m (6 ft) of the point of use, a separate point-of-use shutoff valve shall not be required.

10.2.3.3 Line regulators that have their source away from the point of use shall have a manual shutoff valve on the high-pressure side of the regulator.

Δ **10.2.3.4** Educational and instructional laboratory work areas that have flammable gas piped in from an external source shall have an emergency gas shutoff device in an accessible location near one of the egress doors from the laboratory work area in addition to valves required elsewhere.

10.2.4 Overpressure Protection.

N **10.2.4.1*** Every portion of a piping system shall be rated for a pressure equal to or greater than the maximum system pressure that can develop or shall have uninterruptible and adequately sized pressure relief.

10.2.4.2* A pressure relief system shall be designed to provide a discharge rate sufficient to avoid further pressure increase and shall vent to a safe location.

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10.2.5* Permanent piping shall be identified at the supply point and at each discharge point with the name of the material being transported.

10.2.6* Piping systems, including regulators, shall not be used for gases other than those for which they are designed and identified unless a thorough review of the design specifications, materials of construction, and service compatibility is made by a qualified person and any appropriate modifications have been made.

10.3 Outdoor Installation of Compressed Gas Cylinders for Servicing Laboratory Work Areas (Located Outside of Laboratory Work Areas).

10.3.1 Compressed gas cylinders installed or stored outside of laboratory buildings shall be installed and operated in accordance with the requirements in NFPA 55.

10.3.2 Compressed gas delivery systems shall be designed in accordance with NFPA 55.

10.4 Cryogenic Fluids.

10.4.1 All system components used for cryogenic fluids shall be selected and designed for such service.

10.4.1.1 Design pressure for vessels and piping shall be not less than 150 percent of maximum pressure relief.

10.4.1.2* Systems or apparatus handling a cryogenic fluid that can cause freezing or liquefaction of the surrounding atmosphere shall be designed to prevent contact of the condensed air with organic materials.

10.4.1.3 Systems or apparatus handling liquid oxygen shall be designed to prevent contact of the oxygen with organic materials.

10.4.2 Pressure relief of vessels and piping handling cryogenic fluids shall comply with the applicable requirements of Section 10.2.

10.4.3 The space in which cryogenic systems are located shall be ventilated commensurate with the properties of the specific cryogenic fluid in use.

Chapter 11 Laboratory Operations and Apparatus

11.1 General. This chapter shall apply to new and existing laboratories.

11.2 Operations.

11.2.1* Hazards of Chemicals and Chemical Reactions.

11.2.1.1 Before laboratory tests or chemical reactions are begun, evaluations shall be made for hazards that can be encountered or generated during the course of the work.

11.2.1.2 Evaluations shall include the hazards associated with the properties and the reactivity of the materials used and any intermediate and end products that can be formed, hazards associated with the operation of the equipment at the operating conditions, and hazards associated with the proposed reactions — for example, oxidation and polymerization. *(See also 11.2.1.4.)*

11.2.1.3 Regular reviews of laboratory operations and procedures shall be conducted with special attention given to any change in materials, operations, or personnel.

11.2.1.4* Where reactions are being performed to synthesize materials, the hazard characteristics of which have not yet been determined by test, precautions shall be employed to control the highest possible hazard based on a known hazard of similar material.

11.2.1.5* Where use of a new material or the premixing of flammable and oxidizing materials might present an explosion potential, initial experiments or tests shall be conducted in an enclosure that is designed to protect people and property from potential explosion damage. *(See Annex C.)*

11.2.1.6 Unattended or automatic laboratory operations involving hazardous chemicals shall be provided with regular surveillance for abnormal conditions. *(See 11.3.3.4 and 11.3.4.1.)*

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11.2.2 Distillation Operations.

11.2.2.1 Distillations shall be conducted in equipment designed and fabricated for this use and shall be assembled with consideration being given to fire hazards from vent gases and possible equipment breakage or failure.

11.2.2.2 Care shall be taken to avoid the presence of unstable components (e.g., peroxides) in the still pot and to avoid overheating still contents.

11.2.2.3 Glass equipment used for distillations shall be inspected for cracks, scratches, and other defects prior to each use.

11.2.2.4 Faulty glass equipment shall be discarded or repaired.

11.2.3* Other Separation Operations. Filtrations, extractions, sublimations, adsorptions, evaporations, centrifuging operations, and other separation techniques that involve flammable or combustible materials shall be protected from ignition sources and shall be provided with ventilation that prevents the accumulation of an ignitible concentration of vapors in the work area.

11.2.4 Mixing and Grinding Operations.

11.2.4.1 Mixing, grinding, stirring, and agitating operations involving flammable and combustible materials shall require the same precautions against fire as set forth in 11.2.3.

11.2.4.2 Precautions shall be taken to avoid local overheating during grinding and mixing of solids.

11.2.4.3 Care shall be taken to avoid fire or explosion hazards from flammable or combustible materials.

11.2.5 Pyrophoric Reagent and Water Reactive Material Handling.

11.2.5.1 Pyrophoric reagents and water reactive solids and liquids shall be handled in systems or enclosures that prevent the chemicals from igniting when a dry or an inert atmosphere is required by the manufacturer or the safety data sheet.

11.2.5.2 Pyrophoric reagents shall be handled only by those with experience in their hazards and properties or under close, direct supervision by those with experience in their hazards and properties. No one should work alone with pyrophoric reagents during transfer or cleanup operations.

11.2.5.3 Personal Protective Equipment shall be worn as required in Section 6.6.

11.2.5.4* Pyrophoric liquids dispensed in a chemical fume hood shall be from sure-seal-type bottles with syringes or double-tipped needles in accordance with the manufacturer's recommendation and nationally established laboratory safety practices.

11.2.5.5 Open dispensing of pyrophoric liquids shall be done inside of an inert atmosphere glove box.

11.2.5.6 Pyrophoric solids shall be handled/dispensed inside of an inert atmosphere glove box.

11.2.5.7 Water reactive solids that are not protected by mineral oil or solvents shall be handled/dispensed inside of an inert atmosphere glove box.

11.2.5.8 Residual moisture and contaminates shall be cleaned from reaction vessels, glassware, needles, and other lab equipment that will be exposed to pyrophoric reagents and water reactive materials. Equipment shall be purged with a high-purity dry inert gas prior to use.

11.2.5.9 The void space at the top of containers of pyrophoric reagents shall be backfilled with a high-purity dry inert gas as the reagent is removed.

11.2.5.10 Needles, spatulas, wipes, and tools that have been in contact with pyrophoric reagents and water reactive materials shall be stored in an inert atmosphere or shall be neutralized in accordance with the manufacturer's written instructions.

11.2.5.11* Pyrophoric reagents and water reactive materials in glove boxes shall be sealed in airtight containers when the chemicals are not in use.

11.2.6 Open Flame Operations.

11.2.6.1 Laboratory operations using open flames shall be performed in accordance with the following requirements:

(1) Whenever possible, alternative methods to the use of open flames, such as heating mantels, hot plates, glass bead sterilizers, or infrared loop sterilizers, shall be used.
(2) Hoses/tubing connecting a gas supply to a torch or Bunsen burner shall be in good condition, compatible with the gas being used, and rated for at least the source pressure of the gas or the relief pressure provided. Tubing connections shall be clamped at the gas supply and torch/burner.
(3) Open flame equipment with a small gas cylinder attached shall be handheld, clamped, or weighted to prevent equipment from falling over.
(4) If open flame operations are performed outside a hood, operations shall not be conducted under shelves, cabinets, or other overhanging equipment.

11.2.6.2 Biological operations using open flames and flammable liquids shall be performed in accordance with 11.2.6.1 and the following requirements:

(1) The volume of flammable liquid in use in an open container shall be limited to 50 ml or less. The container of flammable liquid shall be glass or metal and shall have a tight fitting, slip-on lid to seal the container when not in use or if the flammable liquid catches on fire.
(2) The container of flammable liquid shall be kept as far as possible from the open flame but not less than 0.305 m (12 in.).
(3) Flammable liquids and other hazardous materials that are not used for open flame operations shall be placed in storage.
(4) Combustible materials shall be kept at least 0.610 m (2 ft) away from the open flame and the container of flammable liquid. Absorbent paper shall not be used under the open flame operation.

11.2.7 Other Operations.

11.2.7.1 Other laboratory operations, such as reactions at temperatures and pressures either above or below ambient conditions, shall be conducted in a manner that minimizes hazards.

11.2.7.2 Shielding shall be used whenever there is a reasonable probability of explosion or vigorous chemical reaction and associated hazards during charging, sampling, venting, and discharge of products. *(See Annex C and 11.3.5.)*

11.2.7.3 Glass apparatus containing gas or vapors under vacuum or above ambient pressure shall be shielded, wrapped with tape, or otherwise protected from shattering (such as engineering controls or by apparatus design) during use.

11.2.7.4* Quantities of reactants shall be limited and procedures shall be developed to control or isolate vigorous or exothermic reactions.

11.2.7.5 Flammable gases or vapors evolved during drying operations shall be condensed, trapped, or vented to avoid ignition.

11.2.7.6* Spraying of flammable or combustible paint and varnishes shall comply with the requirements of NFPA 33.

11.3 Apparatus.

11.3.1 General.

11.3.1.1 Apparatus shall be installed in compliance with applicable requirements of NFPA standards, including *NFPA 70*, as well as manufacturer's recommendations and generally accepted good engineering practices.

11.3.1.2 Operating controls shall be accessible under normal and emergency conditions.

11.3.2 Refrigeration and Cooling Equipment.

11.3.2.1* Each refrigerator, freezer, or cooler shall be prominently marked to indicate whether it meets the requirements for safe storage of flammable liquids.

11.3.2.2* Refrigerators, freezers, and other cooling equipment used to store or cool flammable liquids shall be listed as special purpose units for use in laboratories or equipment listed for Class I, Division 1 locations, as described in Article 501 of *NFPA 70*.

11.3.2.3 Refrigerators, freezers, and cooling equipment located in a laboratory work area designated as a Class I location shall be approved for Class I, Division 1 or 2 locations and shall be installed in accordance with Article 501 of *NFPA 70*.

11.3.3 Heating Equipment and Heating Operations.

11.3.3.1 All heating of flammable liquids, combustible liquids, or flammable gases shall be conducted so as to minimize fire hazards.

N **11.3.3.2** Provisions shall be made to contain liquid that might be accidentally released from glass apparatus containing more than 0.25 L (8.4 oz) of flammable liquid or combustible liquid heated to its flash point.

N **11.3.3.3** Supplementary fire-extinguishing equipment shall be provided, if necessary.

N **11.3.3.4** All heating operations whether attended or unattended shall be provided with an independent high-temperature alarm and an automatic shutdown with manual reset to prevent system failure that can result in fire or explosion.

N **11.3.3.5** Strong oxidizing materials, such as perchloric acid, shall not be heated by gas flames or oil baths.

11.3.3.6 Heating equipment with circulation fans or water cooling shall be equipped with an interlock arranged to disconnect current to the heating elements if the fan fails or the water supply is interrupted.

11.3.3.7 Burners, induction heaters, ovens, furnaces, and other heat-producing equipment shall be located a safe distance from areas where temperature-sensitive and flammable materials and compressed gases are handled.

11.3.3.8 Oven and furnace installations shall comply with NFPA 86.

11.3.4 Heated Constant Temperature Baths.

11.3.4.1 Electrically heated constant temperature baths shall be equipped with over-temperature shutoff switches in addition to normal temperature controls, if overheating could result in a fire or an explosion.

11.3.4.2 Bath containers shall be of noncombustible materials.

11.3.5 Pressure Equipment.

11.3.5.1* Equipment used at pressures above 103 kPa gauge (15 psi) shall be designed and constructed by qualified individuals for use at the expected temperature, pressure, and other operating conditions affecting safety.

11.3.5.2 Pressure equipment shall be fitted with a pressure relief device, such as a rupture disc or a relief valve. The pressure relief device shall be vented to a safe location.

11.3.5.3 Equipment operated at pressures above 103 kPa gauge (15 psi), such as autoclaves, steam sterilizers, reactors, and calorimeters, shall be operated and maintained according to manufacturers' instructions, the design limitations of the equipment, and applicable codes and regulations.

11.3.5.3.1 Such equipment shall be inspected on a regular basis.

11.3.5.3.2 Any significant change in the condition of the equipment, such as corrosion, cracks, distortion, scale formation, or general chemical attack, or any weakening of the closure, or any inability of the equipment to maintain pressure, shall be documented and removed from service immediately and shall not be returned to service until approved by a qualified person.

11.3.5.3.3 Any pressure equipment that has been found to be degraded shall be derated or discarded, whichever is appropriate.

N **11.3.5.4 Hazard Analysis.**

N **11.3.5.4.1** Pressure containing equipment shall have a hazard analysis and risk assessment of the potential for hazards before use, including the need for leak testing and grounding.

N **11.3.5.4.2** The hazard analysis and risk assessment shall be maintained for the life of the equipment, updated as necessary based on revised operations and modifications, and communicated to all operating personnel.

11.3.6* Analytical Instruments.

11.3.6.1 Analytical instruments, such as infrared, ultraviolet, atomic absorption, x-ray, mass spectrometers, chromatographs, and thermal analyzers, shall be installed in accordance with the manufacturers' instructions and applicable standards and codes.

11.3.6.2* Analytical instruments shall be operated in accordance with manufacturers' instructions or approved recommended operating procedures.

N **11.3.7** Paragraphs 11.3.7.1, 11.3.7.2, and 11.3.7.3 shall only apply to equipment in laboratories in health care facilities.

N **11.3.7.1** Distillation and solvent recycling equipment shall be separated by 1.52 m (5 ft) from the storage and use of combustible materials or enclosed in 1-hour fire resistive construction.

N **11.3.7.2*** Ignitable (i.e., flammable or combustible) vapors released by tissue processors and similar automatic equipment shall comply with 7.2.6.

N **11.3.7.3** Tissue processors and similar automatic equipment that release ignitable vapors shall be provided with the following safeguards and interlocks as part of a monitored audible and visual alarm:

(1) Low liquid level
(2) High vapor

N **11.3.7.4** Existing equipment installed in accordance with the 2005 edition of NFPA 99 or earlier shall not be required to comply with 11.3.7.3.

Chapter 12 Educational and Instructional Laboratory Operations

12.1 General. This chapter provides fire protection and safety requirements for new and existing educational and instructional laboratories where experiments are conducted or demonstrations are performed using hazardous materials.

12.2 Instructor Responsibilities.

N **12.2.1*** Where instructors are performing demonstrations or students are conducting experiments using hazardous materials, the instructor shall be required to perform a documented hazard risk assessment, provide a safety briefing to students, provide adequate personal protective equipment (PPE), and place a safety barrier (as required) between students and the demonstration or experiment to prevent personal injury.

12.2.2* Instructors in teaching labs shall be trained and knowledgeable in fire safety procedures, emergency plans, the hazards present in the lab, the appropriate use of PPE, and how to properly conduct a hazard risk assessment.

12.3 Chemical Storage and Handling.

12.3.1* Bulk quantities of chemicals shall be stored in a locked room outside of the classroom in educational labs. Chemicals stored and in use in an educational lab classroom shall be limited to the amount needed for one day's use, preapportioned to the amount needed for each class session. The amount of chemical that is not in use during an individual class session shall be kept in an appropriate, locked cabinet.

12.3.1.1 Quantities of chemicals in an instructional lab shall be limited to the lowest possible level necessary and in no case shall exceed the per-laboratory unit quantities specified in 9.1.1 or the maximum allowable quantities specified in fire or building codes.

12.3.1.2 Dispensing of bulk quantities of chemicals for an experiment or demonstration shall be performed in a prep room outside of the classroom.

12.3.1.3 For existing educational and instructional laboratories that do not have a separate preparation room, the dispensing of bulk quantities of chemicals for experiments or demonstrations shall be performed prior to the arrival of the students in the classroom.

12.3.1.4* The minimum amount of chemical(s) needed to perform the experiment or demonstration shall be transferred to a small, appropriately labeled, sealable bottle(s) or dropping bottle(s).

12.3.1.5 Bottles of chemicals shall only be open in the classroom only when the experiment or demonstration is being performed.

12.3.2* Performance of Experiments or Demonstrations.

12.3.2.1 Experiments or demonstrations for students involving open flames or fire, or the use of flammable, reactive, toxic, or corrosive materials, shall be performed by a knowledgeable instructor and in accordance with 12.3.2.1.1, and 12.3.2.1.2, 12.3.2.1.3, or 12.3.2.1.4.

12.3.2.1.1 Experiments or demonstrations shall be performed in a location that does not block access to the primary means of egress from the laboratory work area.

12.3.2.1.2* Experiments or demonstrations that involve or produce hazardous quantities of fumes, vapors, particulates, or gases shall be performed in a chemical fume hood or other ventilation device, including demonstration hoods or other devices that meet the requirements of 2.1.1 of ANSI/AIHA Z9.5, *Laboratory Ventilation*, that is able to capture the materials being evolved.

12.3.2.1.3* Experiments or demonstrations involving chemicals that are performed outside a fume hood where the separation distance in 12.3.2.1.4 is not possible shall be performed behind an impact-resistant plastic or tempered-glass safety shield that meets both of the following:

(1) The shield shall be at least 0.610 m (24 in.) high and shall wrap 180 degrees around the hazard or extend at least 0.305 m (12 in.) beyond the hazard in both directions.
(2) The shield shall be secured to the work surface with bolts or clamps to keep it in place.

Δ **12.3.2.1.4** Experiments or demonstrations involving chemicals that are performed outside a fume hood where a shield is not utilized shall be performed in a location that is at least 3.05 m (10 ft) from students.

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12.3.2.2 In educational and instructional laboratories where experiments are conducted by students, the instructor shall be responsible for conducting a safety briefing prior to the start of each experiment to review the hazards of the chemicals used, the personal protective equipment required for the experiment, and a review of the emergency procedures.

12.4 Other Requirements. Educational and instructional laboratory units shall be classified in accordance with 4.2.2.

12.4.1 Educational laboratory units shall be provided with fire-rated separation in accordance with 5.1.3.

12.4.2 Life safety classification for educational and instructional laboratory units shall be in accordance with Section 5.2.

12.4.3 The allowed quantities of flammable and combustible liquids for educational and instructional laboratory units shall be in accordance with Section 9.1.

12.4.4 The allowed quantities of compressed gases for educational and instructional laboratory units shall be in accordance with 10.1.6.

12.4.5 Emergency gas shutoffs for educational and instructional laboratory work areas shall be in accordance with 10.2.3.4.

Chapter 13 Hazard Identification

13.1 General. This chapter shall apply to new and existing laboratories.

13.2 Identification of Entrances.

13.2.1* Entrances to laboratory units, laboratory work areas, storage areas, and associated facilities shall be identified by signs to warn emergency response personnel of unusual or severe hazards that are not directly related to the fire hazard of contents.

13.2.2 The hazards shall be communicated in the plans for fire fighting. *(See 6.5.3.1.)*

13.3* Exhaust Systems. Exhaust systems used for the removal of hazardous materials shall be identified to warn personnel of the possible hazards.

13.4 Labeling of Containers.

13.4.1* Content identification, including precautionary information, shall be provided directly on all original and subsequent containers of hazardous chemicals, except those being used in ongoing experiments.

13.4.2 Containers of materials that become hazardous during prolonged storage shall be dated upon receipt and when first opened to facilitate hazard control. Materials shall be properly disposed of according to the expiration date and recommendations on the label and safety data sheets (SDSs) *(see 8.3.4.4 and A.8.3.4.4)*.

13.5 Identification Systems. Graphic systems used to identify hazards shall comply with ANSI Z535.1, *Safety Color Code*; ANSI Z535.2, *Environmental and Facility Safety Signs*; ANSI Z535.3, *Criteria for Safety Symbols*; and ANSI Z535.4, *Product Safety Signs and Labels*; or other approved graphic systems.

Annex A Explanatory Material

Annex A is not a part of the requirements of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.

Δ **A.1.1.1** For fire hazard ratings of many chemicals, see the NFPA's *Fire Protection Guide to Hazardous Materials*, which contains NFPA 49 and NFPA 325.

A.1.1.3(1) Either condition of 1.1.3(1) meeting the minimum quantity will bring the lab within the scope of NFPA 45. A school lab with a low pressure natural gas system supplying Bunsen burners (with less than the minimum quantities of combustible or flammable liquids and less than the minimum quantities of other flammable gases) is an example of a lab outside the scope of NFPA 45.

A.1.1.3(2) The hazards of pilot plants are primarily based on the process, the chemistry, and the equipment, not the laboratory environment. Laboratories that have pilot plants within the laboratory unit should apply NFPA 45 to the laboratory portion. NFPA 45 should not be used to justify applying laboratory requirements, such as a general-purpose-area electrical classification, to the pilot plant itself.

A.1.1.3(7) NFPA 801 provides direction for controlling hazards associated with radioactive materials. NFPA 801 should be used only for issues related to radioactive materials in a laboratory. All other nonradioactive, laboratory issues are covered by NFPA 45.

A.1.1.3(9) While NFPA 45 does not cover laboratories which contain an explosion hazard great enough to cause property damage outside the laboratory work area or injury outside the laboratory work area requiring medical treatment beyond first aid, information in Annex C provides guidance for management of explosion hazards and the consequences of explosions.

A.1.1.4 For explosion hazard protection requirements, see Annex C.

Δ **A.1.1.4.1(3)** For sources of data on chemical reactivity hazard and hazardous chemical reactions, see the NFPA's *Fire Protection Guide to Hazardous Materials*, which contains NFPA 49, NFPA 325, and NFPA 491.

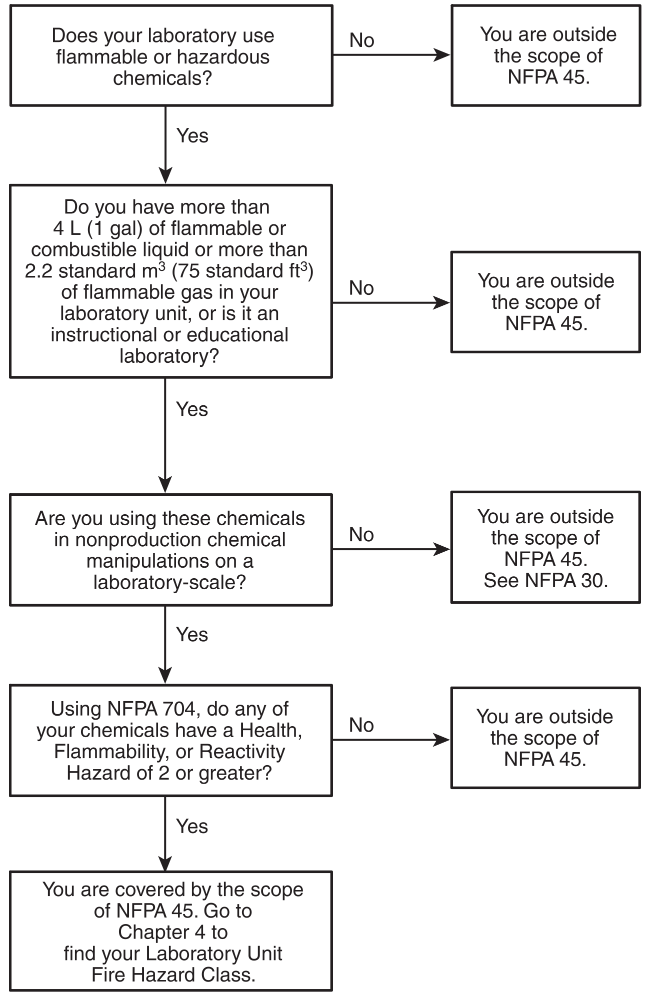
A.1.3 See Figure A.1.3 for determining the applicability of NFPA 45 to a lab setting other than educational or instructional labs. Existing laboratories using chemicals that are not in compliance with this standard should be permitted to be continued being used if they provide protection to life and adjoining property that is equivalent to that in this standard.

N **A.2.1(1)** For example, NFPA 10 is referenced in Chapter 2. This does not mean that all buildings must have portable fire extinguishers. Portable fire extinguishers are mandatory only to the extent called for elsewhere in this standard.

N **A.2.1(3)** The Committee on Laboratories Using Chemicals recognizes that it is impractical to continually upgrade existing buildings or installations to comply with all the requirements of the referenced publications included in Chapter 2.

A.3.2.1 Approved. 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, 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 that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A.3.2.2 Authority Having Jurisdiction (AHJ). The phrase "authority having jurisdiction," or its acronym AHJ, 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, or 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 or her 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.



Δ **FIGURE A.1.3 Guide for Determining the Applicability of NFPA 45 to a Laboratory Setting.**

A.3.2.4 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations 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.

A.3.3.4 Biological Safety Cabinet. There are several types of biological safety cabinets. *Class II Type A1 cabinets (formerly designated Type A).* Type A1 cabinets, which are not suitable for work with volatile toxic chemicals and volatile radionuclides, have the following characteristics:

(1) Maintain minimum average inflow velocity of 0.38 m/sec (75 ft/min) through the work access opening
(2) Have HEPA-filtered downflow air that is a portion of the mixed downflow and inflow air from a common plenum (i.e., a plenum from which a portion of the air is exhausted from the cabinet and the remainder supplied to the work area)
(3) Can exhaust HEPA-filtered air back into the laboratory or to the environment through an exhaust canopy
(4) Can have positive pressure contaminated ducts and plenums that are not surrounded by negative pressure plenums

Class II Type A2 cabinets (formerly designated Type B3). Type A2 cabinets used for work with minute quantities of volatile toxic chemicals and tracer amounts of radionuclides required as an adjunct to microbiological studies must be exhausted through properly functioning exhaust canopies. Type A2 cabinets have the following characteristics:

(1) Maintain a minimum average inflow velocity of 0.5 m/sec (100 ft/min) through the work access opening
(2) Have HEPA-filtered downflow air that is a portion of the mixed downflow and inflow air from a common exhaust plenum
(3) Can exhaust HEPA-filtered air back into the laboratory or to the environment through an exhaust canopy
(4) Have all biologically contaminated ducts and plenums under negative pressure or surrounded by negative pressure ducts and plenums

Class II Type B1 cabinets. Type B1 cabinets can be used for work treated with minute quantities of volatile toxic chemicals and tracer amounts of radionuclides required as an adjunct to microbiological studies if work is done in the direct exhausted portion of the cabinet, or if the chemicals or radionuclides will not interfere with the work when recirculated in the downflow air. Type B1 cabinets have the following characteristics:

(1) Maintain a minimum average inflow velocity of 0.5 m/sec (100 ft/min) through the work access opening
(2) Have HEPA-filtered downflow air composed largely of uncontaminated recirculated inflow air
(3) Exhaust most of the contaminated downflow air through a dedicated duct exhausted to the atmosphere after passing through a HEPA filter
(4) Have all biologically contaminated ducts and plenums under negative pressure or surrounded by negative pressure ducts and plenums

Class II Type B2 cabinets (sometimes referred to as total exhaust). Type B2 cabinets can be used for work with volatile toxic chemicals and radionuclides required as an adjunct to microbiological studies. Type B2 cabinets have the following characteristics:

(1) Maintain a minimum average inflow velocity of 0.5 m/sec (100 ft/min) through the work access opening
(2) Have HEPA-filtered downflow air drawn from the laboratory or the outside air (i.e., downflow air is not recirculated from the cabinet exhaust air)
(3) Exhaust all inflow and downflow air to the atmosphere after filtration through a HEPA filter without recirculation in the cabinet or return to the laboratory
(4) Have all contaminated ducts and plenums under negative pressure, or surrounded by directly exhausted (nonrecirculated through the work area) negative pressure ducts and plenums

A.3.3.7 Canopy Hood. This is not a chemical fume hood and generally is not as effective for exhausting toxic or flammable materials.

Δ **A.3.3.8 Chemical Fume Hood.** For further information on descriptions of types of chemical fume hoods and exhaust ventilation devices, see ANSI/AIHA Z9.5, *Laboratory Ventilation*. The following are types of chemical fume hoods:

(1) *Conventional hood.* A square-post hood without an airfoil directional vane across the bottom of the hood face, and in most cases without provision for a bypass. As the sash is lowered in hoods without an air bypass, the face velocity increases rapidly. The square-post design and absence of a deflector vane have been known to create turbulence at the hood face. The turbulence at the hood face can bring fumes from the hood interior out to the hood face, where they are easily drawn out into the room by the air turbulence caused by a person working at the hood, persons passing the hood, or minor room cross drafts. If hoods are not equipped with a bypass, face velocities could become objectionably high as the sash is closed, and with the sash completely closed, airflow can be insufficient to carry vapors away.
(2) *Bypass air hood.* A hood having a bypass protected by a grille that serves to maintain a relatively constant volume of airflow regardless of sash position. Current design recommends a streamlined entry profile with a deflector vane across the bottom of the hood to direct the airflow across the work surface.
(3) *Auxiliary air hood.* A bypass air hood with the addition of an auxiliary air bonnet to provide a direct source of makeup air in addition to the makeup air from the laboratory work area.
(4) Special-purpose hoods are as follows:
    (a) *Radioisotope hoods.* Designed primarily for use with radiochemicals
    (b) *Perchloric acid hoods.* Designed primarily for use with perchloric acid
    (c) *Floor-mounted hoods.* Designed primarily for extra headroom to accommodate tall equipment

A.3.3.11 Cryogenic Fluid. See National Safety Council Data Sheet 1-688-86, *Cryogenic Fluids in the Laboratory*.

A.3.3.17 Face (of hood). This area is used to calculate the square footage of the hood opening, and face velocity is measured in this plane.

A.3.3.22 Flammable Solid. A chemical is considered to be a flammable solid if, when tested by the method described in 16 CFR 1500.44, it ignites and burns with a self-sustained flame at a rate greater than one-tenth of an inch per second along its major axis.

A.3.3.25 Health Care Facilities. Health care facilities include, but are not limited to, hospitals, nursing homes, limited care facilities, clinics, medical and dental offices, and ambulatory health care centers, whether permanent or movable. This definition applies to normal, regular operations and does not pertain to facilities during declared local or national disasters. A health care facility is not a type of occupancy classification as defined by NFPA *101*. Therefore, the term *health care facility* should not be confused with the term *health care occupancy*. All health care occupancies (and ambulatory health care occupancies) are considered health care facilities; however, not all health care facilities are considered health care occupancies, as health care facilities also include ambulatory health care occupancies and business occupancies. [**99,** 2018]

A.3.3.30 Inside Liquid Storage Area. Such areas include the following:

(1) *Inside a room.* A room totally enclosed within a building and having no exterior walls
(2) *Cut-off room.* A room within a building and having at least one exterior wall
(3) *Attached building.* A building having only one common wall with another building having other types of occupancies
(4) *Liquid warehouse.* A separate, detached building or attached building used for warehousing-type operations for liquids

A.3.3.37 Laboratory Unit. A laboratory unit can include offices, lavatories, and other incidental contiguous rooms maintained for or used by laboratory personnel, and corridors within the unit. It can contain one or more separate laboratory work areas. It can be an entire building. A laboratory unit is classified as A, B, C, or D in accordance with Section 4.2 *(see also Annex D).*

A.3.3.39 Laboratory Work Area. This work area can be enclosed.

A.3.3.46.2 Educational Occupancy. Educational occupancies include academies, kindergartens, and schools. An educational occupancy is distinguished from an assembly occupancy in that the same occupants are regularly present.

A.3.3.46.4 Industrial Occupancy. See NFPA *101,* Chapter 40, for more information.

A.3.3.49 Oxidizer. Examples of other oxidizing gases include bromine, chlorine, or fluorine.

A.3.3.53 Pyrophoric Reagent. The three general types of pyrophoric reagents that produce these results include the following:

(1) Alkali metals, some alkali earth metals, and other metals that are finely divided (small particulates and nanoparticles) react with water vapor to generate hydrogen and heat.
(2) Metal hydrides react in the same manner, generating heat and hydrogen.
(3) Organometallics are reagents with carbon metal bonds that generate a volatile organic compound and heat when they react with moisture. The most common examples are alkyl lithium reagents, Gringards (C-MgX), and phosphines. Some compounds that have carbon transition metal bonds are also known as pyrophoric reagents.

A.3.3.60 Unattended Laboratory Operation. Absence for lunch, telephone calls, and so forth, without coverage by a knowledgeable person, constitutes an unattended laboratory operation.

N **A.3.3.61.1 Closed System Use.** For this standard, a vessel includes containers used in the laboratory.

A.4.2.1 The largest amounts of flammable and combustible liquids are permitted in Class A laboratory units, and the least amounts in Class D laboratory units.

A.5.1.4 Requirements for opening protectives in fire-rated barriers are referred to in 8.3.4 of NFPA *101.* Through-penetration firestopping is referred to in 8.3.5 of NFPA *101.*

N **A.5.1.5** Spills in laboratories are common and measures are required to prevent them from leaking outside the laboratory or to spaces below creating a hazard. This spread can be prevented by permanent means (e.g., curbs around internal floor penetrations, trenches at doors, a small curb around the perimeter to raise the start of the walls, and so on) or by other means such as sealing standard sheetrock walls with construction sealant, putting sills sealed with sealant on doors, and providing sealants on floor penetrations. These other means might need to be repaired or replaced following a spill depending on the sealant, chemical, and exposure time.

Fire stopping, required by fire codes to prevent the spread of smoke, might not be chemically resistant enough to stop leakage. If it can stop leakage for a time sufficient for cleaning up the spill, it might be adequate if inspected and repaired as necessary after a leak. If fire stopping is not leak tight, other measures, such as curbing, could be required.

A.5.3.1 A door to an adjoining laboratory work area or laboratory unit is considered to be a second means of access to an exit, provided that the laboratory unit is not of a higher fire hazard classification.

A.5.3.3 It should be noted that while doors swinging against egress and horizontally sliding doors are permitted in certain Class C and Class D laboratory work areas, NFPA *101* and *NFPA 5000* place limitations on their use based on number of occupants and area. Before doors swinging against egress and horizontally sliding doors are used, both NFPA *101* and *NFPA 5000* should be reviewed for requirements and limitations.

A.5.4 Modern laboratory design concepts provide a wide selection of laboratory furniture and equipment. Although such selections will be dictated by several factors, such as laboratory function, cost, serviceability, accessibility, repair, and so forth, any laboratory design should recognize and accommodate — to the extent practical — several needs directly related to improving the fire safety posture of the laboratory work area.

Casework design should be flexible to provide optimum use of storage capacity without interfering with the normal needs of the laboratory. This design can include desk areas that do not encourage underdesk storage, restraining techniques for items stored above eye level, ease of egress, provision for separation of incompatible chemicals or materials, provisions for ventilated or corrosion-resistant storage, or properly identified special facilities for unique waste storage needs, such as chemical, biological, or radioactive materials.

Easy access to laboratory utilities, such as piping, valves, and electrical switches and circuit-breaker panels, should be provided. All valves and switches should be properly identified in accordance with the governing codes and standards.

The use of slip-resistant floor surfaces should be considered.

A.5.5.1 Almost any liquid spill could affect electrical equipment located in the immediate area. Therefore, electrical receptacles, switches, and controls should not be located on, adjacent to, or directly below horizontal surfaces where a liquid spill could directly impact the equipment.

A.5.5.2 A qualified design professional and owner safety officer should review the laboratory conditions through a hazard analysis and/or risk assessment to determine if a hazardous (ignitable) atmosphere could be developed within the laboratory work area, laboratory unit, and/or fume hood. If a hazardous atmosphere could be developed, these areas should be electrically classified per *NFPA 70*, Article 500.

A.6.1.1.2 A series of fire tests in typical chemical laboratories was conducted to evaluate quick-response sprinkler technology and the use of quick-response sprinklers in chemical laboratories. Fire test results demonstrated that both standard-response and quick-response sprinklers were effective in controlling fires. Additionally, fire test results of the quick-response sprinklers showed lower maximum temperatures at the 5 ft level consistent with what is considered acceptable tenability in the room of fire origin, as discussed in NFPA 13D, and evaluated by ANSI/UL 1626, *Residential Sprinklers for Fire Protection Service*. Also see NISTIR 89-4200, "Quick Response Sprinklers in Chemical Laboratories: Fire Test Results," sponsored by the National Institutes of Health, Bethesda, MD.

A.6.1.2 The basic philosophy of NFPA 45 is to protect laboratory work areas with sprinklers in accordance with NFPA 13. If a hazard assessment shows that the presence of water-reactive materials would create a serious fire or personnel hazard in the event of the discharge of sprinkler water, a nonwater automatic fire extinguishing system designed to protect the portion of the lab work area containing water-reactive materials is acceptable.

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A.6.2.1 For laboratory buildings where trained personnel are available, Class III standpipe systems can be installed.

N **A.6.4.3** On-site emergency responders, if provided, should also be automatically notified of an alarm.

A.6.5.2 Maintenance procedures should include inspection, testing, and maintenance of the following:

(1) Utilities (steam, gas, electrical)
(2) Air supply and exhaust systems
(3) Fire protection equipment
(4) Detectors and alarms
(5) Compressed gas regulators and pressure relief valves
(6) Waste disposal systems
(7) Fire doors
(8) Emergency lighting and exit signs
(9) Electrically operated equipment

A.6.5.3 An emergency response plan should be prepared and updated. The plan should be available for inspection by the AHJ, upon reasonable notice. The following information should be included in the emergency plan:

(1) The type of emergency equipment available and its location
(2) A brief description of any testing or maintenance programs for the available emergency equipment
(3) An indication that hazard identification marking is provided for each storage area
(4) Location of posted emergency response procedures
(5) Safety data sheets (SDSs) for all hazardous materials stored on site
(6) A list of responsible personnel who are designated and trained to be liaison personnel for the fire department; these individuals should be knowledgeable in the site emergency response procedures and should aid the emergency responders with the following functions:
    (a) Pre-emergency planning
    (b) Identifying where flammable, pyrophoric, oxidizing, and toxic gases are located
    (c) Accessing SDSs
(7) A list of the types and quantities of compressed and liquefied gases normally at the facility

A.6.5.3.2 Laboratory personnel should be thoroughly indoctrinated in procedures to follow in cases of clothing fires. The 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 and run if clothing ignites, resulting in more severe, often fatal, burn injuries.

Flame-resistant clothing is one option available to help reduce the occurrence of clothing fires. Refer to NFPA 2112 for performance requirements and test methods for flame-resistant clothing.

It should be emphasized that use of safety showers, fire blankets, or fire extinguishers are of secondary importance. These items should be used only when immediately at hand. It should be recognized that rolling on the floor not only smothers the fire but also helps to keep flames out of the victim's face, reducing inhalation of smoke.

N **A.6.5.3.3** Laboratory users are people who occupy a laboratory work area to conduct laboratory work, testing, analysis, research, instruction, teaching, or to engage in learning, or similar activities that involve the use of chemicals.

A.6.6.2 Flame-resistant lab coats should be considered when handling flammable liquids and other hazardous materials that are easily ignited.

A.6.6.3 Flame-resistant gloves can also absorb hazardous liquids and consideration should be given to using the gloves in conjunction with appropriate chemically resistant gloves.

A.6.6.4 Synthetic clothing can catch fire easily and/or melt in a fire. Natural fiber clothing tends to char instead of melt when exposed to flames or high temperatures

A.7.1 NFPA 90A and NFPA 91 contain additional requirements for general environmental ventilating systems.

A.7.2.1 For additional information on laboratory ventilation, see ANSI/AIHA Z9.5, *Laboratory Ventilation*. For information on preventing the spread of smoke by means of utilizing supply and exhaust systems to create airflows and pressure differences between rooms or building areas, see NFPA 92.

A.7.2.2.1 A minimum ventilation rate for unoccupied laboratories (e.g., nights and weekends) can be as low as four room air changes per hour with proper laboratory operations and storage of chemicals. Occupied laboratories typically operate at rates greater than six air changes per hour, consistent with the conditions of use for the laboratory. Occupied laboratories should determine their supply airflow rates based on cooling requirements, amount of exhaust air required for the hoods, or exhaust devices in the lab, whichever is greatest. Use of only an "air change per hour" criteria is not considered proper design. Adequate ventilation should be provided to ensure occupant safety and safe operation of exhaust devices inside the laboratory.

Laboratory ventilation operating at lower rates should employ specific measures to monitor for potentially hazardous conditions and increase the ventilation automatically upon detection of any condition within 25 percent of the level of concern. If such a monitoring system is to be used, it should be fail-safe and be of such a nature that it will detect all potential leakage throughout the entire laboratory area. These systems should be reserved for locations where the anticipated contaminants can be measured reliably and activate the control system within a sufficiently rapid time period to provide occupant protection. In the event of a failure of the monitoring system or control components, the ventilation system should return to the designated occupied ventilation rate. Detailed analyses of flow paths, dead pockets, and failure modes under all credible scenarios should be performed to avoid exposure.

It is not the intent of this standard to require emergency or standby power for laboratory ventilation systems.

A.7.2.3 Hoods having explosionproof electrical devices are sometimes referred to as *explosionproof hoods*. This term does not imply that they will contain an explosion, only that the electrical equipment will not provide a source of ignition.

N **A.7.3.1** This is not meant to prevent recirculation within a laboratory unit for heating or cooling.

A.7.3.2 Special studies such as air-dispersion modeling might be necessary to determine the location of air intakes for laboratories away from the influence of laboratory exhaust and other local point source emissions.

A.7.3.4 Room air current velocities in the vicinity of fume hoods should be as low as possible, ideally less than 30 percent of the face velocity of the fume hood. Air supply diffusion devices should be as far away from fume hoods as possible and have low exit velocities.

A.7.3.5 NFPA 90A requires that approved fire dampers be provided in all air-transfer openings in partitions required to have a fire resistance rating. The standard requires that approved fire dampers be provided where ducts or air grilles penetrate partitions required to have a fire resistance rating of 2 hours or more. Thus, although any air-transfer opening would have to be fire dampered in a required fire barrier of any rating, penetrations by ducts or air grilles would not have to be fire dampered if the required rating of the barrier is less than 2 hours.

A.7.4.1 Ductless chemical fume hoods that pass air from the hood interior through an adsorption filter and then discharge the air into the laboratory are only applicable for use with nuisance vapors and dusts that do not present a fire or toxicity hazard. See ANSI Z9.5, *Laboratory Ventilation*, and other applicable standards for additional information for the proper use and application.

A.7.4.2 Consideration should be made of potential contamination of the fresh air supply by exhaust air containing vapors of flammable or toxic chemicals when using devices for energy conservation purposes.

Where fume hood exhaust is manifolded with general laboratory exhaust, energy recovery devices should be evaluated to ensure they would not recirculate contaminants through an active purge or filtration treatment. Energy recovery systems should be designed with a fail-safe alarm(s) and equipment interlocks to prevent cross contamination or recirculation from occurring, including shutdown of systems if needed.

Enthalpy wheels, in particular, have potential for cross-contamination and should be carefully evaluated for all potential hazards and failure modes.

A.7.4.2.2 It is not the intent of the standard to prohibit or impede the use of any energy conservation devices. However, the committee is concerned that adequate design consideration should be given as to how to clean and maintain these devices as the systems age.

A.7.4.2.3 This might be as simple as verifying that a pressure drop remains within design levels or airflow remains within design parameters. The intent is to require some means for ensuring that dirt and buildup does not unknowingly adversely affect the effectiveness of the exhaust system.

A.7.4.4 Ducts should be sealed to prevent condensation, and so forth, from leaking into occupied areas.

A.7.4.7 Laboratory fume hood containment can be evaluated using the procedures contained in ASHRAE 110, *Method of Testing Performance of Laboratory Fume Hoods*. Face velocities of 0.4 to 0.6 m/sec (80 to 120 ft/min) generally provide containment if the hood location requirements and laboratory ventilation criteria of this standard are met.

Lower flow fume hoods (those with an average face velocity or 0.3 to 0.4 m/sec (60 to 80 ft/min) are often desirable for energy conservation. Lower hood face velocities are effective with hoods designed for lower face velocities. However, many circumstances can lead to inadequate contaminant containment. These include crowding, larger equipment, high thermal loads, internal circulation from equipment and numerous other issues. Hence the owner should carefully consider all potential applications when determining the face velocity to use.

In addition to maintaining proper fume hood face velocity, fume hoods that reduce the exhaust volume as the sash opening is reduced should maintain a minimum exhaust volume to ensure that contaminants are diluted and exhausted from a hood. The chemical fume hood exhaust airflow should not be reduced to less than the flow rate recommended in ANSI/AIHA Z9.5, *Laboratory Ventilation*.

A.7.4.9 Due to their low capture efficiency, canopy hoods should be used only for exhausting heat and nuisance odors and not for exhausting chemicals. It is not the intent of this standard to prohibit the use of ductless enclosures (often incorrectly called "ductless hoods"). However, the use of such devices requires careful hazard analysis and risk assessment of all potential failure modes (mechanical, breakthrough, contamination, off gassing, etc.), how the owner is able to control uses for which the enclosure will not be adequate, how the user can continuously verify that the adsorption media is working properly, and how the spent media is to be safely removed and replaced, among numerous other concerns. The committee does not believe these enclosures are a suitable replacement for a chemical fume hood except after careful and thorough analysis.

A.7.4.11 Exhaust stacks should extend at least 3 m (10 ft) above the highest point on the roof to protect personnel on the roof. Exhaust stacks might need to be much higher to dissipate effluent effectively, and studies might be necessary to determine adequate design. Related information on stack height can be found in Chapter 14, Airflow Around Buildings, of the ASHRAE *Handbook of Fundamentals*.

Δ **A.7.5.10** Subsection 4.2.2 of NFPA 91 states that incompatible materials shall not be conveyed in the same system. Paragraph 7.5.9.2 allows exhaust ducts within a laboratory unit to be combined. The apparent inconsistency is due to the focus of both standards. NFPA 45 assumes that in normal routine laboratory operations, the amount of materials released into the exhaust system is small and will be diluted below any levels of concern.

A.7.5.10.1.2 In 2001, at the University of California, a fire resulted in an injury and caused approximately $3.5 million in damage. Based on the investigation, it was concluded that the practice of not having fire dampers on the exhaust duct of the ventilation system at the shaft wall appears to have been beneficial in this fire scenario. The investigation observed that the exhaust system was effective at removing significant quantities of combustion products from the building during the fire, thereby reducing the amount of combustion products spreading to other areas of the building. The shutting down of the supply air by fire dampers did not significantly hinder the exhaust system because fresh air was provided though a broken window. However, if the window had not failed, the team concluded that the exhaust system probably would not have performed as well.

N **A.7.5.10.2.2(3)** See Figure A.5.3 of NFPA 90A.

A.7.6 Consideration for maintaining minimum duct velocities in the exhaust system should be given when using VAV or low-flow fume hoods. Reducing the volume of air exhausted through fume hoods can increase the potential for low transport velocities within the exhaust system. Low velocities in the exhaust system can result in the accumulation of dust particles as well as condensation from condensable vapors.

A.7.7.4 For informative material regarding spark-resistant fan construction, see ANSI/Air Movement and Control Association (AMCA) Standard 99 for classifications for spark-resistant construction.

A.7.7.6 Exhaust fans should be tested to ensure they do not rotate backward in new installations or after repair on motors.

A.7.8.1.1 Specifying the flame spread rating alone does not ensure that the liner will provide containment of a small fire.

A.7.8.1.3 Baffles normally should be adjusted for the best operating position for general use. Only where high heat loads or the routine use of large quantities of light or heavy gases occur should compensating adjustment be made. In most cases, however, the low concentrations of heavier-than-air and lighter-than-air vapors take on the characteristics of the large volumes of air going through the hood. It is recommended that the total adjustment not exceed 20 percent of the total airflow.

A.7.8.1.4 The means of containing minor spills might consist of a 6.4 mm (¼ in.) recess in the work surface, use of pans or trays, or creation of a recess by installing a curb across the front of the hood and sealing the joints between the work surface and the sides, back, and curb of the hood.

A.7.8.2 A hood sash greatly enhances the safety provided by a chemical fume hood, and it is recommended that the hood design incorporate this feature. For example, a hood sash can be adjusted to increase the face velocity when working on high hazard material. The sash can be used as a safety shield. It can be closed to contain a fire or runaway reaction, and it can be closed to contain experiments when the hood is left unattended.

Hoods without sashes or hoods with a side or rear sash in addition to a front sash do not offer the same degree of protection as do hoods with protected single face openings, and, thus, their use is not recommended. A small face opening can be desirable to save exhaust air and energy or to increase the maximum face velocity on existing hoods.

A.7.8.3 Users should be instructed and periodically reminded not to open sashes rapidly and to allow hood sashes to be open only when needed and only as much as necessary.

A.7.8.3.2 It is not the intent of this standard to require automatic sash closing devices.

A.7.8.4 Locating services, controls, and electrical fixtures external to the hood minimizes the potential hazards of corrosion and arcing.

A.7.8.7.1 Where a laboratory exhaust system can be overdrawn (as in a VAV system, for which it is assumed that all hoods are not at full capacity all the time — the so-called diversity factor) the hood alarm provides immediate warning to all users that their hood is no longer working properly. Hence, an indication that the exhaust system capacity has been breached is not required, although it might be desired by the owner.

A.7.8.7.2 The intent of previous versions of this standard was to provide a local device that alerted users to improper hood performance. However, many commercially common installations showed face velocities that varied slightly, particularly during operation. This has led to frequent "alarms" even when the hoods were still within their design limits. Hence a Go/No Go-type sensor is actually preferred. ANSI/AIHA Z9.5, *Laboratory Ventilation,* recommends alarming if the average face velocity deviates by 20 percent or more; other sources and industry practice have suggested tighter limits of 10 percent.

A.7.9.1 A person walking past the hood can create sufficient turbulence to disrupt a face velocity of 0.5 m/sec (100 ft/min). In addition, open windows or air impingement from an air diffuser can completely negate or dramatically reduce the face velocity and can also affect negative differential air pressure.

A.7.9.3 Place low hazard activities (such as desks and microscope benches) away from the chemical fume hood. The term *directly in front of* does not include those areas that are separated by a barrier such as a lab bench or other large structure that would serve as a shield.

A.7.10.1 A hazard and risk assessment should be conducted for fume hood operations. Circumstances exist where hood fire suppression systems might be appropriate as a stand-alone protection measure or as part of a more comprehensive strategy to reduce hazards and risks. This assessment should be reviewed when fume hood operations change. See the objectives of the standard stated in Section 1.2.

A.7.10.2.1 For further information, see the report entitled "An Investigation of Chemical Fume Hood Fire Protection Using Sprinkler and Water Mist Nozzles" prepared by Factory Mutual Research Corporation.

A.7.10.4 Installation of sprinklers in the void area or in the chemical fume hood is an acceptable method to prevent flame spread.

A.7.11 Inert atmosphere glove boxes are used to provide a controlled environment where pyrophoric reagents, water-reactive materials, and air-sensitive materials can be handled to prevent these chemicals from reacting with air or water vapor in the air.

A.7.11.1 Additional fire protection, design, and operating criteria can be found in AGS-G010–2001, *Standard of Practice for Glovebox Fire Protection*.

A.7.12.1.1 If perchloric acid is heated above ambient temperature, it will give off vapors that can condense and form explosive perchlorates. Limited quantities of perchloric acid vapor can be kept from condensing in laboratory exhaust systems by trapping or scrubbing the vapors at the point of origin. Scrubbing systems have been described in published articles.

A.7.12.1.2 See also Chapter 16 of the ASHRAE *HVAC Applications Handbook* for design guidance on the installation of perchloric acid ducts.

A.7.12.8 Perchloric acid hoods should be washed down after each use.

A.7.12.10 A simple and sensitive test for perchlorates is available that uses a 0.3 percent solution of methylene blue in water. A few drops of the test solution in a small quantity [about 25 mL (0.84 oz)] of water washed from the duct to be tested will produce a violet precipitate if perchlorates are present. Approximately 12 mg (0.00042 oz) of perchlorate in this volume [500 mg/L (0.067 oz/gal)] can be recognized easily as a positive test. Because the methylene blue test can produce false negatives and false positives, as shown in "Returning Perchlorate-Contaminated Fume Hood Systems to Service, Part II" (Bader et al.), a more specific and quantifiable method for perchlorates is available that uses a perchlorate ion selective electrode. Several methods were compared in "Returning Perchlorate-Contaminated Fume Hood Systems to Service, Part I" (Phillips et al.) and in *Perchloric Acid and Perchlorates* (Schilt).

An effective method for washing down ductwork suspected of perchlorate contamination has been recommended in the CRC *Handbook of Laboratory Safety*. The method uses steaming of the ducts for 24 hours to condense water on all surfaces and dissolve and wash away perchlorate deposits. If tests after 24 hours show perchlorates in the final wash water, the steaming should be continued for another 24 hours until the test is negative. Where radiation contamination is present, in other than airtight ductwork, a continuous washdown or use of steam methods should not be done unless all the exhaust system is made airtight.

A.7.13.1 Laboratory hoods in which radioactive materials are handled should be identified with the radiation hazard symbol. For information, see NFPA 801.

A.7.14.1 The operating characteristics of some chemical fume hood designs, particularly auxiliary air chemical fume hoods, change at intermediate positions of sash height. It is, therefore, important to verify inward airflow over the face of the hood according to 7.14.1(5) at several sash heights from full open to closed.

A number of test procedures for verifying performance of chemical fume hoods that have been installed in the field have been published.

A test procedure is given in *Standard on Laboratory Fume Hoods*, by The Scientific Equipment and Furniture Association (SEFA), that uses a velometer and visible fume for checking hood performance.

A standard has been issued by the American Society of Heating, Refrigerating, and Air Conditioning Engineers entitled ASHRAE 110, *Method of Testing Performance of Laboratory Fume Hoods*.

The Environmental Protection Agency's *Procedure for Certifying Laboratory Fume Hoods to Meet EPA Standards* contains a test procedure utilizing sulfur hexafluoride as a test gas.

A.7.14.5.1 The annual inspection of air supply and exhaust fans, motors, and components should ensure that equipment is clean, dry, tight, and friction-free. Bearings should be properly lubricated on a regular basis, according to manufacturers' recommendations. Protective devices should be checked to ensure that settings are correct and that ratings have been tested under simulated overload conditions. Inspections should be made by personnel familiar with the manufacturers' instructions and equipped with proper instruments, gauges, and tools.

Δ **A.8.2** 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, NFPA 325, NFPA 484, and NFPA 491 which are contained in NFPA's *Fire Protection Guide to Hazardous Materials*.

A.8.3.3.1 The route used to transport hazardous materials between receiving rooms, storage rooms, dispensing rooms, and laboratory units of a facility should be appropriate to both the quantity and characteristics of the material being transported. Where possible, heavy or bulky quantities of hazardous materials should be transported by elevator, preferably one reserved exclusively for freight. In any event, the transport of hazardous materials in any quantity on an elevator should be accomplished by the minimum number of persons necessary to accomplish the task safely. All other persons should be excluded from an elevator while hazardous materials are present. Use of stairways for transport of small quantities of hazardous materials should be minimized. Transport of flammable, corrosive, toxic or highly toxic gases, cryogenic cylinders or dewars, or dry ice and similar oxygen depleting compounds should always be done with no one in the elevator.

A.8.3.3.2 Some common construction materials are subject to serious corrosion or formation of explosive compounds if used for or contacted by certain chemicals and gases commonly used in the laboratory. For example, copper tubing forms explosive compounds if it is used to pipe acetylene; azide salts are not compatible with copper or lead piping; mercury amalgamates in lead pipes.

Thermoplastic pipe used in chemical service, such as in laboratory waste drains, will frequently soften even when not directly attacked by chemical solvents. When this happens, much of the original strength and rigidity of the pipe is lost. If installed above ground or floor level, such piping should be provided with adequate rack support to prevent sagging. Burying plastic pipe used for chemical waste is not recommended because normal expansion might cause the pipe to collapse if the pipe has been softened by solvent attack.

A.8.3.4.1 This section establishes maximum allowable quantities of hazardous materials for individual laboratory units based upon reference to the locally adopted building and/or fire code. It is the intent of the committee to draw a correlation between the term *laboratory unit* used in NFPA 45 and other terms such as *control area* or *laboratory suite*, that are typically used in locally adopted building and fire codes. For example, if the locally adopted building code utilizes a control area methodology, the maximum allowable quantities of hazardous materials for an individual laboratory unit would be equal to the baseline maximum quantities established for a control area. The maximum quantities of flammable and combustible liquids in a laboratory unit might then need to be modified based upon the application of Table 9.1.1(a) and Table 9.1.1(b).

The quantities of flammable and combustible liquids allowed by this standard, while they might differ from other fire and building codes, have proved to provide a reasonable level of fire prevention for laboratories based on the additional fire protection requirements in this standard.

Δ **A.8.3.4.2** For guidance, see NFPA's *Fire Protection Guide to Hazardous Materials*, which contains NFPA 49 and NFPA 491.

A.8.3.4.3 Some local jurisdictions require bottom-venting of flammable liquids storage cabinets. Although this is not required by NFPA 30, some manufacturers provide plugged vent connections to accommodate these local jurisdictions.

A.8.3.4.4 There are several chemicals that can increase in hazard potential if subjected to long-term storage. Time alone can be only partially responsible, depending on the specific chemical. For example, exposure to air or light can cause the formation of highly shock-sensitive or friction-sensitive peroxides. Some hygroscopic or water-reactive compounds, such as metallic sodium, can autoignite on exposure to air or moisture. Another example is picric acid, which becomes highly shock-sensitive when its normal water content is allowed to evaporate. Reactive monomers that have been inhibited to reduce the chance of unintentional polymerization can become unstable when the inhibitor is consumed.

Such chemicals as described in 8.3.4.4 and A.8.3.4.4, which can increase in hazard potential over time, are common to chemical laboratories and are routinely handled without incident. Still, the user should use appropriate reference material to adequately assess the often multiple hazards associated with the use of chemicals.

A.8.3.4.4.1 Managing time-sensitive chemicals might be perceived as being complex. For help in determining what chemicals are time-sensitive, their inspection periods, inspection methodologies, and pass/fail criteria for these inspections, see one of the two sources by Bailey et al. or the source by Quigley et al.

A.8.3.4.5 See NFPA 30 for performance-based requirements if storage cabinets are vented for any reason.

N **A.8.4.2** Not thoroughly evaluating all the hazards of a combination of hazardous chemicals frequently leads to unnecessary accidents (e.g., the mixing of acids and organic solvents, acids and bases, mineral acids, and so on). See NFPA's *Fire Protection Guide to Hazardous Materials*.

A.9.1.2 Transferring flammable liquids from 1 gal– or 4 L–sized glass shipping containers to metal containers is a relatively expensive and hazardous operation. Such practices are not considered prudent, and are not recommended or required by NFPA for fire protection in laboratories using chemicals.

NFPA 45 allows glass containers in accordance with 9.1.2(1).

Class IA and IB flammable liquids in glass containers larger than the 500 mL (1 pt) and 1 L (1 qt) sizes permitted by Table 9.1.2 should be kept in containers of sufficient size to hold the contents of the glass containers.

The presence of flammable liquids in glass containers presents substantial hazards from accidental breakage. Many suppliers furnish glass containers with shatter-resistant coatings. These shatter-resistant glass containers offer significant protection from accidental breakage and are recommended for use when hazardous chemicals need to be kept in glass rather than plastic or metal containers.

Δ **A.9.3.1** Ventilation for dispensing operations should be provided to prevent overexposure of personnel dispensing flammable liquids. Control of solvent vapors is most effective if local exhaust ventilation is provided at or close to the point of transfer. Movement of liquid to or from equipment in a closed system is not subject to this requirement.

N **A.9.3.1(2)** Such an area should be ventilated to maintain the vapor concentration below 25 percent of the lower flammability limit at the point of dispensing. In general, to meet this requirement, the dispensing would need to be in an enclosure of some kind. Dispensing near or in front of a hood, for example, relying on the hood to provide the required capture effectiveness would not be considered meeting this requirement.

While it is possible to meet this requirement by proper use of a well-designed local exhaust arm, it is difficult to practically ensure that the limitation is always being met. Common design problems include inadequate exhaust rates, too low an exhaust capture velocity, and lack of any viable way to hold the exhaust in a position in which it will be effective. Since even a small increase in the capture distance makes an exponential decrease in the capture effectiveness, it is difficult to ensure the effectiveness of this approach.

In addition to the requirement to be below 25 percent of the lower flammable limit, the path of the vapors to the exhaust need to be carefully considered to ensure they do not pass over or near any ignition sources such as pumps, motors, and other electrical equipment. Even electrical outlets can be a source of ignition when a plug is inserted or removed. Similarly ovens, furnaces, hot plates, and other heated equipment could ignite the vapors before they are diluted enough.

A.9.3.2 Where practicable, dispensing operations should be separated from the storage of flammable and combustible liquids because of the exposure of greater quantities to the hazards of dispensing operations. Movement of liquid to or from equipment in a closed system is not subject to this requirement.

A.9.3.3 The requirement permits the use of squeeze bottles in laboratories. Their use greatly reduces spills, while aiding in accurately dispensing liquids onto small components or surfaces. The small rate of intermittent discharge through a squeeze bottle's discharge tube has not proven to be a hazard over many years of use.

In laboratory occupancies where pouring from and filling of laboratory-size containers is performed within a laboratory fume hood or other similarly ventilated enclosure or space, ignition due to static discharge is not likely to occur. This might be attributed to a combination of factors such as the following:

(1) Smaller size containers than those used in industrial or commercial occupancies
(2) Low flow rates during manual pouring/ filling
(3) Ventilation to below the lower flammable limits
(4) Contact made between containers (Good laboratory technique dictates that liquids be poured down the side of the container or by use of a stirring rod, thus avoiding splashing or turbulence.)

Perhaps of some yet-to-be-determined significance is the undefined charge transfer mechanism that can take place between nonconductive containers or between containers and the person performing the transfer. (For information on methods to reduce static electricity, see NFPA 77.)

A.9.4.3 Relief discharge to a laboratory exhaust might not be appropriate for all sizes of containers for all solvents. Not all lab hoods and exhaust systems are constructed the same and might not be capable of containing or withstanding the vented vapors. Many fume hoods contain ignition sources. The user should evaluate each system based on the use.

A.9.4.6 Examples of these methods include, but are not limited to, a dead man valve or a remotely actuated valve on the liquid line or removal of the pressure being applied.

A.9.5.3 The requirements of 9.5.3 can be accomplished by either of the following:

(1) Limiting the temperatures of internal heated surfaces that can be exposed to the vapors to no more than 80 percent of the autoignition temperature of the material being heated
(2) Providing mechanical exhaust ventilation that discharges to a safe location to keep the concentration of flammable gas or vapor below 25 percent of the lower flammable limit (The ventilation equipment should be interlocked with the heating system so that heating cannot take place unless the ventilation system is operating.)

Also, any electrical equipment located within the outer shell, within the compartment, on the door, or on the door frame should be suitable for Class I, Division 1 hazardous (classified) locations and any electrical equipment mounted on the outside of the equipment should be as follows:

(1) Suitable for Class I, Division 2 hazardous (classified) locations
(2) Installed on the outside surface of the equipment where exposure to vapors will be minimal

Consideration should also be given to providing deflagration venting, as described in NFPA 86.

A.10.1.2 Cylinders of hydrogen fluoride and hydrogen bromide should be returned to the supplier within 2 years of the shipping date.

Cylinders of corrosive or unstable gases should be returned to the supplier when the expiration date of the maximum recommended retention period has been reached. Examples of such corrosive or unstable gases include the following:

(1) Acid and alkaline gases
(2) Gases subject to autopolymerization
(3) Gases subject to explosive decomposition

Cylinders not in active use should be removed from laboratory work areas to a storage facility, as described in CGA Pamphlet P-1, *Safe Handling of Compressed Gases in Containers*. In the absence of a maximum recommended retention time, a 36-month interval should be used.

A.10.1.3 Such vessels cannot be used in commerce unless DOT approved.

A.10.1.4.2 Due to the limited volume of lecture bottles, a chemical fume hood can provide adequate ventilation to contain leaks of hazardous gases from a lecture bottle.

A.10.1.5.1 Consider locating in-use compressed gas cylinders outside of the building or outside of the laboratory area in a gas storage room whenever possible.

A.10.2.1 For additional information, see the following:

(1) CGA Pamphlet P-1, *Safe Handling of Compressed Gases in Containers*
(2) ASME B31.1, *Power Piping* (including addendum)
(3) ASME B31.3, *Process Piping*
(4) National Safety Council Data Sheet 1-688-86, *Cryogenic Fluids in the Laboratory*

A.10.2.3 Additional shutoff valves, located in accessible locations outside of the areas in which the gases are used, are acceptable.

N **A.10.2.4.1** Pressure relief should only be provided by devices designed and approved for this purpose. Providing pressure relief by use of a loosely attached plastic laboratory tubing, by leaving glass stoppers in a flask to pop off, or by other similar methods do not meet the requirements of this section. Failure of any device cannot be considered as pressure relief.

N **A.10.2.4.2** Typically, relief devices are sized to provide the full flow rate at no more than 10 percent overpressure per ASME guidelines.

A safe location per 10.2.4.2 is into an exhaust duct, into the plenum of a laboratory hood, or into a vent that exits outside the building.

A.10.2.5 It is recommended that each intermediate regulator and valve also be identified. The identification should conform to ANSI/ASME A13.1, *Scheme for the Identification of Piping Systems*.

A.10.2.6 Great care should be taken when converting a piping system from one gas to another. In addition to the requirements of 10.2.6, thorough cleaning to remove residues might be essential. For example, inert oil-pumped nitrogen will leave a combustible organic residue that is incompatible with oxygen and other oxidizing agents. Similar incompatibilities can occur with other materials.

A.10.4.1.2 Air can be condensed when it contacts containers or piping containing cryogenic fluids. When this occurs, the concentration of oxygen in the condensed air increases, thereby increasing the likelihood of ignition of organic material.

Δ **A.11.2.1** Hazard evaluations and risk assessments should be performed by a team of people who are familiar with hazardous chemicals, chemical reactions, equipment, and operational procedures prior to laboratory work. In particular, when new or existing experiments involve a scale-up, an increase in flow rate, changes in physical properties (such as temperature or pressure), changes in equipment or supplies, mixing of incompatible materials, or a potential for explosion, hazard evaluations and risk assessments should be performed prior to initiating research. The hazard evaluation and risk assessment team should include the stakeholders, such as the principal investigator, and representatives working in the laboratory, in addition to any experts on the design and controls of the chemical process.

The hazard evaluations and risk assessments should include understanding of the interactivity of materials, associated energies, side reactions, and temperature rise for worst-case reactions and side reactions. The evaluation should also consider evaluation with the materials and equipment associated with the laboratory operation.

Where the hazard evaluation identifies significant hazards, appropriate controls need to be implemented to mitigate the hazards to prevent fires or explosions. Mitigations could include adequate pressure relief/venting, limited size of vessels, shielding, controllers, and analyzers with automated shutdowns.

Reference sources include the following:

(1) NFPA 49, NFPA 325, and NFPA 491, which are contained in NFPA's *Fire Protection Guide to Hazardous Materials*
(2) NFPA 551
(3) Chapter 4 of *Prudent Practices in the Laboratory*
(4) *Handbook of Chemical Health and Safety*
(5) A free tool for chemical reactivity, available at https://www.aiche.org/ccps/resources/chemical-reactivity-worksheet-40

A.11.2.1.4 When a new chemical is produced, it should be subjected to a hazard analysis as appropriate to the reasonably anticipated hazard characteristics of the material. Such tests might include, but are not limited to, differential thermal analysis, accelerating rate calorimetry, drop weight shock sensitivity, autoignition temperature, flash point, thermal stability under containment, heat of combustion, and other appropriate tests.

N **A.11.2.1.5** In 2016, an experiment involving the use of a hydrogen, oxygen, and carbon dioxide gas mixture exploded in a laboratory, causing a serious injury and destroying the laboratory.

A.11.2.3 Protection against ignition sources associated with typical laboratory apparatus can be achieved by distance, pressurization of motor or switch housings, or inerting techniques that can effectively prevent flammable vapor concentrations from contacting ignition sources. (See NFPA 496 for requirements for purge systems for electrical enclosures, and NFPA 69 for requirements for inerting systems.)

A.11.2.5.4 For acceptable methods of handling pyrophoric reagents, see "Methods for the Safe Storage, Handling, and Disposal of Pyrophoric Liquids and Solids in the Laboratory," from the *Journal of Chemical Health and Safety*.

N **A.11.2.5.11** Pyrophoric materials that are left open inside a glove box can ignite if the inert environment inside the glove-box is compromised and oxygen or water vapor are allowed to enter the box.

A.11.2.7.4 Procedures might include chilling, quenching, cutoff of reactant supply, venting, dumping, and "short-stopping" or inhibiting.

N **A.11.2.7.6** The use of fume hoods for spray operations of paints, adhesives, or other material that can stick and accumulate could result in a buildup of flammable material that can both change airflow in the hood as well as increase the potential for a fire in the ductwork. Installation of devoted spray booths is the best solution. If that is not done, additional maintenance activities, enhanced (or increased) inspections, and routine cleaning should be considered.

A.11.3.2.1 Figure A.11.3.2.1 gives examples of labels that can be used on laboratory refrigerators.

A.11.3.2.2 Protection against the ignition of flammable vapors in refrigerated equipment is available through two types of laboratory refrigerators: explosionproof and laboratory-safe (or explosion-safe) models.

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 laboratory work areas where all electrical equipment is required to meet the requirements of Article 501 of *NFPA 70*.

The design concepts of the explosion-safe or laboratory-safe refrigerator are based on a typical laboratory environment. The primary intent is to eliminate ignition of vapors inside the storage compartment by sources also within the compartment. In addition, commercially available laboratory-safe refrigerators incorporate design features such as thresholds, self-closing doors, friction latches, or magnetic door gaskets, and special materials for the inner shell. All of these features are intended to control or limit the damage if an exothermic reaction should occur within the storage compartment. Finally, the compressor and its circuits and controls are 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 laboratory-safe refrigerator provide important safeguards not easily available through modification of domestic models.

A.11.3.5.1 Pressure vessels require specialized design beyond the scope of normal workshop practice. For design of pressure vessels, see Section VIII, "Rules for Construction of Pressure Vessels," Division 1, ASME *Boiler and Pressure Vessel Code*.

Do not store flammable solvents in this refrigerator.

Label used for unmodified domestic models

Notice: This is not an explosionproof refrigerator, but it has been designed to permit safe storage of materials producing flammable vapors. Containers should be well-stoppered or tightly closed.

Label for laboratory-safe or modified domestic models

FIGURE A.11.3.2.1 Labels to Be Used in Laboratory Refrigerators.

A.11.3.6 Refer to Part III of NFPA 30, Supplement 5, Electrostatics, for guidance regarding electrostatic safety issues. This guidance should be reviewed in laboratories in which the use of high-density polyethylene (HDPE) for the collection of spent laboratory flammable liquid wastes from a high-performance liquid chromatograph (HPLC) or similar apparatus occurs.

A.11.3.6.2 Hazards to personnel from high voltage, vapors or fumes, radiation, flames, flashbacks, and explosions should be minimized.

N **A.11.3.7.2** Tissue processors that operate as a closed system contain ignitible vapor hazards within the processor and thus do not pose a hazard.

A.12.2.1 A documented hazard assessment is a written evaluation of the hazards of the experiment, including the appropriate personnel protective equipment required, safe work practices, emergency procedures, and waste disposal. It is recommended that this assessment be peer reviewed.

A.12.2.2 Instructors should be knowledgeable of the five general principles of safety as referenced in the OSHA Standard for Occupational Exposure to Hazardous Chemicals in Laboratories, Section 1910.1450, Appendix A - Culture of Safety. This information can be found on the OSHA website at www.osha.gov.

A.12.3.1 The presence of bulk quantities (2 L or larger bottles) of chemicals in a classroom have resulted in accidents (fire) where the bottle has spilled or a fire has ignited the contents of the bottle. The fires have caused serious burn injuries to the students and instructors.

N **A.12.3.1.4** Containers with a restricted neck opening, unlike a beaker with straight sides and a full opening, used to pour flammable liquid should have a flame arrestor or other flame mitigation device that prevents flames from igniting a flammable atmosphere inside the container. Testing by ATF has proven that any size of necked container of flammable liquid can generate a flame jet of burning flammable liquid that can travel more than 3.0 m (12 ft).

A.12.3.2 For additional guidance, see Kaufman, *Science Demonstrations: Safety and Liability.*

A.12.3.2.1.2 Demonstration-type fume hoods are chemical fume hoods with an operating sash on one side and a safety glass panel on the opposite side to provide viewing of the operations in the hood and to minimize the exposure to the hazards associated with the operation in the hood.

N **A.12.3.2.1.3** Demonstration shields are utilized primarily to protect the students from experimental mishap (e.g., splash hazards, flying glass). A portable shield that does not fully enclose the experiment does not provide protection at the sides or back of the equipment, and if it is not sufficiently secured for forward protection the shield could topple toward students during a demonstration.

Portable shields should be rated for the hazards against which they are intended to protect. For example, the shielding material should be nonflammable or slow burning where combustion is possible. Shields of polycarbonate, methacrylate, polyvinyl chloride, and laminated safety plate glass can offer characteristics of transparency, impact, heat, and shatter resistance, and high tensile strength. These shields might offer some chemical-resistant characteristics but also are subject to various chemical degradations, and one will need to consider their use and cleaning.

A.13.2.1 Examples of severe or unusual hazards that might require posting of signs include the following:

(1) Unstable chemicals
(2) Radioactive chemicals
(3) Carcinogens, mutagens, and teratogens
(4) Pathogens
(5) High-pressure reactions
(6) High-powered lasers
(7) Water-reactive materials
(8) Cryogens

Also, the names and home telephone numbers of one or more persons working in each laboratory work area should be posted at the entrance to that work area. Such information should be kept current.

It is important to recognize that an extremely toxic substance need not be identified as a proportionately hazardous substance. The quantity of the substance, the ease of penetration of its container or risk of its release by fire, and the probability of harming emergency response personnel are the true measures of the hazard level. This standard does not exclusively endorse any particular convention for communicating unusual hazards to emergency response personnel, recognizing that professional judgments need to be made on a facility-by-facility basis. These judgments should recognize several existing conventions.

Use of the system presented in NFPA 704, which might be suitable for flammable liquid storage cabinets or those laboratories containing a nearly constant chemical inventory, is not recommended for multichemical laboratories where the chemicals can change frequently. Such laboratories can include any of the following:

(1) Analytical, biological (public health, genetic engineering, bacteriological)
(2) Physical and chemical (organic, inorganic, physical, research, crystallographic, forensic)
(3) Instructional (college and high school chemistry and physics laboratories)
(4) Metallurgical
(5) Mineralogical
(6) Fine art restoration and identification
(7) Dental

Even where storage within a laboratory involves unusually high amounts of flammable or toxic or reactive materials (and hence calls for hazard identification), a lettered sign is generally more easily understood than a numerical designation. Hence, the NFPA 704 system is not recommended for laboratories in general.

A.13.3 The exhaust system should be identified "WARNING — Chemical Laboratory Exhaust" (or "Chemical Fume Hood Exhaust" or other appropriate wording). Exhaust system discharge stacks and discharge vents and exhaust system fans should be marked to identify the laboratories or work areas being served.

A.13.4.1 Labels on original containers and secondary vessels that are used to store hazardous chemicals must include the chemical name and applicable hazard warnings. Microvials and other small containers of similar contents that are compatible that will not support a conventional label can be identified with a numbering system and stored in a properly labeled collection vessel. Maintain a master log of the numbered containers within the laboratory.

Annex B Supplementary Definitions

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

B.1 NFPA 30 Definitions. The following definitions are extracted from NFPA 30.

B.1.1 Classification of Combustible Liquids. Combustible liquids shall be classified in accordance with the following:

(1) Class II Liquid — Any liquid that has a flash point at or above 100°F (37.8°C) and below 140°F (60°C)
(2) Class III Liquid — Any liquid that has a flash point at or above 140°F (60°C)
    (a) Class IIIA Liquid — Any liquid that has a flash point at or above 140°F (60°C), but below 200°F (93°C)
    (b) Class IIIB — Any liquid that has a flash point at or above 200°F (93°C)

[**30:**4.3.2]

B.1.2 Classification of Flammable Liquids. Class I liquids shall be further subclassified in accordance with the following:

(1) Class IA Liquid — Any liquid that has a flash point below 73°F (22.8°C) and a boiling point below 100°F (37.8°C)
(2) Class IB Liquid — Any liquid that has a flash point below 73°F (22.8°C) and a boiling point at or above 100°F (37.8°C)
(3) Class IC Liquid — Any liquid that has a flash point at or above 73°F (22.8°C), but below 100°F (37.8°C)

[**30:**4.3.1]

B.1.3 Combustible Liquid. Any liquid that has a closed-cup flash point at or above 37.8°C (100°F), as determined by the test procedures and apparatus set forth in Section 4.4 of NFPA 30. [**30,** 2018]

B.1.4 Flammable Liquid. Any liquid that has a closed-cup flash point below 37.8°C (100°F), as determined by the test procedures and apparatus set forth in Section 4.4 of NFPA 30 and a Reid vapor pressure that does not exceed an absolute pressure of 40 psi (276 kPa) at 100°F (37.8°C), as determined by ASTM D323, *Standard Test Method for Vapor Pressure of Petroleum Products (Reid Method)*. [**30,** 2018]

B.2 NFPA 704 Definitions. The following definitions are extracted from NFPA 704.

B.2.1 Flammability Hazards. Flammability hazards ratings shall address the degree of susceptibility of materials to burning [**704:**6.1.1]. Because many materials will burn under one set of conditions but will not burn under others, the form or condition of the material shall be considered, along with its inherent properties. [**704:**6.1.2]

B.2.2 Health Hazard. Health hazard ratings shall address the capability of a material to cause personal injury due to contact with or entry into the body via inhalation, ingestion, skin contact, or eye contact. [**704:**5.1.1]

The degrees of health hazard shall be ranked according to the probable severity of the effects of exposure to emergency response personnel detailed in Table B.2.2. [**704:**5.2]

B.2.3 Instability Hazards.

B.2.3.1 This [section] shall address the degree of instrinsic susceptibility of materials to release energy, and those materials capable of rapidly releasing energy by themselves, through self-reaction or polymerization. [**704:**7.1.1]

B.2.3.2 The violence of a reaction or decomposition can be increased by heat or pressure…[or] by mixing with other materials to form fuel–oxidizer combinations, or by contact with incompatible substances, sensitizing contaminants, or catalysts. [**704:** A.7.1.1]

Δ **B.2.3.3** Because of the wide variations of unintentional combinations possible in fire or other emergencies, these extraneous hazard factors (except for the effect of water) shall not be applied to a general numerical rating of hazards. Where large quantities of materials are stored together, inadvertent mixing shall be considered in order to establish appropriate separation or isolation. [**704:**7.1.4]

The NFPA 704 ratings are applied to numerous chemicals in the NFPA *Fire Protection Guide to Hazardous Materials*, which contains withdrawn standards NFPA 49 and NFPA 325. These were withdrawn as NFPA standards (and are therefore no longer published in the *National Fire Codes*®). However, they are maintained by NFPA staff in a database and in the NFPA *Fire Protection Guide to Hazardous Materials*. The committee wishes to note that the documents were withdrawn solely for expediency in updating the data, which was not possible in a 3- to 5-year revision cycle. [**704:** A.4.2.2]

B.2.3.4 The degree of instability hazard shall indicate to firefighting and emergency personnel whether the area shall be evacuated, whether a fire shall be fought from a protected location, whether caution shall be used in approaching a spill or fire to apply extinguishing agents, or whether a fire can be fought using normal procedures. [**704:**7.1.5]

B.2.3.5 Definitions.

B.2.3.5.1 Stable Materials. Those materials that normally have the capacity to resist changes in their chemical composition, despite exposure to air, water, and heat as encountered in fire emergencies. [**704,** 2017]

B.2.3.5.2 Unstable Materials. A material that, in the pure state or as commercially produced, will vigorously polymerize, decompose, or condense; become self-reactive; or otherwise undergo a violent chemical change under conditions of shock, pressure, or temperature. [**704,** 2017]

Δ **B.2.4 Degrees of Flammability Hazard.** The degrees of flammability hazard shall be ranked according to the susceptibility of materials to burning as detailed in Table B.2.4. [**704:**6.2]

B.2.5 Degrees of Hazard. The degrees of hazard shall be ranked according to ease, rate, and quantity of energy release of the material in pure or commercial form detailed in Table B.2.5. [**704:**7.2]

Δ Table B.2.2 Degrees of Health Hazards

Degree of Hazard*	Criteria
4 — Materials that, under emergency conditions, can be lethal	Gases whose LC_{50} for acute inhalation toxicity is less than or equal to 1000 parts per million (ppm) Any liquid whose saturated vapor concentration at 20°C (68°F) is equal to or greater than ten times its LC_{50} for acute inhalation toxicity, if its LC_{50} is less than or equal to 1000 ppm Dusts and mists whose LC_{50} for acute inhalation toxicity is less than or equal to 0.5 milligrams per liter (mg/L) Materials whose LD_{50} for acute dermal toxicity is less than or equal to 40 milligrams per kilogram (mg/kg) Materials whose LD_{50} for acute oral toxicity is less than or equal to 5 mg/kg
3 — Materials that, under emergency conditions, can cause serious or permanent injury	Gases whose LC_{50} for acute inhalation toxicity is greater than 1000 ppm but less than or equal to 3000 ppm Any liquid whose saturated vapor concentration at 20°C (68°F) is equal to or greater than its LC_{50} for acute inhalation toxicity, if its LC_{50} is less than or equal to 3000 ppm and that does not meet the criteria for degree of hazard 4 Dusts and mists whose LC_{50} for acute inhalation toxicity is greater than 0.5 mg/L but less than or equal to 2 mg/L Materials whose LD_{50} for acute dermal toxicity is greater than 40 mg/kg but less than or equal to 200 mg/kg Materials that are corrosive to the respiratory tract Materials that are corrosive to the eye or cause irreversible corneal opacity Materials that are corrosive to skin Cryogenic gases that cause frostbite and irreversible tissue damage Compressed liquefied gases with boiling points at or below –55°C (–66.5°F) that cause frostbite and irreversible tissue damage Materials whose LD_{50} for acute oral toxicity is greater than 5 mg/kg but less than or equal to 50 mg/kg
2 — Materials that, under emergency conditions, can cause temporary incapacitation or residual injury	Gases whose LC_{50} for acute inhalation toxicity is greater than 3000 ppm but less than or equal to 5000 ppm Any liquid whose saturated vapor concentration at 20°C (68°F) is equal to or greater than one-fifth its LC_{50} for acute inhalation toxicity, if its LC_{50} is less than or equal to 5000 ppm and that does not meet the criteria for either degree of hazard 3 or degree of hazard 4 Dusts and mists whose LC_{50} for acute inhalation toxicity is greater than 2 mg/L but less than or equal to 10 mg/L Materials whose LD_{50} for acute dermal toxicity is greater than 200 mg/kg but less than or equal to 1000 mg/kg Compressed liquefied gases with boiling points between –30°C (–22°F) and –55°C (–66.5°F) that can cause severe tissue damage, depending on duration of exposure Materials that are respiratory irritants Materials that cause severe but reversible irritation to the eyes or lacrimators Materials that are primary skin irritants or sensitizers Materials whose LD_{50} for acute oral toxicity is greater than 50 mg/kg but less than or equal to 500 mg/kg
1 — Materials that, under emergency conditions, can cause significant irritation	Gases and vapors whose LC_{50} for acute inhalation toxicity is greater than 5000 ppm but less than or equal to 10,000 ppm Dusts and mists whose LC_{50} for acute inhalation toxicity is greater than 10 mg/L but less than or equal to 200 mg/L Materials whose LD_{50} for acute dermal toxicity is greater than 1000 mg/kg but less than or equal to 2000 mg/kg Materials that cause slight to moderate irritation to the respiratory tract, eyes, and skin Materials whose LD_{50} for acute oral toxicity is greater than 500 mg/kg but less than or equal to 2000 mg/kg
0 — Materials that, under emergency conditions, would offer no hazard beyond that of ordinary combustible materials	Gases and vapors whose LC_{50} for acute inhalation toxicity is greater than 10,000 ppm Dusts and mists whose LC_{50} for acute inhalation toxicity is greater than 200 mg/L Materials whose LD_{50} for acute dermal toxicity is greater than 2000 mg/kg Materials whose LD_{50} for acute oral toxicity is greater than 2000 mg/kg Materials that are essentially nonirritating to the respiratory tract, eyes, and skin

*For each degree of hazard, the criteria are listed in a priority order based upon the likelihood of exposure. [**704:** Table 5.2]

Δ Table B.2.4 Degrees of Flammability Hazards

Degree of Hazard	Criteria
4 — Materials that rapidly or completely vaporize at atmospheric pressure and normal ambient temperature or that are readily dispersed in air and will burn readily.	Flammable gases. Flammable cryogenic materials. Any liquid or gaseous material that is liquid while under pressure and has a flash point below 22.8°C (73°F) and a boiling point below 37.8°C (100°F) (i.e., Class IA liquids). Materials that ignite spontaneously when exposed to air. Solids containing greater than 0.5 percent by weight of a flammable or combustible solvent are rated by the closed cup flash point of the solvent.
3 — Liquids and solids (including finely divided suspended 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. See Annex D of NFPA 704 for more information on the ranking of combustible dusts.	Liquids having a flash point below 22.8°C (73°F) and a boiling point at or above 37.8°C (100°F) and those liquids having a flash point at or above 22.8°C (73°F) and below 37.8°C (100°F) (i.e., Class IB and Class IC liquids). Finely divided solids, typically less than 75 micrometers (μm) (200 mesh), that present an elevated risk of forming an ignitible dust cloud, such as finely divided sulfur, *National Electrical Code* Group E dusts (e.g., aluminum, zirconium, and titanium), and bis-phenol A. Materials that burn with extreme rapidity, usually by reason of self-contained oxygen (e.g., dry nitrocellulose and many organic peroxides). Solids containing greater than 0.5 percent by weight of a flammable or combustible solvent are rated by the closed cup flash point of the solvent.
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 could release vapor in sufficient quantities to produce hazardous atmospheres with air. Materials in this degree also include finely divided suspended solids that do not require heating before ignition can occur. See Annex D of NFPA 704 for more information on ranking of combustible dusts.	Liquids having a flash point at or above 37.8°C (100°F) and below 93.4°C (200°F) (i.e., Class II and Class IIIA liquids). Finely divided solids less than 420 μm (40 mesh) that present an ordinary risk of forming an ignitible dust cloud. Solid materials in a flake, fibrous, or shredded form that burn rapidly and create flash fire hazards, such as cotton, sisal, and hemp. Solids and semisolids that readily give off flammable vapors. Solids containing greater than 0.5 percent by weight of a flammable or combustible solvent are rated by the closed cup flash point of the solvent.
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. Materials in this degree also include finely divided suspended solids that do not require heating before ignition can occur. See Annex D of NFPA 704 for more information on ranking of combustible dusts.	Materials that will burn in air when exposed to a temperature of 815.5°C (1500°F) for a period of 5 minutes in accordance with ASTM D6668, *Standard Test Method for the Discrimination Between Flammability Ratings of F = 0 and F = 1.* Liquids, solids, and semisolids having a flash point at or above 93.4°C (200°F) (i.e., Class IIIB liquids). Liquids with a flash point greater than 35°C (95°F) that do not sustain combustion when tested using the *Method of Testing for Sustained Combustibility*, per 49 CFR 173, Appendix H, or the UN publications *Recommendations on the Transport of Dangerous Goods, Model Regulations* and *Manual of Tests and Criteria.* Liquids with a flash point greater than 35°C (95°F) in a water-miscible solution or dispersion with a water noncombustible liquid/solid content of more than 85 percent by weight. Liquids that have no fire point when tested by ASTM D92, *Standard Test Method for Flash and Fire Points by Cleveland Open Cup*, up to the boiling point of the liquid or up to a temperature at which the sample being tested shows an obvious physical change. Combustible pellets, powders, and granules greater than 420 μm (40 mesh). Finely divided solids less than 420 μm that are nonexplosible in air at ambient conditions, such as low volatile carbon black and polyvinylchloride (PVC). Most ordinary combustible materials. Solids containing greater than 0.5 percent by weight of a flammable or combustible solvent are rated by the closed cup flash point of the solvent.
0 — Materials that will not burn under typical fire conditions, including intrinsically noncombustible materials such as concrete, stone, and sand	Materials that will not burn in air when exposed to a temperature of 816°C (1500°F) for a period of 5 minutes in accordance with ASTM D6668, *Standard Test Method for the Discrimination Between Flammability Ratings of F = 0 and F = 1*

[**704:** Table 6.2]

Δ **Table B.2.5 Degrees of Instability Hazards**

Degree of Hazard	Criteria
4 — Materials that in themselves are readily capable of detonation or explosive decomposition or explosive reaction at normal temperatures and pressures.	Materials that are sensitive to localized thermal or mechanical shock at normal temperatures and pressures Materials that have an instantaneous power density (product of heat of reaction and reaction rate) at 250°C (482°F) of 1000 W/mL or greater
3 — Materials that in themselves are capable of detonation or explosive decomposition or explosive reaction, but that require a strong initiating source or that must be heated under confinement before initiation.	Materials that have an instantaneous power density (product of heat of reaction and reaction rate) at 250°C (482°F) at or above 100 W/mL and below 1000 W/mL Materials that are sensitive to thermal or mechanical shock at elevated temperatures and pressures
2 — Materials that readily undergo violent chemical change at elevated temperatures and pressures.	Materials that have an instantaneous power density (product of heat of reaction and reaction rate) at 250°C (482°F) at or above 10 W/mL and below 100 W/mL
1 — Materials that in themselves are normally stable, but that can become unstable at elevated temperatures and pressures.	Materials that have an instantaneous power density (product of heat of reaction and reaction rate) at 250°C (482°F) at or above 0.01 W/mL and below 10 W/mL
0 — Materials that in themselves are normally stable, even under fire conditions.	Materials that have an instantaneous power density (product of heat of reaction and reaction rate) at 250°C (482°F) below 0.01 W/mL

[**704:** Table 7.2]

Annex C Information on Explosion Hazards and Protection

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

C.1 Scope. This annex is intended to provide laboratory management with information to assist in understanding the potential consequences of an explosion in a laboratory and the need for adequately designed protection. It is not intended to be a design manual.

C.2 General.

C.2.1 Where a laboratory work area or a laboratory unit is considered to contain an explosion hazard great enough to cause property damage outside that laboratory work area or injury outside that laboratory area requiring medical treatment beyond first aid, appropriate protection should be provided for the occupants of the laboratory work area, the laboratory unit, adjoining laboratory units, and nonlaboratory areas.

C.2.2 Protection should be provided by one or more of the following:

(1) Limiting amounts of flammable or reactive chemicals or chemicals with unknown characteristics used in or exposed by experiments
(2) Special preventive or protective measures for the reactions, equipment, or materials themselves (e.g., high-speed fire detection with deluge sprinklers, explosion-resistant equipment or enclosures, explosion suppression, and explosion venting directed to a safe location)
(3) Explosion-resistant walls or barricades around the laboratory work area containing the explosion hazard
(4) Remote control of equipment to minimize personnel exposure
(5) Sufficient deflagration venting in outside walls and/or roofs to maintain the integrity of the walls separating the hazardous laboratory work area or laboratory unit from adjoining areas
(6) Conducting experiments in a detached or isolated building or outdoors

C.2.3 Explosion-Resistant Construction. Where explosion-resistant construction is used, adequately designed explosion resistance should be achieved by the use of one of the following methods:

(1) Reinforced concrete walls
(2) Reinforced and fully grouted concrete block walls
(3) Steel walls
(4) Steel plate walls with energy-absorbing linings
(5) Barricades, such as those used for explosives operations, constructed of reinforced concrete, sand-filled/wood-sandwich walls, wood-lined steel plate, or earthen or rock berms
(6) Specifically engineered construction assemblies

C.2.4 Explosion Venting. Where explosion venting is used, it should be designed to ensure the following:

(1) Fragments will not strike other occupied buildings or emergency response staging areas.
(2) Fragments will not strike critical equipment (e.g., production, storage, utility services, and fire protection).
(3) Fragments will be intercepted by blast mats, energy-absorbing barrier walls, or earthen berms.

C.2.5 Unauthorized Access. Properly posted doors, gates, fences, or other barriers should be provided to prevent unauthorized access to the following:

(1) Laboratory work areas containing an explosion hazard
(2) Laboratory units containing an explosion hazard
(3) The space between explosion vents and fragment barriers

C.2.6 Inspection and Maintenance.

C.2.6.1 Inspection of all protective construction devices and systems should be conducted at least annually.

C.2.6.2 Required maintenance should be done to ensure integrity and operability.

C.2.6.3 Explosion shields and special explosion-containing hoods should be inspected prior to each use for deterioration, especially transparent shields and sight panels in special explosion-containing hoods.

C.3 Explosion. An explosion is the bursting or rupture of an enclosure or a container due to the development of internal pressure from a deflagration. [**69,** 2019] Reactive explosions are further categorized as deflagrations, detonations, and thermal explosions.

C.3.1 Container Failure. When a container is pressurized beyond its burst strength, it can violently tear asunder (explode). A container failure can produce subsonic, sonic, or supersonic shock waves, depending on the cause of the internal pressure.

C.3.1.1 The energy released by failure of a vessel containing a gas or liquid is the sum of the energy of pressurization of the fluid and the strain energy in the vessel walls due to pressure-induced deformation.

C.3.1.2 In pressurized gas systems, the energy in the compressed gas represents a large proportion of the total energy released in a vessel rupture, whereas in pressurized liquid systems, the strain energy in the container walls represents the more significant portion of the total explosion energy available, especially in high-pressure systems.

C.3.1.3 Small-volume liquid systems pressurized to over 34,500 kPa (5000 psi), large-volume systems at low pressures, or systems contained by vessels made of materials that exhibit high elasticity should be evaluated for energy release potential under accident conditions. This does not imply that nonelastic materials of construction are preferred. Materials with predictable failure modes are preferred.

C.3.1.4 Liquid systems containing entrained air or gas store more potential energy and are, therefore, more hazardous than totally liquid systems because the gas becomes the driving force behind the liquid.

C.3.1.5 For gas-pressurized liquid systems, such as nitrogen over oil, an evaluation of the explosion energy should be made for both the lowest and highest possible liquid levels.

C.3.1.6 For two-phase systems, such as carbon dioxide, an energy evaluation should be made for the entire system in the gas phase, and the expansion of the maximum available liquid to the gas phase should then be considered.

C.3.2 Deflagration. A deflagration is propagation of a combustion zone at a velocity that is less than the speed of sound in the unreacted medium. [**68,** 2018]

C.3.2.1 The reaction rate is proportional to the increasing pressure of the reaction. A deflagration can, under some conditions, accelerate and build into a detonation.

C.3.2.2 The deflagration-to-detonation transition (D-D-T) is influenced by confinement containment that allows compression waves to advance and create higher pressures that continue to increase the deflagration rates. This is commonly called *pressure piling*.

C.3.3 Detonation.

C.3.3.1 A detonation is propagation of a combustion zone at a velocity that is greater than the speed of sound in the unreacted medium. [**68,** 2018]

C.3.3.2 A detonation causes a high-pressure shock wave to propagate outwardly, through the surrounding environment, at velocities above the speed of sound.

C.3.4 Thermal Explosion. A thermal explosion is a self-accelerating exothermic decomposition that occurs throughout the entire mass, with no separate, distinct reaction zone.

C.3.4.1 A thermal explosion can accelerate into a detonation.

C.3.4.2 The peak pressure and rate of pressure rise in a thermal explosion are directly proportional to the amount of material undergoing reaction per unit volume of the container. This is quite unlike gas or vapor explosions, where the loading density is normally fixed by the combustible mixture at one atmosphere. Frank-Kamenetskii's "Calculation of Thermal Explosion Limits" is useful in evaluating the critical mass in the thermal explosion of solids.

C.4 Effects of Explosions.

Δ **C.4.1 Personnel Exposure.** Personnel exposed to the effects of an explosion are susceptible to injury from the following:

(1) Missiles and explosion-dispersed materials
(2) Thermal and corrosive burns
(3) Inhalation of explosion products
(4) Overpressure, including incident, reflection-reinforced incident, and sustained overpressure
(5) Body blowdown and whole-body displacement

Injuries from missiles and explosion-dispersed materials, burns, and inhalation of toxic gases account for the majority of injuries related to small explosions. Approximation of physiological damage due to explosions is given in Table C.4.1(a) and Table C.4.1(b).

C.4.2 Damage to Structural Elements. The potential for damage to high-value buildings and equipment also warrants special consideration. Failure of building components should not be overlooked as a source of injury to personnel.

C.4.2.1 Where the incident impulse is reinforced by reflection, as will be the case in large explosions within or near structures, the incident peak pressures for given damage are substantially lowered. The reflected pressure might be from 2 to 19 times greater than the incident pressure, depending on the magnitude of the incident pressure and the distance from reflecting surfaces. However, when a small explosion located more than a few inches from a reflecting surface has a TNT equivalence of less than 100 g (3.5 oz), the reinforcement phenomenon is negligible because of the rapid decay of both the incident pressure wave and the reflected pressure wave with distance.

Table C.4.1(a) Blast Effects from Detonations

Blast Effect	Range (ft) for Indicated Explosive Yield (TNT Equivalent)				Criteria	
	0.1 g	1.0 g	10 g	100 g		
1% eardrum rupture	1.1	2.4	5.2	11	23.5 kPa	(P_i = 3.4 psi)
50% eardrum rupture	0.47	1.0	2.2	4.7	110 kPa	(P_i = 16 psi)
No blowdown	0.31	1.3	6.9	~30	57 kPa · msec 0.9 m/sec	($I_i + I_q$ = 1.25 psi · msec) (V_{max} = 0.3 ft/sec)
50% blowdown	<0.1	0.29	1.1	4.1	57 kPa · msec 0.6 m/sec	($I_i + I_q$ = 8.3 psi · msec) V_{max} = 2.0 ft/sec
1% serious displacement injury	<0.1	<0.2	<0.5	~1.1	373 kPa · msec V_{max} 4 msec	($I_i + I_q$ = 54 psi · msec) (V_{max} = 13 ft/sec)
Threshold lung hemorrhage	<0.1	<0.2	0.5	1.8	180 kPa · msec	($I_i + I_q$ = 26 psi · msec)
Severe lung hemorrhage	<0.1	<0.2	<0.5	~1.1	360 kPa · msec	($I_i + I_q$ = 52 psi · msec)
1% mortality	<0.1	<0.2	<0.5	<1	590 kPa · msec	($I_i + I_q$ = 85 psi · msec)
50% mortality	<0.1	<0.2	<0.5	<1	900 kPa · msec	($I_i + I_q$ = 130 psi · msec)
50% large 1.5 m^2 to 2.3 m^2 (16 ft^2 to 25 ft^2) windows broken	0.26	1.1	5.7	~ 30	21 kPa · msec	(I_r = 3 psi · msec)
50% small 0.12 m^2 to 0.56 m^2 (1.3 ft^2 to 6 ft^2) windows broken	0.17	0.40	1.9	9.9	55 kPa · msec	(I_r = 8 psi · msec)

For U.S. customary units, 1 g = 0.04 oz; 1 m = 3.3 ft.
P_i = peak incident overpressure kPa (psi)
V_{max} = maximum translational velocity for an initially standing man m/sec (ft/sec)
I_i = impulse in the incident wave kPa · msec (psi · msec)
I_q = dynamic pressure impulse in the incident wave kPa · msec (psi · msec)
I_r = impulse in the incident wave upon reflection against a surface perpendicular to its path of travel kPa · msec (psi · msec)
Note: The overpressure-distance curves of thermal explosions and deflagrations do not match those of TNT detonations. Nondetonation explosions have lower overpressures in close for comparable energy releases but carry higher overpressures to greater distances. The critical factor is impulse. Impulse is the maximum incident overpressure (psi) multiplied by the pulse duration (msec).

C.4.2.2 Thermal explosions and deflagrations having impulses with rates of pressure rise greater than 20 milliseconds require peak pressures approximately three times those of detonations in order to produce similar damage.

C.4.2.3 A sustained overpressure will result when a large explosion occurs in a building with few openings or inadequate explosion venting. This sustained overpressure is more damaging than a short duration explosion of equivalent rate of pressure rise and peak pressure. Explosions with TNT equivalencies of less than 100 g (3.5 oz) would not be expected to create significant sustained overpressures, except in small enclosures. (In small explosions, burns, inhalation of toxic gases, and missile injuries usually exceed blast wave injuries.)

C.5 Hazard Analysis.

C.5.1 The determination of the degree of hazard presented by a specific operation is a matter of judgment. An explosion hazard should be evaluated in terms of likelihood, severity, and the consequences of an explosion, as well as the protection required to substantially reduce the hazard. A review of the explosion hazard analysis by an appropriate level of management is recommended.

Δ **Table C.4.1(b) Criteria for Estimating Missile Injuries**

Kind of Missile	Critical Organ or Event	Related Impact Velocity	
		m/sec	ft/sec
Nonpenetrating 4.5 kg (10 lb) object	Cerebral concussion:		
	Threshold	4.6	15
	Skull fracture:		
	Threshold	4.6	15
	Near 100%	7.0	23
Penetrating* 10 g (0.35 oz) glass fragments	Skin laceration:		
	Threshold	15	50
	Serious wounds:		
	Threshold	30	100
	50%	55	180
	100%	91	300

*Eye damage, lethality, or paralysis can result from penetrating missiles at relatively low velocities striking eyes, major blood vessels, major nerve centers, or vital organs.

C.5.2 The severity of an explosion is measured in terms of the rate of pressure rise, peak explosion pressure, impulse, duration of the overpressure, dynamic pressure, velocity of the propagating pressure wave, and residual overpressures. The effects of an explosion within an enclosure, such as a laboratory hood, laboratory work area, or laboratory unit can be far more severe than the effects of a similar explosion in an open space. Of primary importance is the missile hazard. Some explosions, such as in overpressurized lightweight glassware, can generate pressure waves that, in themselves, do not endanger personnel, but the resulting fragments can blind, otherwise injure, or kill the experimenter. An explosion that develops pressures sufficient to endanger personnel in a laboratory work area usually will present a serious missile hazard. Consideration of missile hazards should include primary missiles from the vessel in which the explosion originates, secondary missiles accelerated by the expanding blast wave, and the mass, shape, and velocity of the missiles. It should be noted that an improperly anchored or inadequately designed shield also can become a missile. The possibility of flames and dispersion of hot, corrosive, or toxic materials likewise should be considered.

C.5.3 The likelihood of an explosion is estimated by considering such factors as the properties of the reactants; history of the reaction based on literature search, and so forth; possible intermediates and reaction products; pressure, volume, stored energy, design integrity, and safety factors of reaction vessels; pressure relief provisions, in the case of pressure vessels; and explosive limits, quantities, oxygen enrichment, and so forth, of flammable gases or vapors. The term *likelihood*, rather than *probability*, is used to describe an estimated event frequency based on experience, knowledge, or intuitive reasoning, rather than on statistical data. In general, there will be insufficient data to develop mathematical probabilities.

C.5.4 The consequences of an explosion can be estimated by considering the interactions of the explosion with personnel, equipment, and building components at varying distances from the center of the explosion. This analysis should include the following:

(1) Numbers and locations of personnel
(2) Injury and fatality potentials
(3) Repair or replacement cost of equipment
(4) Ability of the building or room or equipment to withstand the explosion and the cost to restore the facility and equipment
(5) Adverse impact on research and development and business interruption costs as a result of loss of use of the facility

C.5.5 Items C.5.5.1 through C.5.5.4 contain recommendations for protecting against explosion hazards of reactions conducted above atmospheric pressures.

C.5.5.1 High-pressure experimental reactions should be conducted behind a substantial fixed barricade that is capable of withstanding the expected lateral forces. The barricade should be firmly supported at top and bottom to take these forces. At least one wall should be provided with explosion venting directed to a safe location. *(SeeNFPA 68.)*

C.5.5.2 Reaction vessels should be built of suitable materials of construction and should have an adequate safety factor.

C.5.5.3 All reaction vessels should be provided with a pressure relief valve or a rupture disc.

C.5.5.4 Low-pressure reactions should be conducted in or behind portable barricades.

C.6 Explosion Hazard Protection.

C.6.1 It is important to remember that a conventional laboratory hood is not designed to provide explosion protection.

C.6.2 The design of explosion hazard protection measures should be based on the following considerations:

(1) Blast effects, as follows:
    (a) Impulse
    (b) Rate and duration of pressure rise
    (c) Peak pressure
    (d) Duration of overpressure
    (e) Velocity of the propagating pressure wave
    (f) Residual overpressure and underpressure
(2) Missiles, as follows:
    (a) Physical properties of the material
    (b) Mass
    (c) Shape
    (d) Velocity

C.6.3 Protection can be provided by one or more of the following methods:

(1) Providing special preventive or protective measures (such as explosion suppression, high-speed fire detection with deluge sprinklers, explosion venting directed to a safe location, or explosion-resistant enclosures) for reactions, equipment, or the reactants themselves
(2) Using remote control to minimize personnel exposure
(3) Conducting experiments in a detached or isolated building, or outdoors
(4) Providing explosion-resistant walls or barricades around the laboratory
(5) Limiting the quantities of flammable or reactive chemicals used in or exposed by the experiments
(6) Limiting the quantities of reactants of unknown characteristics to fractional gram amounts until the properties of intermediate and final products are well established
(7) Providing sufficient explosion venting in outside walls to maintain the integrity of the walls separating the hazardous laboratory work area from adjacent areas (Inside walls should be of explosion-resistant construction.)
(8) Disallowing the use of explosion hazard areas for other nonexplosion hazard uses
(9) Locating offices, conference rooms, lunchrooms, and so forth, remote from the explosion hazard area

C.6.4 Explosion-Resistant Hoods and Shields. Laboratory personnel can be protected by specially designed explosion-resistant hoods or shields for TNT equivalencies up to 1.0 g (0.04 oz). For slightly greater TNT equivalencies, specially designed hoods provided with explosion venting are required. For TNT equivalencies greater than 2.0 g (0.07 oz), explosion-resistant construction, isolation, or other protective methods should be used.

C.6.4.1 Conventional laboratory hoods are not designed to provide explosion protection.

C.6.4.2 When explosion-resistant hoods or shields are used, they should be designed, located, supported, and anchored so as to do the following:

(1) Withstand the effects of the explosion
(2) Vent overpressures, injurious substances, flames, and heat to a safe location
(3) Contain missiles and fragments
(4) Prevent the formation of secondary missiles caused by failure of hood or shield components

C.6.4.3 Commercially available explosion shields should be evaluated against the criteria of C.6.4.2 for the specific hazard.

C.6.4.4 Mild steel plate offers several advantages for hood and shield construction. It is economical, easy to fabricate, and tends to fail, at least initially, by bending and tearing, rather than by spalling, shattering, or splintering.

The use of mirrors or closed-circuit television to view the experiments allows the use of nontransparent shields without hampering the experimenter.

C.6.4.5 When transparent shields are necessary for viewing purposes, the most common materials used are safety glass, wire-reinforced glass, and acrylic or polycarbonate plastic. Each of these materials, although providing some missile penetration resistance, has a distinct failure mode.

Glass shields tend to fragment into shards and to spall on the side away from the explosion. Plastics tend to fail by cracking and breaking into distinct pieces. Also, plastics can lose strength with age, exposure to reactants, or mechanical action. Polycarbonates exhibit superior toughness compared to acrylics.

Glass panels and plastic composite panels (safety glass backed with polycarbonate, with the safety glass toward the explosion hazard) have been suggested as an improved shield design. The glass blunts sharp missiles, and the polycarbonate contains any glass shards and provides additional resistance to the impulse load.

C.6.5 Explosion-Resistant Construction. As explained in C.6.4, explosion-resistant construction can be required for TNT equivalencies greater than 2.0 g (0.07 oz). Explosion-resistant construction should be designed based on the anticipated blast wave, defined in terms of peak impulse pressure and pulse duration, and the worst-case expected missile hazard, in terms of material, mass, shape, and velocity. Missile velocities of 305 m/sec to 1220 m/sec (1000 ft/sec to 4000 ft/sec) normally can be expected.

C.6.5.1 The response of a wall to an explosive shock is a function of the pressure applied and of the time period over which the pressure is applied. The pressure-time product is known as impulse.

Detonations of small quantities of explosive materials usually involve very short periods of time (tenths of milliseconds) and high average pressure.

Gaseous deflagrations usually involve longer time periods and low average pressures.

C.6.5.2 Information on design of explosion-resistant walls and barricades can be obtained from references in Annex G.

C.6.6 Explosion Venting. Peak pressure and impulse loadings resulting from deflagrations (not detonations) can be significantly reduced by adequate explosion venting. *(See NFPA 68 for information on calculating required vent areas.)*

C.6.6.1 Explosion vents should be designed and located so that fragments will not strike occupied buildings or areas where personnel could be located. Blast mats, energy-absorbing barriers, or earthen berms can be used to interrupt the flight of fragments.

C.6.6.2 An air blast, unlike a missile, is not interrupted by an obstacle in its line of travel. Instead, the blast wave will diffract around the obstacle and, except for slight energy losses, is essentially fully reconstituted within five to six obstacle dimensions beyond the obstacle. However, in the case of a small [TNT equivalence of 100 g (3.5 oz) or less] explosion, the wave decay with distance can more than offset the reinforcement phenomena.

Annex D Supplementary Information on the Concept of the Laboratory Unit

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

D.1 Definitions. The following terms, defined in Section 3.3 of this standard, are essential to the understanding of this annex:

(1) Laboratory
(2) Laboratory work area
(3) Laboratory unit
(4) Laboratory unit separation
(5) Exit access corridor

D.2 Basic Concepts.

D.2.1 The concept of a laboratory is too nebulous to be used for establishing requirements for fire protection. The term *laboratory* has too many differing and conflicting interpretations.

D.2.2 The requirements of this standard are based on the concept of the laboratory work area and the laboratory unit.

D.2.3 The term *laboratory work area* applies to any area that serves the purpose of a laboratory, such as areas used for testing, analysis, research, instruction, or similar activities that involve the use or handling of flammable and/or combustible liquids and/or chemicals. The laboratory work area need not be enclosed. If enclosed, it need not constitute an individual fire area. If the boundaries of a laboratory work area do coincide with fire separation from adjacent areas, then that laboratory work area is also a laboratory unit and as such should be properly defined.

D.2.4 The term *laboratory unit* is meant to comprise any separate fire area that contains one or more laboratory work areas. These spaces can include offices and other incidental contiguous rooms maintained for use by laboratory personnel, as well as circulation corridors, with the unit. The fire resistance rating of the separation between the laboratory units and adjacent areas, including areas above or below, is dependent on the size of the unit and its hazard classification in accordance with the amounts of flammable and combustible liquids permitted by Chapter 4.

Consider the laboratory unit shown in Figure D.2.4(a); the laboratory unit is totally enclosed by a fire separation. This laboratory unit can be an entire building, just one floor of a building, or only a portion of one floor of a building (except in mixed-use buildings or buildings with multiple tenants, regardless of whether the tenants are laboratory users).

Figure D.2.4(b) shows the same laboratory unit as that in Figure D.2.4(a) but with more detail. Note that with the addition of work benches and a desk, the laboratory unit is now divided into three distinct work areas and a nonlaboratory area, namely the office area. Although there is no physical separation between these four areas other than the furniture, they are still separate and distinct and can be so treated. For example, the work area at the upper left quadrant might be restricted to very simple, nonhazardous routines, whereas the balance of the areas might be used for more hazardous routines.

In Figure D.2.4(c), the work areas and the office area shown in Figure D.2.4(b) are separated by physical barriers, forming some type of delineation, such as demountable partitions. Although these partitions have no fire-resistance rating, they still afford a some degree of protection.

Figure D.2.4(d), although similar to that of Figure D.2.4(c), shows an entirely different situation. The corridor is now a required means of exit access. Therefore, it should be separated from the laboratory units by fire-rated construction and constructed according to the appropriate building and fire codes. This converts the single laboratory unit into two laboratory units: one having two separate workrooms and one having a workroom and an office.

Figure D.2.4(e) shows how a nonlaboratory area and a Class C laboratory unit are separated from each other and from an exit access corridor passageway. On the other side of the means of exit access, the two laboratory work areas of Figure D.2.4(e) are now separated by a fire partition and/or fire barrier into two laboratory units of differing hazard classifications.

D.3 Factors Affecting Laboratory Unit Fire Hazard Classification.

D.3.1 The primary factor in determining laboratory unit fire hazard classification is the maximum quantity permitted (for both new and waste liquids) of Class I, Class II, and Class IIIA liquids, as defined in Annex B. A survey of flammable liquid usage and storage in any particular laboratory unit should identify the quantities of Class I liquids alone and Class I, Class II, and Class IIIA liquids combined. The survey should differentiate between the total amounts present and the amounts that are not stored in approved storage cabinets or safety cans. Further, flammable and combustible liquids inside liquid storage areas meeting the requirements of NFPA 30 are disregarded.

D.3.2 The area of the laboratory unit will establish whether the quantities of Class I, Class II, and Class IIIA liquids actually present exceed the maximum limits specified in Table 9.1.1(a) and Table 9.1.1(b), as well as the quantities of compressed and/or liquified flammable gases.

D.3.3 The separation requirements in Table 5.1.1 will establish whether the actual laboratory unit's hazard classification is proper for the fire hazard class and size, with respect to its area.

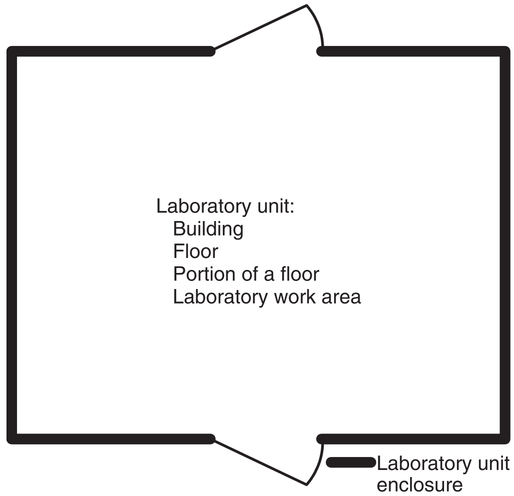

FIGURE D.2.4(a) Laboratory Unit.

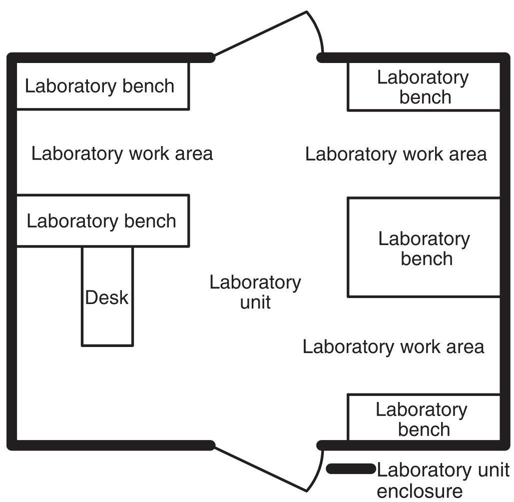

FIGURE D.2.4(b) Laboratory Unit Without Partitioning.

D.4 Correcting Nonconforming Laboratory Units. The simplest, most obvious means of handling a noncomplying laboratory unit is to reduce the quantities of flammable and combustible liquids present. This could involve moving some liquids to an inside liquid storage area or room in accordance with the requirements of NFPA 30, but the chances are that a surprising amount of such liquids is not in frequent use and could even be of no value at all and should be disposed of accordingly.

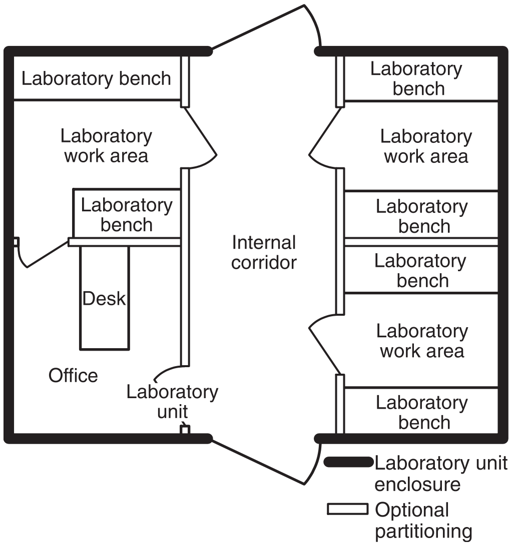

FIGURE D.2.4(c) Laboratory Unit with Optional Partitioning.

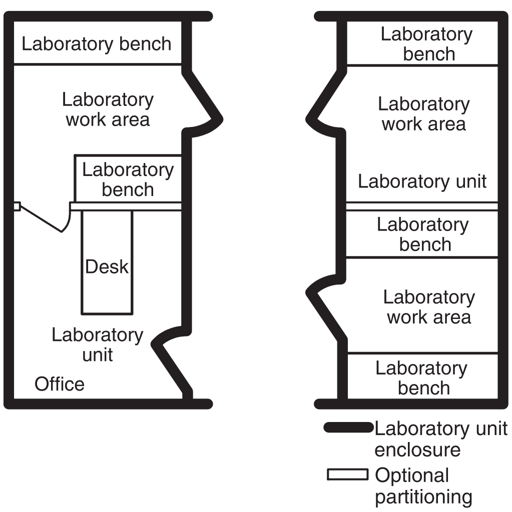

FIGURE D.2.4(d) Laboratory Units Separated by an Exit Passageway.

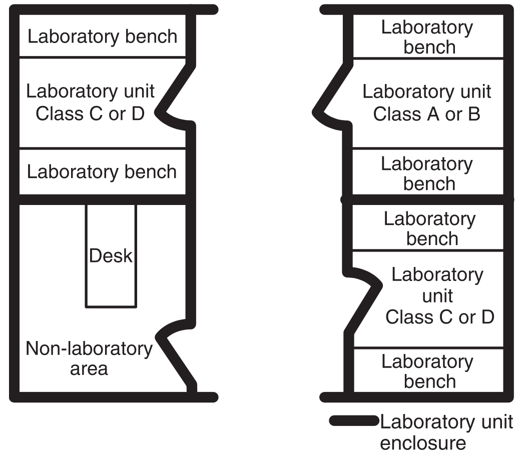

FIGURE D.2.4(e) Separation of Laboratory Units and Nonlaboratory Areas.

D.5 New Construction. In new construction, the laboratory designer should determine the intended use of each laboratory work area and intended storage levels of Class I, Class II, and Class IIIA liquids as well as the quantities of compressed or liquified gases. Then, based on this information and desired space requirements, the laboratory designer can determine the probable laboratory unit fire hazard class, allowable area (as specified in Table 5.1.1), and construction requirements. It should be emphasized that the better design approach of a laboratory building is to provide compartmentation, in addition to reduced means of egress travel distances. Compartmentation limits the spread of a fire and restricts the movement of smoke, thus minimizing the damage or loss of property, work loss, and downtime.

D.6 Nonlaboratory Areas. Laboratory units can include nonlaboratory areas. The assumption is that the personnel in the areas work for the same organization and are knowledgeable about the hazards of the laboratory. If this is not true, then the nonlaboratory areas should not be included in the laboratory unit and should be separated by an appropriate fire-rated barrier. An example of this situation is an education laboratory that other students need to walk past to reach an exit or an industrial laboratory that shares a corridor with the accounting or business part of the same or a different organization.

Annex E Flammability Characteristics of Common Compressed and Liquefied Gases

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

E.1 Table E.1 presents the flammability characteristics of common compressed and liquefied gases. The information provided in Table E.1 is not intended to be inclusive or exhaustive. Furthermore, practically all compressed and liquefied gases present varying health hazards to laboratory or emergency personnel. Therefore, the user is urged to seek additional information from reliable references to adequately assess the reactivity or toxicity of the material.

Δ Table E.1 Flammability Characteristics of Common Compressed and Liquefied Gases

Gas	Flammable Limits (if flammable, percent by volume)	Reference Source
Acetylene	2.5–82	MGD
Allene*	1.5–11.5	MGD
Ammonia*	15–28	MGD
Arsine*	5.1–78	NIOSH
Boron Trichloride*	(a)	MGD
Boron Trifluoride	(a)	MGD
1,3-Butadiene*	2–12	627
n-Butane	1.6–8.4	325
iso-Butane*	1.8–8.4	325
1-Butene*	1.6–10	627, 325
2-Butene*	1.7–9.7	627
Carbon Monoxide	12.5–74	627
Carbonyl Chloride (Phosgene)*	(a)	NIOSH
Carbonyl Fluoride*	(a)	NIOSH
Carbonyl Sulfide*	12–29	325
Chlorine	(a)	NIOSH
Chlorine Dioxide*	(b)	NIOSH
Chlorine Trifluoride*	(a)	NIOSH
1-Chloro-1,1-difluoroethane*	9–14.8	MGD
Chlorotrifluoroethylene*	8.4–38.7	MGD
Cyanogen*	6–32	MGD
Cyanogen Chloride*	(a)	NIOSH
Cyclopropane*	2.4–10.4	MGD, 627
Deuterium	5–75	325
Diazomethane*	(b)	NIOSH
Diborane	0.8–98	325, 627
1,1-Difluoroethane*	3.7–18	MGD
1,1-Difluoroethylene*	5.5–21.3	MGD
Dimethyl Ether*	3.4–27	325, 627
2,2-Dimethyl Propane*	1.4–7.5	325, 627
Ethane*	3.0–12.5	MGD, 325, 627
Ethylacetylene*	(b)	MGD
Ethylamine*	3.5–14	325
Ethyl Chloride*	3.8–15.4	325
Ethylene	2.7–36	325, 627
Ethylene Oxide*	3–100	MGD
Fluorine	(a)	NIOSH
Formaldehyde	7–73	325
Germane	(b)	MGD
Hexafluoroacetone*	(a)	NIOSH
Hydrogen	4–75	325, 627
Hydrogen Bromide*	(a)	NIOSH
Hydrogen Chloride*	(a)	NIOSH
Hydrogen Cyanide*	5.6–40	325, 627
Hydrogen Fluoride*	(a)	NIOSH
Hydrogen Iodide*	(a)	MGD
Hydrogen Selenide*	(b)	NIOSH
Hydrogen Sulfide	4–44	325, 627
Ketene	(b)	NIOSH
Methane	5–15	325, 627

(continues)

Δ Table E.1 *Continued*

Gas	Flammable Limits (if flammable, percent by volume)	Reference Source
Methylacetylene* (Propyne)	2–11.1	325
Methylamine*	4.9–20.7	325
Methyl Bromide*	10–16	325
3-Methyl-1-butene*	1.5–9.1	325, 627
Methyl Chloride*	8.1–17.4	325
Methyl Fluoride*	(b)	MGD
Methyl Mercaptan*	3.9–21.8	325
2-Methylpropene	1.8—9.6	325, 627
Natural Gas	3.8/6.5–13/17	325
Nitric Oxide	(a)	NIOSH
Nitrogen Dioxide*	(a)	MGD
Nitrogen Trioxide*	(a)	MGD
Nitrogen Trifluoride	(a)	MGD
Nitrosyl Chloride*	(a)	MGD
Oxygen	(a)	MGD
Oxygen Difluoride	(a)	NIOSH
Ozone	(a)	NIOSH
iso-Pentane*	1.4–7.6	325
Perchloryl Fluoride*	(a)	NIOSH
Phosphine*	(c)	NIOSH
Propane*	2.1–9.5	325, 627
Propylene*	2.0–11.1	325
Selenium Hexafluoride	(a)	NIOSH
Silane	(c)	MGD
Silicon Tetrafluoride	(a)	MGD
Stibine	(b)	NIOSH
Sulfur Dioxide*	(a)	NIOSH
Sulfur Tetrafluoride*	(a)	NIOSH
Sulfuryl Fluoride*	(a)	NIOSH
Tetrafluoroethylene*	10/11–50/60	MGD, 325
Tetrafluorohydrazine	(b)	MGD
Trimethylamine*	2–11.6	MGD, 325
Vinyl Bromide*	9–15	325
Vinyl Chloride*	3.6–33	325, 627
Vinyl Fluoride*	2.6–21.7	MGD
Vinyl Methyl Ether*	2.6–39	MGD

Notes:
(1) Flammable range:
(a) Not flammable
(b) Flammable, but range not reported
(c) Spontaneously flammable
(2) Reference sources for flammable range:
325 — NFPA 325. Although NFPA 325 has been officially withdrawn from the *National Fire Codes*®, the information is still available in NFPA's *Fire Protection Guide to Hazardous Materials.*
627 — U.S. Bureau of Mines Bulletin 627, *Flammability Characteristics of Combustible Gases and Vapors.*
MGD — *Matheson Gas Data Book.*
NIOSH — National Institute for Occupational Safety and Health, *Pocket Guide to Chemical Hazards.*
*Liquefied gas.

Annex F Safety Tips for Compressed Gas Users

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

F.1 General Hazards. Thoroughly know the hazards of the gas you are using. All compressed gases have the pressure hazard, but a gas can also have more hazards; gases can be toxic, corrosive, flammable, asphyxiating, oxidizing, pyrophoric, and/or reactive. All these factors can impact the design of the system and how the gases are utilized.

F.2 Eye Protection. Always wear eye protection when working on or near compressed gas systems. Make it your job not to let anyone without eye protection into any area where compressed gases are used or stored.

F.3 Train Users. Never let anyone use or connect a cylinder to any system unless that person is trained and knowledgeable in the dangers of pressure, the chemical properties of the compressed gas, and the proper Compressed Gas Association (CGA) compressed gas fittings and connections.

F.4 Cylinder Identification. Do not use a compressed gas cylinder unless the cylinder is clearly marked or labeled with the cylinder's contents. Reject any cylinder that is unmarked or has conflicting markings or labels. Never rely on the color of the cylinder to identify the contents. If there is any conflict or doubt concerning the contents, do not use the cylinder. Return it to your vendor.

F.5 Cylinder Content. Be certain that the content of the cylinder is the correct product for use in the system to which you are connecting it.

F.6 Regulator Use. Never use a compressed gas cylinder without a pressure-reducing regulator or device that will safely reduce the cylinder pressure to the pressure of your system. Only use regulators that have both a high-pressure gauge and a low-pressure gauge. This allows you to monitor both the pressure in the compressed gas cylinder and the pressure in the system.

F.7 Pressure Gauge Use. As per ANSI B 40.1, *Pressure Gauges and Gauge Attachments*, never use a gauge above 75 percent of its maximum face reading. For example, a 20,700 kPa (3000 psi) system should use at least 27,600 kPa (4000 psi) gauges. If your system can achieve a maximum pressure of 517 kPa (75 psi), the gauge monitoring the system should be at least 690 kPa (100 psi). (Immediately replace any gauge whose pointer does not go back to its zero point when pressure is removed.)

F.8 Valves. Be sure the valve on the compressed gas cylinder and the pressure-reducing regulator you are using have the proper CGA connections for the pure gas (CGA V-1) or gas mixture (CGA V-7) you are using. NEVER USE AN ADAPTOR BETWEEN A CYLINDER AND A PRESSURE-REDUCING REGULATOR.

F.9 Proper Connection. Be certain the CGA connection(s) on the cylinder and the pressure-reducing regulator fit together properly without being too loose or too tight. Proper connections will go together smoothly. Never use excessive force to connect a CGA connection. NEVER USE AN AID, such as pipe dope or Teflon® tape, TO CONNECT A REGULATOR TO A CYLINDER.

F.10 Connections. Be certain that the pressure-reducing regulator you are using is compatible with the gas, and be certain that it is rated and marked for the maximum pressure rating of the CGA connection on the compressed gas cylinder valve you are attaching it to. All compressed gas cylinder connections can be found listed with their recommended gases and the maximum allowed pressures in CGA/ANSI V-1, *Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections*.

F.11 Regulator Compatibility. Never replace the CGA connection that the regulator manufacturer has put on a regulator with one for a different gas service. Only the regulator manufacturer or a trained service representative knows the gas compatibility of the regulator's internal design and can properly reclean the regulator.

F.12 Procedures. After attaching a pressure-reducing regulator to a compressed gas cylinder, do the following:

(1) Turn the regulator's adjustment screw out (counterclockwise) until it feels loose.
(2) Stand behind the cylinder with the valve outlet facing away from you.
(3) Observe the high-pressure gauge on the regulator from an angle; do not pressurize a gauge while looking directly at the glass or plastic faceplate.
(4) Open the valve handle on the compressed gas cylinder S-L-O-W-L-Y, until you hear the space between the cylinder valve gently fill the gas. (You can also watch the pressure rise on the high-pressure gauge. If you turned the regulator's adjustment screw back properly, there should be no gas flow out of the regulator or pressure rise on the low-pressure gauge.)
(5) If you are using a nontoxic, nonflammable gas, you can ensure purity by shutting off the cylinder valve and gently cracking the CGA connection at the cylinder valve. (Generally, three pressurizations with venting will ensure the interior of the connection has a clean, representative sample of the gas in the compressed gas cylinder. For toxic or flammable gases, you can purchase special venting regulators that can be safely vented to a fume hood or vented gas cabinet.)
(6) When you are ready to use the compressed gas cylinder, fully open the cylinder valve until you feel it stop. Then, close it one-quarter turn. (A fully open valve that has no play in it can confuse a person who is checking to see if it is open. Many accidents have been recorded by people trying to open a previously fully opened valve by using a large wrench.)
(7) Use the following practices on acetylene cylinders to allow quick closing of the valve in the event of an emergency:
    (a) Open acetylene cylinder valves no more than one and one-half turns.
    (b) Leave the wrench on the valve spindle when the cylinder is being used, if the acetylene cylinder has a T-wrench instead of a hand-wheel valve.

F.13 Pressure Relief. Make sure any system you are pressurizing (piping, manifolds, containers, etc.) that can be isolated or closed off has its own pressure-relief device. It is the user's responsibility to see that the system has proper pressure-relief device(s) built into it. Do not rely on the relief device on the compressed gas cylinder's regulator; it is not designed to protect downstream systems. This is very critical when cryogenic liquids are used. Pressure-relief discharge points should be vented to safe locations (not directed toward people or routed to safe locations for hazardous gases).

F.14 Cylinders Not in Use. Shut off cylinders that are not in use. Always have a cylinder cap on any cylinder that is being stored or is not in use.

F.15 Backflow Precautions. Use backflow check valves where flammable and oxidizing gases are connected to a common piece of equipment or where low- and high-pressure gases are connected to a common set of piping. Do not rely on a closed valve to prevent backflow.

F.16 Pressure Relief. The relief device on a cylinder of liquefied flammable gas (generally found on the cylinder valve) always should be in direct contact (communication) with the vapor space of the cylinder in both use and storage. Never lay a cylinder of liquefied flammable gas on its side unless it is so designed (and so marked) to allow that positioning, as in the case of propane cylinders for forklift trucks.

F.17 Protection of Cylinders in Use. Cylinders in use should be secured by a holder or device specifically designed to secure a cylinder. Never stand a single cylinder in an open area unsecured. Always protect cylinders from dangers of overhead hazards, high temperatures, and other sources of damage, such as vehicle traffic.

F.18 Moving Cylinders. Always use a cylinder cart to move large cylinders or specially designed cylinder holders to carry small cylinders. Never pick up a cylinder by its cap.

F.19 Refilling. Never refill a cylinder or use a cylinder for storing any material. If gas is accidentally forced back or sucked back into a cylinder, mark the cylinder well and inform your gas supplier. (Almost all recent deaths involving compressed gas cylinders occurred as users were putting gas back into cylinders and fillers at the compressed gas plants.)

F.20 Asphyxiation. Possibly the greatest hazard to a user of compressed gases — and especially users of cryogenic fluids — is asphyxiation. Remember that, except for oxygen and for air with at least 19.5 percent oxygen, ALL GAS IS AN ASPHYXIANT. Vent gas only into safe and properly ventilated locations outside the building or fume hood. EXPOSURE TO AN ATMOSPHERE THAT HAS 12 PERCENT OR LESS OXYGEN WILL BRING ABOUT UNCONSCIOUSNESS WITHOUT WARNING AND SO QUICKLY THAT THE INDIVIDUALS CANNOT HELP OR PROTECT THEMSELVES.

F.21 Cryogenic Gases. If you are transferring cryogenic gases inside or have equipment using cryogenic gases that vents anything more than a few cubic centimeters of gas per minute inside (i.e., not to a hood), you should have adequate 24-hour ventilation and install continuous oxygen meter(s)/monitor(s) with a “low oxygen” alarm.

Remember, all compressed gases are hazardous; understand those hazards completely and design your system accordingly. The major compressed gas vendors have the technical expertise available to support users. NEVER BECOME COMPLACENT WHEN USING A COMPRESSED GAS. Always respect the hazards and treat them accordingly.

Annex G Informational References

G.1 Referenced Publications. The documents or portions thereof listed in this annex are referenced within the informational sections of this standard and are not part of the requirements of this document unless also listed in Chapter 2 for other reasons.

G.1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

Fire Protection Guide to Hazardous Materials, 13th edition, 2008.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 2019 edition.

NFPA 13D, *Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes*, 2019 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 2018 edition.

NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, 2018 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, 2019 edition.

NFPA 70®, *National Electrical Code®*, 2017 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 2019 edition.

NFPA 86, *Standard for Ovens and Furnaces*, 2019 edition.

NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems*, 2018 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Particulate Solids*, 2015 edition.

NFPA 92, *Standard for Smoke Control Systems*, 2018 edition.

NFPA *101®*, *Life Safety Code®*, 2018 edition.

NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*, 2017 edition.

NFPA 551, *Guide on Methods for Evaluating Potential for Room Flashover*, 2019 edition.

NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*, 2017 edition.

NFPA 801, *Standard for Fire Protection for Facilities Handling Radioactive Materials*, 2019 edition.

NFPA 1975, *Standard on Emergency Services Work Clothing Elements*, 2019 edition.

NFPA 2112, *Standard on Flame-Resistant Clothing for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire*, 2018 edition.

NFPA 5000®, *Building Construction and Safety Code®*, 2018 edition.

G.1.2 Other Publications.

N **G.1.2.1 AGS Publications.** American Glovebox Society, 526 South E Street, Santa Rosa, CA 95404.

AGS-G010, *Standard of Practice for Glovebox Fire Protection*, 2010.

G.1.2.2 AMCA Publications. Air Movement and Control Association International, Inc., 30 West University Drive, Arlington Heights, IL 60004-1893.

ANSI/AMCA Standard 99, 2016.

G.1.2.3 ANSI Publications. American National Standards Institute, Inc., 25 West 43rd Street, 4th Floor, New York, NY 10036.

ANSI/AIHA Z9.5, *Laboratory Ventilation*, 2012.

ANSI/UL 1626, *Residential Sprinklers for Fire Protection Service*, 2008, revised 2012.

G.1.2.4 ASHRAE Publications. ASHRAE, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305.

ASHRAE 110, *Method of Testing Performance of Laboratory Fume Hoods*, 2016.

ASHRAE *Handbook of Fundamentals*, 2017.

ASHRAE *HVAC Applications Handbook*, 2015.

G.1.2.5 ASME Publications. ASME International, Two Park Avenue, New York, NY 10016-5990.

ASME *Boiler and Pressure Vessel Code*, Section VIII, "Rules for Construction of Pressure Vessels," Division 1, 2017.

ANSI/ASME A13.1, *Scheme for the Identification of Piping Systems*, 2015.

ASME B31.1, *Power Piping*, 2016.

ASME B31.3, *Process Piping*, 2016.

ASME B40.1, *Pressure Gauges and Gauge Attachments*, 2013.

Δ **G.1.2.6 ASTM Publications.** ASTM International, 100 Barr Harbor Drive, P. O. Box C700, West Conshohocken, PA 19428-2959.

ASTM D92, *Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester*, 2016b.

ASTM D323, *Standard Method of Test for Vapor Pressure of Petroleum Products (Reid Method)*, 2015a.

ASTM D6668, *Standard Test Method for the Discrimination Between Flammability Ratings of F = 0 and F = 1*, 2001, reapproved 2016.

ASTM E1491, *Test Method for Minimum Autoignition Temperature of Dust Clouds*, 2006, reapproved 2012.

ASTM E2021, *Test Method for Hot-Surface Ignition Temperature of Dust Layers*, 2015.

Δ **G.1.2.7 CGA Publications.** Compressed Gas Association, 14501 George Carter Way, Suite 103, Chantilly, VA 20151-1788.

CGA P-1, *Safe Handling of Compressed Gases in Containers*, 12th edition, 2015.

CGA/ANSI V-1, *Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections*, 12th edition, 2013.

G.1.2.8 U.S. Government Publications. U.S. Government Publishing Office, 732 North Capitol Street, NW, Washington, DC 20401-0001.

Title 16, Code of Federal Regulations, Part 1500.44.

Title 29, Code of Federal Regulations, Part 1910.1450, Appendix A.

Title 49, Code of Federal Regulations, Part 173, Appendix H.

G.1.2.9 Other Publications.

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NFPA 99, *Health Care Facilities Code*, 2018 edition.

NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*, 2017 edition.

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Sequence of Events for the Standards Development Process

Once the current edition is published, a Standard is opened for Public Input.

Step 1 – Input Stage

- Input accepted from the public or other committees for consideration to develop the First Draft
- Technical Committee holds First Draft Meeting to revise Standard (23 weeks); Technical Committee(s) with Correlating Committee (10 weeks)
- Technical Committee ballots on First Draft (12 weeks); Technical Committee(s) with Correlating Committee (11 weeks)
- Correlating Committee First Draft Meeting (9 weeks)
- Correlating Committee ballots on First Draft (5 weeks)
- First Draft Report posted on the document information page

Step 2 – Comment Stage

- Public Comments accepted on First Draft (10 weeks) following posting of First Draft Report
- If Standard does not receive Public Comments and the Technical Committee chooses not to hold a Second Draft meeting, the Standard becomes a Consent Standard and is sent directly to the Standards Council for issuance (see Step 4) or
- Technical Committee holds Second Draft Meeting (21 weeks); Technical Committee(s) with Correlating Committee (7 weeks)
- Technical Committee ballots on Second Draft (11 weeks); Technical Committee(s) with Correlating Committee (10 weeks)
- Correlating Committee Second Draft Meeting (9 weeks)
- Correlating Committee ballots on Second Draft (8 weeks)
- Second Draft Report posted on the document information page

Step 3 – NFPA Technical Meeting

- Notice of Intent to Make a Motion (NITMAM) accepted (5 weeks) following the posting of Second Draft Report
- NITMAMs are reviewed and valid motions are certified by the Motions Committee for presentation at the NFPA Technical Meeting
- NFPA membership meets each June at the NFPA Technical Meeting to act on Standards with “Certified Amending Motions” (certified NITMAMs)
- Committee(s) vote on any successful amendments to the Technical Committee Reports made by the NFPA membership at the NFPA Technical Meeting

Step 4 – Council Appeals and Issuance of Standard

- Notification of intent to file an appeal to the Standards Council on Technical Meeting action must be filed within 20 days of the NFPA Technical Meeting
- Standards Council decides, based on all evidence, whether to issue the standard or to take other action

Notes:

1. Time periods are approximate; refer to published schedules for actual dates.
2. Annual revision cycle documents with certified amending motions take approximately 101 weeks to complete.
3. Fall revision cycle documents receiving certified amending motions take approximately 141 weeks to complete.

Committee Membership Classifications[1,2,3,4]

The following classifications apply to Committee members and represent their principal interest in the activity of the Committee.

1. M *Manufacturer:* A representative of a maker or marketer of a product, assembly, or system, or portion thereof, that is affected by the standard.
2. U *User:* A representative of an entity that is subject to the provisions of the standard or that voluntarily uses the standard.
3. IM *Installer/Maintainer:* A representative of an entity that is in the business of installing or maintaining a product, assembly, or system affected by the standard.
4. L *Labor:* A labor representative or employee concerned with safety in the workplace.
5. RT *Applied Research/Testing Laboratory:* A representative of an independent testing laboratory or independent applied research organization that promulgates and/or enforces standards.
6. E *Enforcing Authority:* A representative of an agency or an organization that promulgates and/or enforces standards.
7. I *Insurance:* A representative of an insurance company, broker, agent, bureau, or inspection agency.
8. C *Consumer:* A person who is or represents the ultimate purchaser of a product, system, or service affected by the standard, but who is not included in (2).
9. SE *Special Expert:* A person not representing (1) through (8) and who has special expertise in the scope of the standard or portion thereof.

NOTE 1: “Standard” connotes code, standard, recommended practice, or guide.

NOTE 2: A representative includes an employee.

NOTE 3: While these classifications will be used by the Standards Council to achieve a balance for Technical Committees, the Standards Council may determine that new classifications of member or unique interests need representation in order to foster the best possible Committee deliberations on any project. In this connection, the Standards Council may make such appointments as it deems appropriate in the public interest, such as the classification of “Utilities” in the National Electrical Code Committee.

NOTE 4: Representatives of subsidiaries of any group are generally considered to have the same classification as the parent organization.

Submitting Public Input / Public Comment Through the Online Submission System

Soon after the current edition is published, a Standard is open for Public Input.

Before accessing the Online Submission System, you must first sign in at www.nfpa.org. *Note: You will be asked to sign-in or create a free online account with NFPA before using this system:*

a. Click on Sign In at the upper right side of the page.
b. Under the Codes and Standards heading, click on the "List of NFPA Codes & Standards," and then select your document from the list or use one of the search features.

OR

a. Go directly to your specific document information page by typing the convenient shortcut link of www.nfpa.org/document# (Example: NFPA 921 would be www.nfpa.org/921). Sign in at the upper right side of the page.

To begin your Public Input, select the link "The next edition of this standard is now open for Public Input" located on the About tab, Current & Prior Editions tab, and the Next Edition tab. Alternatively, the Next Edition tab includes a link to Submit Public Input online.

At this point, the NFPA Standards Development Site will open showing details for the document you have selected. This "Document Home" page site includes an explanatory introduction, information on the current document phase and closing date, a left-hand navigation panel that includes useful links, a document Table of Contents, and icons at the top you can click for Help when using the site. The Help icons and navigation panel will be visible except when you are actually in the process of creating a Public Input.

Once the First Draft Report becomes available there is a Public Comment period during which anyone may submit a Public Comment on the First Draft. Any objections or further related changes to the content of the First Draft must be submitted at the Comment stage.

To submit a Public Comment you may access the online submission system utilizing the same steps as previously explained for the submission of Public Input.

For further information on submitting public input and public comments, go to: http://www.nfpa.org/publicinput.

Other Resources Available on the Document Information Pages

About tab: View general document and subject-related information.

Current & Prior Editions tab: Research current and previous edition information on a Standard.

Next Edition tab: Follow the committee's progress in the processing of a Standard in its next revision cycle.

Technical Committee tab: View current committee member rosters or apply to a committee.

Technical Questions tab: For members and Public Sector Officials/AHJs to submit questions about codes and standards to NFPA staff. Our Technical Questions Service provides a convenient way to receive timely and consistent technical assistance when you need to know more about NFPA codes and standards relevant to your work. Responses are provided by NFPA staff on an informal basis.

Products & Training tab: List of NFPA's publications and training available for purchase.

Information on the NFPA Standards Development Process

I. Applicable Regulations. The primary rules governing the processing of NFPA standards (codes, standards, recommended practices, and guides) are the NFPA *Regulations Governing the Development of NFPA Standards (Regs)*. Other applicable rules include NFPA *Bylaws*, NFPA *Technical Meeting Convention Rules*, NFPA *Guide for the Conduct of Participants in the NFPA Standards Development Process*, and the NFPA *Regulations Governing Petitions to the Board of Directors from Decisions of the Standards Council*. Most of these rules and regulations are contained in the *NFPA Standards Directory*. For copies of the *Directory*, contact Codes and Standards Administration at NFPA Headquarters; all these documents are also available on the NFPA website at "www.nfpa.org."

The following is general information on the NFPA process. All participants, however, should refer to the actual rules and regulations for a full understanding of this process and for the criteria that govern participation.

II. Technical Committee Report. The Technical Committee Report is defined as "the Report of the responsible Committee(s), in accordance with the Regulations, in preparation of a new or revised NFPA Standard." The Technical Committee Report is in two parts and consists of the First Draft Report and the Second Draft Report. (See *Regs* at Section 1.4.)

III. Step 1: First Draft Report. The First Draft Report is defined as "Part one of the Technical Committee Report, which documents the Input Stage." The First Draft Report consists of the First Draft, Public Input, Committee Input, Committee and Correlating Committee Statements, Correlating Notes, and Ballot Statements. (See *Regs* at 4.2.5.2 and Section 4.3.) Any objection to an action in the First Draft Report must be raised through the filing of an appropriate Comment for consideration in the Second Draft Report or the objection will be considered resolved. [See *Regs* at 4.3.1(b).]

IV. Step 2: Second Draft Report. The Second Draft Report is defined as "Part two of the Technical Committee Report, which documents the Comment Stage." The Second Draft Report consists of the Second Draft, Public Comments with corresponding Committee Actions and Committee Statements, Correlating Notes and their respective Committee Statements, Committee Comments, Correlating Revisions, and Ballot Statements. (See *Regs* at 4.2.5.2 and Section 4.4.) The First Draft Report and the Second Draft Report together constitute the Technical Committee Report. Any outstanding objection following the Second Draft Report must be raised through an appropriate Amending Motion at the NFPA Technical Meeting or the objection will be considered resolved. [See *Regs* at 4.4.1(b).]

V. Step 3a: Action at NFPA Technical Meeting. Following the publication of the Second Draft Report, there is a period during which those wishing to make proper Amending Motions on the Technical Committee Reports must signal their intention by submitting a Notice of Intent to Make a Motion (NITMAM). (See *Regs* at 4.5.2.) Standards that receive notice of proper Amending Motions (Certified Amending Motions) will be presented for action at the annual June NFPA Technical Meeting. At the meeting, the NFPA membership can consider and act on these Certified Amending Motions as well as Follow-up Amending Motions, that is, motions that become necessary as a result of a previous successful Amending Motion. (See 4.5.3.2 through 4.5.3.6 and Table 1, Columns 1-3 of *Regs* for a summary of the available Amending Motions and who may make them.) Any outstanding objection following action at an NFPA Technical Meeting (and any further Technical Committee consideration following successful Amending Motions, see *Regs* at 4.5.3.7 through 4.6.5.3) must be raised through an appeal to the Standards Council or it will be considered to be resolved.

VI. Step 3b: Documents Forwarded Directly to the Council. Where no NITMAM is received and certified in accordance with the Technical Meeting Convention Rules, the standard is forwarded directly to the Standards Council for action on issuance. Objections are deemed to be resolved for these documents. (See *Regs* at 4.5.2.5.)

VII. Step 4a: Council Appeals. Anyone can appeal to the Standards Council concerning procedural or substantive matters related to the development, content, or issuance of any document of the NFPA or on matters within the purview of the authority of the Council, as established by the Bylaws and as determined by the Board of Directors. Such appeals must be in written form and filed with the Secretary of the Standards Council (see *Regs* at Section 1.6). Time constraints for filing an appeal must be in accordance with 1.6.2 of the *Regs*. Objections are deemed to be resolved if not pursued at this level.

VIII. Step 4b: Document Issuance. The Standards Council is the issuer of all documents (see Article 8 of *Bylaws*). The Council acts on the issuance of a document presented for action at an NFPA Technical Meeting within 75 days from the date of the recommendation from the NFPA Technical Meeting, unless this period is extended by the Council (see *Regs* at 4.7.2). For documents forwarded directly to the Standards Council, the Council acts on the issuance of the document at its next scheduled meeting, or at such other meeting as the Council may determine (see *Regs* at 4.5.2.5 and 4.7.4).

IX. Petitions to the Board of Directors. The Standards Council has been delegated the responsibility for the administration of the codes and standards development process and the issuance of documents. However, where extraordinary circumstances requiring the intervention of the Board of Directors exist, the Board of Directors may take any action necessary to fulfill its obligations to preserve the integrity of the codes and standards development process and to protect the interests of the NFPA. The rules for petitioning the Board of Directors can be found in the *Regulations Governing Petitions to the Board of Directors from Decisions of the Standards Council* and in Section 1.7 of the *Regs*.

X. For More Information. The program for the NFPA Technical Meeting (as well as the NFPA website as information becomes available) should be consulted for the date on which each report scheduled for consideration at the meeting will be presented. To view the First Draft Report and Second Draft Report as well as information on NFPA rules and for up-to-date information on schedules and deadlines for processing NFPA documents, check the NFPA website (www.nfpa.org/docinfo) or contact NFPA Codes & Standards Administration at (617) 984-7246.