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NFPA 45
Fire Protection for Laboratories Using Chemicals
1982

NFPA

National Fire Protection Association Batterymarch Park, Quincy, MA 02269

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

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

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

Statement on NFPA Procedures

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

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Standard on

Fire Protection for Laboratories Using Chemicals

NFPA 45-1982

1982 Edition of NFPA 45

This edition of NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, was prepared by the Technical Committee on Chemistry Laboratories, released by the Correlating Committee on Chemicals and Explosives, and acted on by the National Fire Protection Association on November 17, 1981, at its Fall Meeting in Toronto, Ontario, Canada. It was issued by the Standards Council on December 9, 1981, with an effective date of December 29, 1981, and supersedes all previous editions.

The 1982 edition of this standard has been approved by the American National Standards Institute.

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

Origin and Development of NFPA 45

NFPA 45 was developed by the Technical Committee on Chemistry Laboratories. It was tentatively adopted at the 1974 NFPA Annual Meeting. Based on comments received, the tentative document was further amended and the amended text was officially adopted at the 1975 NFPA Fall Meeting.

After the document had been in use for two years, the Technical Committee began an exhaustive review of the text. Some of the major changes include: more extensive requirements for laboratory ventilation systems; more extensive explanatory appendices, including one on explosion hazards and protection and one on the concept of the laboratory unit.

The text presented here is the culmination of many hours of deliberation and review by the Committee and by interested persons.

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.

Correlating Committee on Chemicals and Explosives

Robert W. Van Dolah, *Chairman*
Pittsburgh, PA

Robert P. Benedetti, *Secretary*
National Fire Protection Assn.
(Nonvoting)

William H. Doyle, Simsbury, CT

Thomas E. Duke, Fire Prevention & Engineering Bureau of Texas

Howard F. Kempsell, Exxon Research & Engineering Co.

Richard Y. Le Vine, Olin Corp.

Samuel J. Porter, Falls Church, VA

William J. Wiswesser, US Department of Agriculture

Technical Committee on Chemistry Laboratories

Howard F. Kempsell, *Chairman*
Exxon Research & Engineering Co.

Robert P. Benedetti, *Secretary*
National Fire Protection Assn.
(Nonvoting)

L. H. Bradley, Viking Fire Protection Assoc. Inc.
Rep. NAS & FCA

Harlan R. Bratvold, Underwriters Laboratories Inc.

Murray Cappers, Allied Chemical Corp.
Rep. Chemical Manufacturers Assn.

John F. Clemons, Harvard University, MA

Vernon L. Duke, Sandia National Laboratories
Rep. NFPA Industrial Fire Protection Section

J. Patrick Eaker, Kenosha, WI
Rep. Campus Safety Assn.

Arden W. Forrey, Ph.D., American Assn. for Clinical Chemistry

Lawrence F. Gaffney, US Environmental Protection Agency

John M. Galat, Schering-Plough Corp.
Rep. National Safety Council

Leon D. Horowitz, American Mutual Liability Insurance Co.
Rep. Alliance of American Insurers

F. Owen Kubias, SCM Corp.

Richard Y. Le Vine, Olin Corp.

John R. Leach, National Institute of Health

F. C. Loos, Houston Fire Department, TX
Rep. Fire Marshals Assn. of North America

Lawrence N. Nelson, Kewaunee Scientific Equipment Corp.

David J. Pierce, NC Department of Labor

D. L. Rhynard, Mobil Research & Development Center
Rep. American Petroleum Institute

Theodorus Ruys, Naramore, Bain, Brady & Johnson
Rep. American Institute of Architects

Norman V. Steere, Norman V. Steere Assoc.

Alternates

John Fresina, Massachusetts Institute of Technology
(Alternate to J. P. Eaker)

William D. Jordan, Harvard University, MA
(Alternate to J. F. Clemons)

William B. Meyer, Bendix Corp.
(Alternate to V. Duke)

George F. Murphy, Kennecott Copper Co.
(Alternate to National Safety Council)

Charles C. Randall, US Environmental Protection Agency
(Alternate to L. Gaffney)

Nonvoting

Ralph Berger, Skinner & Sherman Laboratories Inc.

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

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

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Fire Protection for
Laboratories Using Chemicals

NFPA 45-1982

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

Chapter 1 General

1-1 Scope.

1-1.1 This standard shall apply to laboratory buildings, laboratory units and laboratory work areas in which hazardous chemicals are handled or stored.

Exception No. 1: It does not apply to laboratory work areas which are covered by NFPA 56C, Safety Standard for Laboratories in Health-Related Institutions.

Exception No. 2: It does not apply to laboratories that are, in fact, pilot plants.

Exception No. 3: It does not apply to laboratories that are, in fact, primarily manufacturing plants.

Exception No. 4: It does not apply to an incidental testing facility for in-process control located within a manufacturing or operating area. (See definition of Incidental Testing Facility in Section 1-4 of this standard and Section 5-2, "Incidental Storage or Use of Liquids," of NFPA 30, Flammable and Combustible Liquids Code.)

Exception No. 5: It does not apply to physical, electronic, instrument, or similar laboratories which use small quantities of chemicals for incidental purposes, such as cleaning.

1-1.2 This standard contains requirements, but not all inclusive requirements, for conducting laboratory experiments and for handling and storage of hazardous chemicals.

Exception No. 1: It does not cover the special fire protection required when handling explosive materials. (See NFPA 495, Code for the Manufacture, Transportation, Storage and Use of Explosive Materials.)

Exception No. 2: It does not cover the special fire protection required when handling radioactive materials. (See NFPA 801, Recommended Fire Protection Practice for Facilities Handling Radioactive Materials.)

1-1.3 Laboratory work areas, laboratory buildings, equipment, and installations which do not comply strictly with this standard shall be considered to be in compliance if it can be shown that equivalent protection has been provided or that no specific hazard will be created or continued through noncompliance.

1-2 Purpose.

1-2.1 This standard provides basic requirements for the protection of life and property in laboratory work areas where hazardous chemicals are handled through prevention and control of fires and explosions. The unique nature of many laboratory operations may make more stringent requirements necessary.

1-2.2 This standard is designed to protect persons from the effects of toxic, corrosive, or otherwise hazardous chemicals to which they may be exposed as a result of fire or explosion. Although it does not attempt to deal with health hazards unrelated to fires or explosions, many of the requirements to protect against fire or explosion, such as those for hood exhaust systems, also serve to protect persons from exposure to nonfire health hazards of chemicals.

1-2.3 The objective of this standard is to achieve a comprehensive laboratory fire protection program.

1-3 Interface with Existing Codes and Standards.

1-3.1 When interface with existing NFPA or other consensus codes and standards occurs, reference is made to the appropriate source in the text.

1-3.2 Where necessary, due to the special nature of laboratories, existing codes and standards are supplemented in this text, so as to apply more specifically to buildings or portions of buildings devoted to laboratory usage.

1-3.3 Where a construction or protection requirement of a governmental agency having jurisdiction is more stringent than in this standard, the more stringent requirement shall apply.

1-4* Definitions. For the purpose of this standard, the following terms shall have the meanings given below.

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

Approved. Acceptable to the "authority having jurisdiction."

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

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

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

Combustible Liquid. See definition of Liquids, below; see also Appendix B-1.

Cryogenic Fluids. Substances which exist only in the vapor phase above -73°C at one atmosphere pressure and which are handled, stored, and used in the liquid state at temperatures at or below -73°C while at any pressure. (*See National Safety Council Data Sheet 1-688-80, Cryogenic Fluid in the Laboratory.*)

Educational Occupancies. Buildings used for the gathering of six or more persons for purposes of instruction, such as schools, universities, colleges, and academies. (*See definition of Instructional Laboratory Unit, below.*)

Explosive Material. A chemical compound, mixture, or device, the primary or common purpose of which is to function by explosion. (*For a more complete definition, see NFPA 495, Code for the Manufacture, Transportation, Storage, and Use of Explosive Materials.*)

Flammable Gas. A gas that will burn in air.

Flammable Liquid. See definition of Liquids, below; see also Appendix B-1.

Flash Point. The minimum temperature at which a liquid gives off vapor in sufficient concentration to form an ignitible mixture with air near the surface of the liquid within the vessel, as specified by appropriate test procedures and apparatus. (*See Appendix B-2.*)

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

Incidental Testing Facility.* An area of a production facility set aside for the purpose of conducting tests which are not generally integral to the production process.

Instructional Laboratory Unit. A laboratory unit in an educational occupancy in which the person or persons conducting chemical experiments or tests are under the direct supervision of a faculty member or an assistant. Laboratory units used for graduate or post-graduate research shall not be considered instructional laboratory units.

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

Laboratory. A generic term denoting a building, space, equipment, or operation.

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

Laboratory Equipment. See definiton of Apparatus.

Laboratory Hood. See Section 6-3 for definitions *related to* laboratory hoods. See Appendix A-6-3 for descriptions of *types of* laboratory hoods.

Laboratory Unit. An enclosed space used for experiments or tests. Laboratory units may or may not include offices, lavatories, and other contiguous rooms maintained for or used by laboratory personnel, and corridors within the units. It may contain one or more separate laboratory work areas. It may be an entire building. Laboratory units are classified as A, B or C according to the limitations established in Tables 2-2 and 3-1. (*See also Appendix D.*)

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

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

Liquids. Any material which has a fluidity greater than that of 300 penetration asphalt when tested in accordance with ASTM D5-71, *Test for Penetration of Bituminous Materials*. When not otherwise identified, the term liquid shall include both flammable and combustible liquids. (*See Appendix B-1.*)

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

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

Maximum Allowable Working Pressure.* The maximum pressure permissible at the top of a vessel in its normal operating position at the operating temperature specified for that pressure.

Nonlaboratory Area. Any space within a building not included in a laboratory unit. (*See definition of Laboratory Unit.*)

Pilot Plant. An experimental assembly of manufacturing equipment for exploring process variables or for producing semi-commercial quantities of materials.

Potentially Explosive Reaction. Any chemical procedure that uses or forms reactive materials.

Reactive Material. A material that, by itself, is readily capable of detonation, explosive decomposition, or explosive reaction at normal or elevated temperatures and pressures. (*See Appendix B-3-3.1 for definitions of Reactivity 3 and Reactivity 4.*)

Refrigerating Equipment. Any mechanically operated equipment used for storing materials below normal ambient temperature. It includes refrigerators, freezers, and similar equipment. (*See 9-2.2.2 and A-9-2.2.2.*)

Safety Can. An approved container, of not more than five gallons capacity, having a spring-closing lid and spout cover and so designed that it will safely relieve internal pressure when subjected to fire exposure.

Shall. Indicates a mandatory requirement.

Should. Indicates recommendations or that which is advised but not required.

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

Street Floor. Any story or floor level accessible from the street or from outside a building at ground level with floor level at main entrance not more than three risers above or below ground level at these points, and so arranged and utilized as to qualify as the main floor. (*For a more complete definition, see NFPA 101®, Life Safety Code®.*)

Unattended Laboratory Operation. A laboratory procedure or operation at which there is no person present who is knowledgeable regarding the operation and emergency shut-down procedures.

Absence for lunch, telephone calls, etc., without coverage by a knowledgeable person constitutes an unattended laboratory operation.

Chapter 2 Laboratory Unit Hazard Classification

2-1 Scope. This chapter classifies laboratory units on the basis of the amount of flammable and combustible liquids contained within the unit, both in storage and in use. This chapter also defines the existence of a fire or explosion hazard.

2-2 Laboratory Unit Fire Hazard Classification.

2-2.1 Laboratory units shall be classified as Class A, B or C, according to the quantitites of flammable and combustible liquids specified in Table 2-2. The largest amounts of flammable and combustible liquids are allowed in Class A laboratories and the least amounts in

Table 2-2. Maximum Quantities of Flammable and Combustible Liquids in Laboratory Units Outside of Approved Flammable Liquid Storage Rooms

Laboratory Unit Class	Flammable or Combustible Liquid Class	*Excluding* Quantities in Storage Cabinets and Safety Cans: Maximum Quantity[3] Per 100 Square Feet of Laboratory Unit	*Excluding*: Maximum Quantity[4] Per Laboratory Unit — Unsprinklered	*Excluding*: Maximum Quantity[4] Per Laboratory Unit — Sprinklered[6]	*Including* Quantities in Storage Cabinets and Safety Cans: Maximum Quantity[3] Per 100 Square Feet of Laboratory Unit	*Including*: Maximum Quantity[4] Per Laboratory Unit — Unsprinklered	*Including*: Maximum Quantity[4] Per Laboratory Unit — Sprinklered[6]
A[1]	I	10 Gallons	300 Gallons	600 Gallons	20 Gallons	600 Gallons	1200 Gallons
(High Hazard)	I, II and IIIA[5]	20 Gallons	400 Gallons	800 Gallons	40 Gallons	800 Gallons	1600 Gallons
B[2]	I	5 Gallons	150 Gallons	300 Gallons	10 Gallons	300 Gallons	600 Gallons
(Intermediate Hazard)	I, II and IIIA[5]	10 Gallons	200 Gallons	400 Gallons	20 Gallons	400 Gallons	800 Gallons
C[2]	I	2 Gallons	75 Gallons	150 Gallons	4 Gallons	150 Gallons	300 Gallons
(Low Hazard)	I, II and IIIA[5]	4 Gallons	100 Gallons	200 Gallons	8 Gallons	200 Gallons	400 Gallons

[1] Class A Laboratory units shall not be used as instructional laboratory units.

[2] Maximum quantities of flammable and combustible liquids in Class B and Class C instructional laboratory units shall be 50% of those listed in the Table.

[3] For maximum container sizes, see Table 7-2.

[4] Regardless of the maximum allowable quantity, the maximum amount in a laboratory unit shall never exceed an amount calculated by using the maximum quantity per 100 square feet of laboratory unit. The area of offices, lavatories, and other contiguous areas of a laboratory unit are to be included when making this calculation.

[5] The maximum quantities of Class I liquids shall not exceed the quantities specified for Class I liquids alone.

[6] Where water may create a serious fire or personnel hazard, a nonwater extinguishing system may be used instead of sprinklers.

FOR SI UNITS: 1 gal = 3.785 L; 100 sq ft = 9.3 m².

Class C laboratories. (*See Appendix D for further information on laboratory unit fire hazard classification.*)

2-2.2 Class A laboratory units shall not be used as instructional laboratory units. Maximum quantities of flammable and combustible liquids in Class B and Class C instructional laboratory units shall be 50 percent of those listed in Table 2-2.

2-2.3 Maximum capacities of storage containers in laboratory units shall comply with Table 7-2 and 7-2.3.2.

2-2.4 Requirements for laboratory units shall apply to all laboratory units unless identified as applying to a laboratory unit of a specific fire hazard class.

2-2.5 For design, construction, and fire protection requirements for laboratory units, see Chapters 3 and 4.

2-3 Laboratory Work Area and Laboratory Unit Explosion Hazard Classification.

2-3.1 A *laboratory work area* shall be considered to contain an explosion hazard if an explosion of quantities or concentrations of materials in (a) through (e) below could result in serious or fatal injuries to personnel *within* that laboratory work area. (*See Appendix C.*)

(a) Storage of materials with a reactivity hazard rating of 4.

(b) Use or formation of materials with a reactivity hazard rating of 4.

(c) Highly exothermic reactions, such as polymerizations, oxidations, nitrations, peroxidations, hydrogenations, or organo-metallic reactions. (*For sources of data on chemical reactivity hazard and hazardous chemical reactions, see Appendix A-7-1.*)

(d) Use or formation of materials whose chemical structures indicate a potential hazard, but whose properties have not been established, such as triple bonds, epoxy radicals, nitro and nitroso compounds, and peroxides.

(e) High pressure reactions.

WARNING: Persons in the immediate vicinity of an explosion may be injured or killed even though the explosion does not cause major damage.

2-3.2 A *laboratory unit* shall be considered to contain an explosion hazard *only if* a laboratory work area *within that unit* contains an explosion hazard great enough to cause major property damage or serious injury *outside that laboratory work area.*

2-3.3 For explosion hazard protection requirements, see Chapter 5.

Chapter 3 Laboratory Unit Design and Construction

3-1* Laboratory Unit Enclosure.

3-1.1 The required construction of laboratory units depends on the laboratory unit fire hazard classification, the area of the laboratory unit, and the protection to be provided.

3-1.2 The construction requirements are the minimum permitted and do not exclude the use of construction with greater fire resistance.

3-1.3 Laboratory units shall be separated from nonlaboratory areas by construction equal to or greater than the fire resistance requirements shown in Table 3-1.

3-1.4 Laboratory units shall be separated from other laboratory units of equal or lower hazard by construction equal to or greater than the fire resistance requirements shown in Table 3-1.

3-1.5 Laboratory units shall be separated from other laboratory units of a higher hazard class by construction equal to or greater than the fire resistance requirements shown in Table 3-1.

3-1.6 Penetrations of fire-rated floor/ceiling and wall assemblies shall be protected so as to retain the required fire resistance rating and to prevent the passage of smoke, fire, or vapors between floors or through walls. (*See 6-11.3*).

3-1.7 All floor openings shall be sealed or curbed to prevent liquid leakage to lower floors.

3-2 Maximum Area of Laboratory Units. The maximum area of a laboratory unit shall be determined by the fire hazard classification, the construction of the laboratory unit, and the fire protection provided, as shown in Table 3-1.

3-3 Requirements for Means of Egress.

3-3.1 Means of egress for laboratory buildings, laboratory units and laboratory work areas shall comply with NFPA *101*, *Life Safety Code*.

3-3.1.1 Laboratory buildings shall comply with the means of egress requirements of Chapter 28, Industrial Occupancies, of NFPA *101*, *Life Safety Code*.

3-3.1.2 Laboratory units in educational occupancies shall comply with the means of egress requirements of Chapters 10 and 11, Educational Occupancies, of NFPA *101*, *Life Safety Code*.

3-3.2* A second means of access to an exit shall be provided from a laboratory work area if any of the situations described in (a) through (e) exist.

(a) A laboratory work area contains an explosion hazard so located that an incident would block escape from or access to the laboratory work area.

(b) A laboratory work area within a Class A laboratory unit exceeds 500 sq ft (46.5 m^2).

Table 3-1 Construction and Fire Protection Requirements for Laboratory Units[1]
(See also Appendix A-3-1.)

Laboratory Unit Fire Hazard Class	Area of Laboratory Unit. Square Feet	Nonsprinklered Laboratory Units				Sprinklered Laboratory Units[2]	
		Construction Types I and II[3]		Construction Types III, IV and V[3]		Any Construction Type[3]	
		Separation from Nonlaboratory Areas	Separation From Lab. Units of Equal or Lower Hazard Classification	Separation from Nonlaboratory Areas	Separation From Lab. Units of Equal or Lower Hazard Classification	Separation from Nonlaboratory Areas	Separation From Laboratory Units of Equal or Lower Hazard Classification
A	Under 1000	1 Hour	1 Hour	2 Hours	1 Hour	1 Hour	NC/LC[3,4]
	1001-2000	1 Hour	1 Hour	N/A[4]	N/A	1 Hour	NC/LC
	2001-5000	2 Hours	1 Hour	N/A	N/A	1 Hour	NC/LC
	5001-10,000	N/A[4]	N/A	N/A	N/A	1 Hour	NC/LC
	10,001 or more	N/A	N/A	N/A	N/A	N/A	N/A
B	Under 20,000	1 Hour	NC/LC[3,4]	1 Hour	1 Hour	NC/LC[5,7]	NC/LC
	20,000 or more	N/A	N/A	N/A	N/A	N/A	N/A
C	Under 10,000	1 Hour	NC/LC	1 Hour	NC/LC	NC/LC[5,7]	NC/LC[5,6]
	10,000 or more	1 Hour	NC/LC	1 Hour	1 Hour	NC/LC[5,7]	NC/LC

[1] Where a laboratory work area or unit contains an explosion hazard, appropriate protection shall be provided for adjoining laboratory units and nonlaboratory areas, as specified in Chapter 5.
[2] In laboratory units where water may create a serious fire or personnel hazard, a nonwater extinguishing system may be substituted for sprinklers.
[3] See Appendix B-4.
[4] N/A = Not Allowed; NC/LC = Noncombustible/Limited-Combustible Construction. (See Appendix B-4.)
[5] May be ½-hour fire-rated combustible construction.
[6] Existing combustible construction is acceptable.
[7] Laboratory units in educational occupancies shall be separated from nonlaboratory areas by 1-hour construction.
For SI Units: 1 sq ft = 0.0929m².

(c) A laboratory work area within a Class B or Class C laboratory unit exceeds 1000 sq ft (92.9 m²).

(d) A hood in a laboratory work area is located adjacent to the primary means of exit access.

(e) A compressed gas cylinder in use:

1. is larger than lecture bottle size, *and*

2. contains a gas which is flammable or has a Health Hazard rating of 3 or 4, *and*

3. would prevent safe egress in event of accidental release of cylinder contents. (*See Section 8-2.*)

3-3.3 The required exit doors of all laboratory work areas within Class A or Class B laboratory units shall swing in the direction of exit travel.

3-4* Furniture and Equipment. Furniture and equipment in laboratory work areas shall be arranged so that means of access to an exit may be reached easily from any point.

3-5 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, *National Electrical Code®*

3-5.1 Electrical receptacles, switches and controls shall be located so as not to be subject to liquid spills.

3-5.2 Laboratory work areas and laboratory units shall be considered as unclassified electrically with respect to Article 500 of NFPA 70, *National Electrical Code.*

Exception: Under some conditions of extraordinary hazard, it may be necessary to classify a laboratory work area, or a part thereof, as a hazardous location, for the purpose of designating suitable electrical installations. (See 9-2.2 and 9-2.5.)

Chapter 4 Fire Protection

4-1 General.

4-1.1 All laboratory units shall be provided with fire protection appropriate to the fire hazard as follows:

(a) Portable fire extinguishers (*see Section 4-4*).

(b) Fire alarm systems (*see Section 4-5*).

(c) Evacuation and emergency plans (*see Section 4-6*).

4-1.2 In addition to the fire protection specified in 4-1.1, laboratory units under some conditions shall be provided with automatic extinguishing systems (*see Section 4-2*) and inside standpipe and hose systems (*see Section 4-3*).

4-2 Automatic Fire Extinguishing Systems.

4-2.1* General.

4-2.1.1 An automatic fire extinguishing system may be required by Table 3-1 in a laboratory unit, depending on the construction of the building, the hazard class of the laboratory unit, the construction of the laboratory unit enclosure and its area, and the activity within the laboratory unit.

4-2.1.2* The discharge of an automatic fire extinguishing system shall activate an audible fire alarm system on the premises.

4-2.2 Automatic Sprinkler Systems.

4-2.2.1 Automatic sprinklers for Class A laboratory units shall be designed for extra hazard occupancies or shall be hydraulically designed for Ordinary Hazard Group 3, as specified in NFPA 13, *Standard for the Installation of Sprinkler Systems.*

4-2.2.2 Automatic srinklers for Class B laboratory units shall be designed for ordinary hazard occupancies or shall be hydraulically designed for Ordinary Hazard Group 2, as specified in NFPA 13, *Standard for the Installation of Sprinkler Systems.*

4-2.2.3 Automatic sprinklers for Class C laboratory units shall be designed for ordinary hazard occupancies or shall be hydraulically designed for Ordinary Hazard Group 1, as specified in NFPA 13, *Standard for the Installation of Sprinkler Systems.*

4-2.2.4 Automatic sprinkler systems shall be inspected semiannually, cared for properly, and maintained in service. (*See NFPA 13A, Recommended Practice for the Care and Maintenance of Sprinkler Systems.*)

4-2.3 Other Automatic Extinguishing Systems. Where required or used in place of automatic sprinklers, special hazard extinguishing systems and nonwater automatic extinguishing systems shall be designed, installed and maintained in accordance with the following standards, as applicable:

(a) NFPA 11, *Standard for Foam Extinguishing Systems.*

(b) NFPA 11A, *Standard for High Expansion Foam Systems.*

(c) NFPA 11B, *Standard on Synthetic Foam and Combined Agent Systems.*

(d) NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems.*

(e) NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Agent Systems.*

(f) NFPA 12B, *Standard on Halon 1211 Fire Extinguishing Agent Systems.*

(g) NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection.*

(h) NFPA 17, *Standard for Dry Chemical Extinguishing Systems.*

(i) NFPA 69, *Standard on Explosion Prevention Systems.*

4-2.4 The discharge of an automatic fire extinguishing system shall activate an audible alarm system on the premises.

4-3 Standpipe and Hose Systems.

4-3.1* In all unsprinklered laboratory buildings with two or more stories above or below the street floor, a standpipe with 2½-in. hose connections shall be provided for use by the fire brigade or the fire department.

4-3.2 Standpipes shall be installed, inspected and maintained in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems.*

4-3.3 Hose lines shall be of an approved type and shall be tested and cared for in accordance with NFPA 1962, *Standard for the Care, Maintenance and Use of Fire Hose.*

4-4 Portable Fire Extinguishers. Portable fire extinguishers shall be installed, located and maintained in accordance with NFPA 10, *Standard for the Installation of Portable Fire Extinguishers.* For purposes of fire extinguisher placement, Class A laboratory units shall be graded as extra hazard and Class B and C laboratory units as ordinary hazard.

4-5 Fire Alarm Systems.

4-5.1 A manual fire alarm system shall be installed in a laboratory building if a fire may not, of itself, provide adequate warning to building occupants.

4-5.2 Fire alarm systems and fire detection systems, where required, shall be installed and maintained in accordance with the following standards, as applicable:

(a) NFPA 71, *Standard for the Installation, Maintenance, and Use of Central Station Signaling Systems.*

(b) NFPA 72A, *Standard for the Installation, Maintenance, and Use of Local Protective Signaling Systems for Guard's Tour, Fire Alarm, and Supervisory Service.*

(c) NFPA 72B, *Standard for the Installation, Maintenance, and Use of Auxiliary Protective Signaling Systems for Fire Alarm Service.*

(d) NFPA 72C, *Standard for the Installation, Maintenance and Use of Remote Station Protective Signaling Systems.*

(e) NFPA 72D, *Standard for the Installation, Maintenance, and Use of Proprietary Protective Signaling Systems.*

(f) NFPA 72E, *Standard for the Installation, Maintenance, and Use of Automatic Fire Detection Systems.*

4-5.3 Signal transmission for alarms designed to activate signals at more than one location shall be verified at each location during each inspection of the alarm system.

4-5.4 The fire alarm system, where required, shall be so designed that all personnel endangered by the fire condition or a contingent condition shall be alerted.

4-5.5 The fire alarm system shall alert a local fire brigade or public fire department.

4-6 Fire Loss Prevention.

4-6.1 Emergency Procedures.

4-6.1.1* Procedures for laboratory emergencies shall be developed. Such procedures shall include alarm activation, evacuation, and equipment shutdown procedures. Provision for fire fighting actions shall include specific detailed plans for fire control operations by a fire brigade or a public fire department.

4-6.1.2* Emergency procedures for extinguishing clothing fires shall be established.

4-6.2 Fire Prevention Procedures.

4-6.2.1 Fire prevention procedures shall be established. The following critical areas require special consideration:

(a) Handling and storage of flammable and combustible liquids or gases;

(b) Handling and storage of hazardous materials;

(c) Open flame and spark producing equipment work permit system;

(d) Arrangement and use of portable electric cords;

(e) Smoking area controls.

4-6.3* Maintenance Procedures. Maintenance procedures shall be established. Such procedures shall include inspection, testing, and maintenance of:

(a) utilities — steam, gas, electrical;

(b) air supply and exhaust systems;

(c) fire protecton equipment;

(d) detectors and alarms;

(e) pressure and temperature relief valves;

(f) waste disposal systems;

(g) fire doors.

Chapter 5 Explosion Hazard Protection

5-1 General.

5-1.1 When a laboratory work area or a laboratory unit is considered to contain an explosion hazard, as defined in 2-3.1 and 2-3.2, appropriate protection shall be provided to protect the occupants of the laboratory work area, the laboratory unit, adjoining laboratory units, and nonlaboratory areas. (*See Appendix C for further information.*)

5-1.2 Protection shall be provided by one or more of the following:

(a) Limiting amounts of flammable or reactive chemicals or chemicals with unknown characteristics used in or exposed by experiments;

(b) 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, explosion venting directed to a safe location; see 4-2.3).

(c) Explosion-resistant walls or barricades around the laboratory work area containing the explosion hazard; see Section 5-2.

(d) Remote control of equipment to minimize personnel exposure;

(e) Sufficient explosion venting in outside walls to maintain the integrity of the walls separating the hazardous laboratory work area or laboratory unit from adjoining areas.

(f) Conducting experiments in a detached or isolated building, or outdoors.

5-2 Explosion-Resistant Construction. When explosion-resistant construction is used, adequately designed explosion resistance shall be achieved by one of the following methods:

(a) reinforced concrete walls;

(b) rodded and filled concrete block walls;

(c) steel walls;

(d) steel plate walls with energy-absorbing linings;

(e) barricades, such as those used for explosives operations, constructed of reinforced concrete, sand-filled/wood-sandwich walls, woodlined steel plate, or earthen or rock berms;

(f) specifically engineered construction assemblies.

5-3 Explosion Venting. When explosion venting is used, it shall be designed according to information contained in NFPA 68, *Guide for Explosion Venting*, and shall be designed so that:

(a) fragments will not strike other occupied buildings or areas, or

(b) blast mats, energy-absorbing barrier walls, or earthen or rock berms will intercept the flight of fragments.

5-4 Unauthorized Access. Appropriate doors, gates, fences or other barriers, properly posted, shall be provided to prevent or restrict access to laboratory work areas and laboratory units containing an explosion hazard and to the space between explosion vents and fragment barriers.

5-5 Inspection and Maintenance.

5-5.1 Inspection of all protective construction devices and systems shall be conducted at least annually with appropriate maintenance to assure integrity and operability.

5-5.2* Explosion shields and special explosion-containing hoods shall be inspected for deterioration, especially transparent shields and sight panels in special explosion-containing hoods.

Chapter 6 Laboratory Ventilating Systems and Hood Requirements

6-1 Scope.

6-1.1 This chapter applies to laboratory exhaust systems, including laboratory hoods, biological safety cabinets, special local exhaust devices, and other systems for exhausting air from laboratory work areas in which hazardous gases, vapors, or particulate matter may be released.

6-1.2 This chapter also contains certain requirements for supply systems.

6-1.3 This chapter also contains requirements for labeling, inspection and maintenance of laboratory ventilating systems and hoods.

6-2 Basic Requirements.

6-2.1 Except as supplemented by the requirements of this chapter, duct systems for laboratory heating and ventilating, including warm air heating systems, general environmental ventilating systems, air conditioning systems, laboratory exhaust systems and laboratory hood exhaust systems, shall comply with applicable requirements of NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, and NFPA 91, *Standard for the Installation of Blower and Exhaust Systems for Dust, Stock and Vapor Removal.*

6-2.2 Laboratory hoods normally are not designed or intended to provide explosion protection. (*See Chapter 5, Explosion Hazard Protection.*)

6-2.3 When perchloric acid is evaporated in a laboratory hood, the requirements of Section 6-12 shall apply.

6-3* Definitions. For the purpose of this chapter, the following terms shall have the meanings given below.

Auxiliary Air. Supply or supplemental air delivered to a laboratory hood to reduce room air consumption.

Baffle. A panel or panels located at the rear of the hood interior which aid in distributing the flow pattern of air moving into and through the hood.

Biological Safety Cabinet. A special safety enclosure used to handle and contain biological materials. This enclosure is *not* a laboratory hood.

Bypass. An airflow-compensating opening that maintains a relatively constant volume exhaust through a laboratory hood regardless of sash position. It serves to limit the maximum face velocity as the sash is lowered.

Canopy Hood. A suspended ventilating device used only to exhaust heat, water vapor, odors, and other nonhazardous materials. This is *not* a laboratory hood and generally is *not* effective for exhausting toxic or flammable materials.

Deflector Vane. An airfoil-shaped vane along the bottom of the hood face which 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.

Face (of hood). The hood opening or the plane of the inside surface of the sash. This area is used to calculate the square footage of hood opening, and face velocity is measured in this plane.

Face Velocity. The rate of flow or speed of air moving into the laboratory hood entrance or access opening.

Hood Interior. Includes the interior enclosure panels and the plenum.

Laboratory Hood. (Sometimes referred to as a "fume hood.") A ventilated enclosure designed to capture, contain, and exhaust fumes, gases, vapors, mists, and particulate matter generated within the enclosure. It generally consists of side, back, and top enclosure panels, a work surface, an access opening (called a "face"), a sash (or sashes), and an exhaust plenum equipped with a baffle system for airflow distribution. (*See Appendix A-6-3, Description of Types of Laboratory Hoods.*)

Laminar Flow Cabinet. A ventilated, partially enclosed cabinet using laminar air flow methods and primarily intended to provide "clean" air flow over the work surface. Generally designed to utilize recirculated air. This is *not* a type of laboratory hood.

Sash. A moveable panel or panels set in the hood entrance used to form a protective shield and to control the face velocity.

6-4 Supply Systems.

6-4.1 The location of fresh air intakes shall be chosen to avoid drawing in hazardous chemicals or products of combustion coming either from the laboratory building itself or from other structures and devices.

6-4.2* Laboratory units and laboratory work areas in which hazardous chemicals are being used shall be maintained at an air pressure that is negative relative to the corridors or adjacent nonlaboratory areas.

Exception No. 1: Where operations such as those requiring clean rooms preclude a negative pressure relative to surrounding areas, special precautions shall be taken to prevent escape of the atmosphere in the laboratory work area or unit to the surrounding spaces.

Exception No. 2: Laboratory work areas in which not more than one liter of flammable liquids or not more than 30 standard cubic ft of flammable compressed gases are used are excluded from this requirement.

6-4.3 Care shall be exercised in the selection and placement of air supply diffusion devices to avoid air currents that would adversely affect the performance of laboratory hoods, exhaust systems, and fire detection or extinguishing systems. [*See Section 4-2 and 4-5.2(f).*]

6-5 Exhaust Air Discharge.

6-5.1 Air exhausted from laboratory hoods and other special local exhaust systems shall not be recirculated.

6-5.2 If energy conservation devices are used, they shall not recirculate laboratory exhaust air or otherwise compromise the safety of the laboratory hood.

6-5.3 Air exhausted from laboratory work areas shall not pass unducted through other areas.

6-5.4* Air containing hazardous chemicals shall be discharged through duct systems maintained at a negative pressure relative to the pressure of normally occupied areas of the building.

6-5.5 Laboratory hood face velocities shall be sufficient to prevent the escape of contaminants generated in the hood. The hood shall provide confinement of the possible hazards and protection for personnel.

6-5.6 Special local exhaust systems, such as snorkels or "elephant trunks," shall have sufficient capture velocities to entrain the hazardous chemicals being released.

6-6 Duct Construction for Hoods and Local Exhaust Systems.

6-6.1 Ducts from laboratory hoods and from local exhaust systems shall be constructed entirely of noncombustible materials.

Exception No. 1: Flexible ducts of combustible construction may be used for special local exhaust systems within a laboratory work area.

Exception No. 2: Combustible ducts may 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.

Exception No. 3: Combustible ducts may be used if all areas through which they pass are protected with an approved automatic fire extinguishing system, as described in Chapter 4.

6-6.2 Duct systems for perchloric acid hoods shall be constructed in accordance with 6-12.3.

6-6.3 Combustible ducts or duct linings shall have a flame spread index of 25 or less when tested in accordance with NFPA 255, *Method of Test of Surface Burning Characteristics of Building Materials*. Test specimens shall be of the minimum thickness used in the construction of the duct or duct lining.

6-6.4 Ducts shall be of adequate strength and rigidity to meet the conditions of service and installation requirements and shall be protected against mechanical damage.

6-6.5 Vibration isolation connectors shall comply with 6-6.3.

6-6.6 Flexible connectors containing pockets in which conveyed material may collect shall not be used in any concealed space, or where strong oxidizing chemicals are used (e.g., perchloric acid).

6-6.7 Controls and dampers, where required for balancing or control of the exhaust system, shall be of a type that, in event of failure, will fail open to assure continuous draft. (*See 6-11.3.*)

6-6.8 Hand holes 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.

6-6.9 Exhaust ducts from each laboratory unit shall be separately ducted to a point outside the building, to a mechanical space, or to a shaft. Connection to a common duct system may occur at these points. Exhaust ducts from laboratory hoods and other special exhaust systems within the same laboratory unit may be combined within that laboratory unit.

6-7 Duct Velocities. Duct velocities of laboratory exhaust systems shall be high enough to minimize the deposition of materials in the exhaust systems.

6-8 Exhausters (Fans), Controls, Velocities and Discharge.

6-8.1 Fans shall be selected to meet fire, explosion, and corrosion requirements.

6-8.2 Fans conveying both corrosive and flammable or combustible materials may be lined with or constructed of corrosion-resistant materials meeting the requirements of 6-6.3.

6-8.3 Fans shall be located and arranged so as to afford ready access for repairs, cleaning, inspection, and maintenance.

6-8.4 When flammable vapors or combustible dusts are passed through the fans, the rotating element shall be constructed of nonferrous or nonsparking material. Alternatively, the casing shall be constructed of or lined with such material. 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. Nonferrous or nonsparking materials shall meet the requirements of 6-6.3.

6-8.5 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 the location and use.

6-8.6* Fans shall be labeled with an arrow or other means to indicate proper direction of rotation, and with the location of laboratory hoods and exhaust systems served.

6-8.7* Air exhausted from laboratory hoods and special exhaust systems shall be discharged above the roof at a height and velocity sufficient to prevent reentry of hazardous chemicals.

6-9 Laboratory Hood Construction. (*See also 6-2.2 and Section 6-12.*)

6-9.1 Laboratory Hood Interiors.

6-9.1.1 Materials of construction used for the interiors of new laboratory hoods or for the modification of the interiors of existing laboratory hoods shall have a flame spread index of 25 or less when tested according to NFPA 255, *Method of Test of Surface Burning Characteristics of Building Materials*.

6-9.1.2* Baffles shall be constructed so that they may not be adjusted to materially restrict the volume of air exhausted through the laboratory hood.

6-9.1.3* Laboratory hoods shall be provided with a means of containing minor spills.

6-9.2* Laboratory Hood Sash. The sash shall be glazed with material which will provide protection to the operator or the environment against the hazards normally associated with the use of the hood. (*See also Appendix C.*)

6-9.3 Laboratory Hood Air Bypass. The bypass opening shall be shielded by a grill or solid panel to impede or deflect flying glass or flaming debris in case of a runaway reaction within the hood.

6-9.4 Electrical Devices.

6-9.4.1* For new installations or modifications of existing installations, fixed electrical services and their controls shall be located external to the hood and within easy reach.

6-9.4.2 In existing installations where services and controls are within the hood, additional electrical disconnects shall be located within 50 ft (15.25 m) of the hood and shall be accessible and clearly marked.

Exception: If electrical receptacles are located external to the hood, no additional electrical disconnect is required.

6-9.4.3 Hood lighting shall be provided by fixtures external to the hood or, if located within the hood interior, the fixtures shall meet the requirements of Article 501 of NFPA 70, *National Electrical Code*.

6-9.5 Other Hood Services.

6-9.5.1 For new installations or modifications of existing installations, controls for laboratory hood services (gas, air, water, etc.) shall be located external to the hood and within easy reach.

6-9.5.2 In existing installations where service controls are within the hood, additional shut-offs shall be located within 50 ft (15.25 m) of the hood and shall be accessible and clearly marked.

6-9.6 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.

6-9.7 Airflow Indicators. Airflow indicators shall be installed on new laboratory hoods or on existing laboratory hoods, when modified.

6-10 Laboratory Hood Location.

6-10.1* Laboratory hoods shall be located in areas of minimum air turbulence.

6-10.2 For new installations, laboratory hoods shall not be located adjacent to a single means of access to an exit or high traffic areas.

6-10.3 Work areas where personnel will spend much of their working day, such as desks or microscope benches, shall not be located across the aisle from laboratory hoods.

6-11 Laboratory Hood Fire Protection.

6-11.1 Automatic fire protection systems shall not be required in laboratory hoods.

Exception No. 1: Automatic fire protection shall be required for hoods having interiors with a flame spread index greater than 25 in which flammable liquids are handled.

Exception No. 2: Under conditions of extraordinary hazard automatic fire protection may be required for hoods having interiors with a flame spread index of 25 or less.

6-11.2 Automatic fire protection systems, when provided, shall comply with the following standards, as applicable.

(a) NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*;

(b) NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*;

(c) NFPA 12B, *Standard on Halon 1211 Fire Extinguishing Systems*;

(d) NFPA 13, *Standard for the Installation of Sprinkler Systems*;

(e) NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*;

(f) NFPA 17, *Standard for Dry Chemical Extinguishing Systems*.

6-11.2.1 The fire extinguishing system shall be suitable to extinguish fires within the laboratory hood under the anticipated conditions of use.

6-11.3 Automatic fire dampers shall not be used in laboratory hood exhaust systems. Fire detection and alarm systems shall not be interlocked to automatically shut down laboratory hood exhaust fans unless required by special extinguishing systems. (*See 4-2.3.*)

6-12 Perchloric Acid Hoods.

6-12.1* If perchloric acid is heated above ambient temperature and vapors are not trapped or scrubbed before entering the laboratory hood or its exhaust system, a separate hood, designed for use with perchloric acid and labeled "For Perchloric Acid Use Only," shall be provided. (*See also 9-1.2.4.*)

6-12.2* If a laboratory hood or exhaust system has been exposed to 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.

6-12.3 Perchloric acid hoods and exhaust duct work shall be constructed of materials that are acid resistant, nonreactive, and impervious to perchloric acid.

6-12.4 The exhaust fan shall be acid resistant and nonsparking. The exhaust fan motor shall not be located within the duct work. Drive belts shall be conductive and shall not be located within the duct work.

6-12.5 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. Horizontal runs shall be as short as possible, with no sharp turns or bends. The duct work shall provide a positive drainage slope back into the hood. Duct work shall consist of sealed sections. Flexible connectors shall not be used.

6-12.6 Sealants, gaskets, and lubricants used with perchloric acid hoods, duct work, and exhaust systems shall be acid resistant and nonreactive with perchloric acid.

6-12.7* A water spray system shall be provided for washing down the hood interior behind the baffle and the entire exhaust system. The hood work surface shall be watertight with a minimum depression of ½ in. (12.7 mm) at the front and sides. An integral trough shall be provided at the rear of the hood to collect wash down water.

6-12.8 The hood baffle shall be removable for inspection and cleaning.

6-13 Labeling of Laboratory Hoods. Laboratory hoods and special local exhaust systems shall be labeled to indicate intended use.

6-13.1 Laboratory hoods in which radioactive materials are handled shall be identified with the radiation hazard symbol.

6-13.2 A sign shall be affixed to each hood containing the following information from the last inspection:

(a) inspection interval;

(b) last inspection date;

(c) average face velocity;

(d) location of fan which serves hood;

(e) inspector's name.

Exception: In lieu of a sign, a properly maintained log of all hoods giving the above information shall be deemed acceptable.

6-14 Inspection, Testing and Maintenance.

6-14.1 When installed and at least annually thereafter, laboratory hood exhaust systems and laboratory special exhaust systems shall be inspected or tested. The following inspections and tests, as applicable, shall be made:

(a) visual inspection of the physical condition of the hood interior, sash, and duct work (*see 5-5.2*);

(b) airflow indicator systems;

(c) low airflow and loss-of-airflow alarms at each alarm location;

(d) face velocity;

(e) verification of inward airflow over the entire hood face;

(f) changes in work area conditions that may affect hood performance.

6-14.2 Deficiencies in hood performance shall be corrected or:

(a) the activity within the hood shall be restricted to the capability of the hoods; or,

(b) the hood shall not be used.

6-14.3 Laboratory hood face velocity profile and/or exhaust air quantity shall be checked after any adjustment to the ventilation balance.

6-14.4 Detectors and Alarms. Air system flow detectors, if installed, shall be inspected and tested annually. Where potentially corrosive or obstructive conditions exist, the inspection and test frequency shall be increased appropriately.

6-14.5 Fans and Motors.

6-14.5.1 Air supply and exhaust fans, motors, and components shall be inspected at least annually.

6-14.5.2 When air flow detectors are not provided or air flowrate tests are not made, fan belts shall be inspected quarterly. Frayed or broken belts shall be replaced promptly. When double sheaves and belts are employed, the inspection frequency may be semiannual.

6-14.6 Fixed fire extinguishing systems protecting filters shall be inspected quarterly for accumulation of deposits on nozzles. Nozzles shall be cleaned as necessary.

Chapter 7 Chemical Storage, Handling, and Waste Disposal

7-1* Ordering Procedures. When a chemical is ordered, steps shall be taken to determine the hazards and to transmit that information to those who will receive, store, use, or dispose of the chemical. Restrictions imposed by governmental regulations and in-house rules shall be followed.

7-2 Handling and Storage.

7-2.1 Facilities.

7-2.1.1 Hazardous chemicals shall not be brought into a laboratory work area unless design, construction, and fire protection of receiving and storage facilities are commensurate with the quantities and hazards of chemicals involved.

7-2.1.2 Safe storage facilities shall be provided for materials having unique physical or hazardous properties, such as temperature sensitivity, water reactivity, or explosibility. *(See A-7-1 for sources of additional information.)*

7-2.2 Handling.

7-2.2.1* Receiving, transporting, unpacking, and dispensing of chemicals and other hazardous materials shall be carried out by trained personnel in such locations and manner as to minimize hazards from flammable, reactive, or toxic materials.

7-2.2.2* Materials of construction for ducts, piping, and vessels shall be compatible with materials to be transferred or handled.

7-2.2.3 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.

7-2.2.4 Class I liquids shall not be stored or transferred from one vessel to another in any exit access.

7-2.2.5* Transfer of Class I liquids to smaller containers from bulk stock containers not exceeding 5 gal (18.9 L) in capacity inside a laboratory building or laboratory work area shall be made:

(a) in a laboratory hood; or

(b) in an area provided with ventilation adequate to prevent accumulations of flammable vapor/air mixtures exceeding 25 percent of the lower flammable limit; or

(c) in a separate inside storage area, as described in NFPA 30, *Flammable and Combustible Liquids Code.*

7-2.2.6* Transfer of Class I liquids from containers of 5 gal (18.9 L) or more capacity shall be carried out in:

(a) a separate area outside the building; or

(b) in a separate area inside the building which meets the requirements of NFPA 30, *Flammable and Combustible Liquids Code*, for inside areas.

7-2.2.7 Class I liquids shall not be transferred between metal containers unless the containers are electrically interconnected by direct bonding or by indirect bonding through a common grounding system in the room. The maximum impedance of the bonding shall not exceed 6 ohms.

7-2.3* Storage.

7-2.3.1 Hazardous chemicals stored in the open in the laboratory work area shall be kept to the minimum necessary for the work being done.

7-2.3.2* Container types and maximum capacities shall comply with Table 7-2.

Exception No. 1: Glass containers as large as 1 gal (3.785 L) may be used if needed and if the required purity would be adversely affected by storage in a metal or an approved plastic container, or if the liquid would cause excessive corrosion or degradation of a metal or approved plastic container.

Exception No. 2: Drums of up to and including 60 gal (227 L) capacity are permitted in approved storage rooms. (See NFPA 30, Flammable and Combustible Liquids Code.)

7-2.3.3 Hazardous chemical inventories shall be within the prescribed capacities of the storage facility.

7-2.3.4* Incompatible materials shall be segregated to prevent accidental contact with one another.

Table 7-2 Maximum Allowable Container Size for Use in Laboratories Using Chemicals[1]

Container Type	Flammable Liquids[2] IA	IB	IC	Combustible Liquids[2] II	IIIA
Glass	1 pt[3]	1 qt[3]	1 gal	1 gal	5 gal
Metal (other than DOT Drums) or Approved Plastic	1 gal	5 gal[1]	5 gal[4]	5 gal[4]	5 gal
Safety Cans	2 gal	5 gal[4]	5 gal[4]	5 gal[4]	5 gal
Metal Drums (DOT)	N/A[5]	5 gal[4]	5 gal[4]	60 gal[4]	60 gal

[1] This table is taken from NFPA 30, *Flammable and Combustible Liquids Code*, except for allowable quantities of Flammable Liquids in metal DOT drums.

[2] See Appendix B1 for definitions of the various classes of flammable and combustible liquids.

[3] See Exception No. 1 of 7-2.3.2 and A-7-2.3.2.

[4] In instructional laboratory work areas, no container for Class I or II liquids shall exceed a capacity of 1 gallon, except that safety cans may be of 2 gallon capacity.

[5] N/A = Not Allowed. See Exception No. 2 of 7-2.3.2.

For SI Units: 1 gal = 3.785 liters; 1 qt = 0.95 liter; 1 pt = .48 liters

7-2.3.5 Laboratory storage facilities shall be inspected to ensure compliance with the provisions of this chapter.

7-3* Collection and Disposal of Chemical Wastes.

7-3.1 General. The handling, storage, and transportation of chemical wastes shall be subject to the appropriate provisions of this standard.

7-3.2 Collection. Special consideration shall be given to the classification of chemical waste at the time of collection so as to avoid chemical incompatibilities.

7-3.3 Disposal.

7-3.3.1 Disposal of chemical wastes shall be in accordance with good safety practices and applicable government regulations.

7-3.3.2 Persons or agencies employed to remove chemical wastes from the premises shall be apprised of the basic character and hazards of the waste.

Chapter 8 Compressed and Liquefied Gases

8-1 Storage and Piping Systems.

8-1.1* Method of storage and piping systems for compressed gases and liquefied gases shall comply with the requirements of applicable NFPA and American National Standards Institute (ANSI) standards, including the following:

(a) NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites*;

(b) NFPA 50A, *Standard for Gaseous Hydrogen Systems at Consumer Sites*;

(c) NFPA 50B, *Liquefied Hydrogen Systems at Consumer Sites*;

(d) NFPA 51, *Standard for Oxygen-Fuel Gas Systems for Cutting and Welding*;

(e) NFPA 54, *National Fuel Gas Code*;

(f) NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*;

(g) ANSI B31.1.0, *Power Piping* (including Addenda B31.1.0a, B31.1.1.0b, B31.1.1.0c, and B31.1.1.0d);

(h) ANSI B31.2, *Fuel Gas Piping*;

(i) ANSI B31.3, *Petroleum Refinery Piping*;

8-1.2 Systems for other compressed gases and for cryogenic materials shall comply with the manufacturers' design and specifications.

8-1.3* Manual shut-off valves shall be provided at all points of supply and at all points of use.

Exception No. 1: If the containers supplying the piping system are equipped with shut-off valves, a separate valve on the piping system is not required.

Exception No. 2: A valve at the point of use is not required if there is a supply shut-off valve within immediate reach of the point of use.

8-1.4 Each and every portion of a piping system shall have uninterruptible pressure relief. Any part of the system that can be isolated from the rest of the system shall have adequate pressure relief.

Exception: Piping systems designed with a working pressure greater than the maximum allowable working pressure developed at ambient temperature.

8-1.4.1 Pressure relief systems shall be designed to provide a discharge rate sufficient to avoid further pressure increase and shall vent to a safe location.

8-1.5* Permanent piping shall be identified at the supply point and at each discharge point with the name of the material to be piped.

8-1.6 Piping systems, including regulators, shall not be used for gases, other than those for which they are designed and identified.

8-2 Compressed and Liquefied Gases in Cylinders. (*See Appendix E.*)

8-2.1 Maximum size and number of compressed or liquefied gas cylinders containing hazardous materials or oxygen shall comply with Table 8-2.

Table 8-2 Maximum Size and Quantity Limitations for Compressed or Liquefied Gas Cylinders in Laboratory Work Areas.

	Flammable Gases[1] Oxygen		Liquefied Flammable Gases[1]		Gases With Health Hazard Rating of 3 or 4[1]
	NS[3]	AS[3]	NS[3]	AS[3]	
Max. cylinder Size (Approx. Dimensions in Inches)	10 × 50		9 × 30		5 × 15
Max. No. of Cylinders per 500 sq ft or less[2]	3	6	2	3	3[4]

[1] See Appendix E for Examples of Flammable Gases. Liquefied Flammable Gases, and Gases with Health Hazard Ratings of 3 or 4.

[2] In Instructional Laboratory Work Areas, the total number of cylinders shall be reduced to 3 maximum size cylinders or ten 2 in. × 12 in. cylinders (or equivalent volume). In all other cases twenty-five 2 in. × 12 in. cylinders (or equivalent volume) shall be permitted.

[3] NS = Nonsprinklered space; AS = Sprinklered space.

[4] See 8-2.5.

8-2.2 Cylinders shall be handled and stored as specified in the references identified in 8-1.1(a), (b), (c), (d), and (f).

8-2.3 Cylinders which are not necessary for current laboratory requirements shall be stored in a safe location outside the laboratory work area.

8-2.4* Gases which are corrosive to cylinders or cylinder valves or which may become unstable while stored in the cylinder shall have a maximum retention period of six months, unless otherwise specified by the manufacturer.

8-2.5 Cylinders of all gases having Health Hazard ratings of 3 or 4 and cylinders of gases having a Health

Hazard rating of 2 with no physiological warning properties shall be kept in a continuously mechanically ventilated hood or other continuously mechanically ventilated enclosure. There shall be no more than 3 cylinders of gases with Health Hazard ratings of 3 or 4 per hood or other enclosures. (*See also A-8-2.4.*)

8-2.6 All cylinders shall be secured in place to prevent falling.

8-3 Cryogenic Fluids.

8-3.1 All system components used for cryogenic fluids shall be selected and designed for such service. Design pressure for vessels and piping shall be not less than 150 percent of maximum pressure relief.

8-3.1.1 Systems or apparatus handling cryogens which cause freezing or liquefaction of the surrounding atmosphere and systems or apparatus handling liquid oxygen shall be designed to avoid contact of the cryogen or of condensed air with organic matter.

8-3.2 Pressure relief of vessels and piping handling cryogenic fluids shall comply with applicable requirements of Section 8-1.

8-3.3 The space in which cryogenic systems are located shall be ventilated commensurate with the properties of the specific cryogenic fluid in use.

8-4 Means of Egress. See 3-3.3 for specific requirements for means of egress.

Chapter 9 Laboratory Operations and Apparatus

9-1 Operations.

9-1.1 Hazards of Chemicals and Chemical Reactions.

9-1.1.1* Before laboratory tests or chemical reactions are begun, evaluations shall be made for hazards that may be encountered or generated during the course of the work. Evaluations shall include hazards associated with the properties and reactivity of the materials used, hazards associated with the operation of the equipment at the operating conditions, and hazards associated with the proposed reactions (e.g., oxidation, polymerization).

9-1.1.2 Periodic reviews of laboratory operations and procedures shall be conducted with special attention given to any change in materials, operations, or personnel.

9-1.1.3* 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 hazard possible based on a known hazard of similar material. Where use of a new material may present a severe explosion potential, initial experiments or tests shall be conducted in a suitable enclosure using minimal quantities and with appropriate protection for the operation. (*See Chapter 5.*)

9-1.1.4 Unattended operations and automatic laboratory apparatus shall be provided with periodic surveillance for abnormal operations. (*See 9-1.2.3 and 9-2.4.1.*)

9-1.2 Heating Operations.

9-1.2.1 All heating of flammable or combustible liquids shall be conducted so as to minimize fire hazards.

9-1.2.2 Provision shall be made to contain spilled liquid by providing metal catch pans or other heat-resistant noncombustible receptacles of suitable size for glass apparatus containing more than 0.25 L of flammable liquid or combustible liquid heated to its flash point. Suitable supplementary fire extinguishing equipment shall be provided, if necessary.

9-1.2.3 Unattended operations shall be provided with override control and automatic shutdown to prevent system failure that can result in fire or explosion.

9-1.2.4 Strong oxidizing materials, such as perchloric acid, shall not be heated by gas flames or oil baths.

9-1.3 Distillation Operations.

9-1.3.1 Distillations shall be conducted in suitable equipment properly assembled with consideration being given to fire hazards from vent gases and possible equipment breakage or failure. Care shall be taken to avoid the presence of unstable components in the still pot (e.g., peroxides) and to avoid overheating still contents. Metal catch pans or other heat-resistant noncombustible receptacles of a suitable size shall be utilized beneath glass pots and receivers with volumes of more than 0.25 L.

9-1.3.2 Glass equipment for distillations, particularly vacuum distillations, shall be inspected for cracks, scratches, or other defects prior to each use. Faulty glass equipment shall be discarded or repaired.

9-1.3.3 Glass equipment operated under vacuum shall be shielded or wrapped with suitable tape during use.

9-1.4* Other Separation Operations. Filtrations, extractions, sublimations, adsorptions, evaporations, centrifuging and other separation techniques that involve flammable or combustible materials shall be protected from ignition sources and shall be provided with suitable ventilation.

9-1.5 Mixing and Grinding Operations. Mixing, grinding, stirring, and agitation operations involving flammable and combustible materials shall require the same precautions against fire as set forth in 9-1.4. Precautions shall be taken to avoid local overheating during grinding and mixing of solids. Care shall be taken to avoid fire or explosion hazards from flammable or combustible materials.

9-1.6 Other Operations.

9-1.6.1 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. Shielding shall be used whenever there is a reasonable probability of explosion or vigorous decomposition, and associated hazards, during charging, sampling, venting, and discharge of products. (*See Chapter 5 and 9-2.6.3.*)

9-1.6.2* Quantities of reactants shall be limited and procedures developed to control or isolate vigorous or exothermic reactions.

9-1.6.3 During drying operations evolving flammable or combustible vapors, suitable procedures shall be followed to condense, trap, or vent such vapors and to avoid ignition sources.

9-1.6.4 Spraying of flammable or combustible paint and varnishes shall comply with the requirements of NFPA 33, *Standard for Spray Application Using Flammable and Combustible Materials.*

9-1.6.5 Flammable liquids stored in refrigerated equipment shall be in closed containers. (*See 9-2.2.*)

9-2 Apparatus.

9-2.1 General.

9-2.1.1 Apparatus shall be installed in compliance with applicable requirements of NFPA standards including NFPA 70, *National Electrical Code.*

9-2.1.2 Operating controls shall be accessible under normal and emergency conditions.

9-2.2 Refrigeration and Cooling Equipment.

9-2.2.1 Each refrigerator, freezer, or cooler shall be prominently labeled to indicate whether it is or is not suitable for storing flammable liquids.

9-2.2.2* Refrigerators, freezers, and other cooling equipment used to store or cool flammable liquids shall be designed or modified as follows:

(a) Any electrical equipment located within the outer shell, within the storage compartment, on the door, or on the door frame, shall meet the requirements for Class I, Division I locations, as described in Article 501 of NFPA 70, *National Electrical Code.*

(b) Because of hazardous vapors transmitted due to leakage and opening of the storage compartment door, electrical equipment mounted on the outside of the storage compartment shall be either:

1. suitable for Class I, Division 2 locations, or
2. installed above the storage compartment, or
3. installed on the outside surface of the equipment where exposure to hazardous concentrations of vapors will be minimal.

Exception: Refrigeration and cooling equipment installed under counters shall meet the requirements of 9-2.2.2(b)1.

9-2.2.3 Refrigerators, freezers, and cooling equipment located in a laboratory work area designated as a Class I location, as specified in the Exception to 3-5.2, shall be approved for Class I, Division 1 or 2 locations and shall be installed in accordance with Article 501 of NFPA 70, *National Electrical Code.*

9-2.3 Heating Equipment.

9-2.3.1 All unattended electrical heating equipment shall be equipped with a manual reset overtemperature limit switch, in addition to normal temperature controls, if overheating could result in a fire or explosion.

9-2.3.2 Heating equipment with circulation fans shall be equipped with an interlock arranged to disconnect current to the heating elements if the fan is inoperative.

9-2.3.3 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.

9-2.3.4 Oven and furnace installations shall comply with NFPA 86A, *Standard for Ovens and Furnaces.*

9-2.4 Heated Constant Temperature Baths.

9-2.4.1 Electrically heated constant temperature baths shall be equipped with overtemperature shut-off switches in addition to normal temperature controls, if overheating could result in fires or explosions.

9-2.4.2 Bath containers shall be of noncombustible materials.

9-2.4.3 Baths handling flammable liquids or combustible liquids heated to their flash points shall be placed in a laboratory hood or shall be vented to a safe location to control vapors.

9-2.5 Motor-Driven Apparatus. Electric motors used to drive stirrers in open containers of flammable liquids or combustible liquids heated above their flashpoints shall be suitable for use in Class I, Division 2 locations, as defined in Article 500-2 of NFPA 70, *National Electrical Code.*

9-2.6 Pressure Equipment.

9-2.6.1* Pressure vessels require specialized design beyond the scope of normal workshop practice. Equipment used at pressures above 15 psig (103.4 kPa) shall be designed and constructed by qualified individuals for use at the expected temperature, pressure, and other operating conditions affecting safety.

9-2.6.2 Pressure equipment shall be fitted with a suitable pressure relief device, such as a rupture disc or a relief valve. The pressure relief device shall be vented to a safe location.

9-2.6.3 All equipment operated at pressures above 15 psig (103.4 kPa), such as autoclaves, sterilizers, and calorimetry bombs, shall be operated according to manufacturers' instructions and design limitations. Equipment shall be regularly inspected and a log shall be kept on corrosion, cracks, distortion, weakening of closure, difficulty in maintaining pressure, scale formation, and general chemical attack. Any significant change in the condition of the equipment shall be noted; the equipment shall be removed from service immediately and tested or inspected by a qualified person.

9-2.6.4 Any pressure equipment whose condition or operation has been found to be affected shall be discarded or, if appropriate, derated.

9-2.7 Analytical Instruments.

9-2.7.1 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.

9-2.7.2 Analytical instruments shall be operated in accordance with manufacturers' instructions or approved recommended operating procedures. Hazards to personnel from high voltage, vapors or fumes, radiation, flames, flashbacks, and explosions shall be minimized.

Chapter 10 Hazard Identification

10-1 Identification of Facilities. Entrances to laboratory units, laboratory work areas, storage areas, and associated facilities shall be identified by signs to warn emergency personnel of unusual or severe hazards that are not directly related to the fire hazard of contents.

10-2 Labeling of Containers.

10-2.1 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. Storage cabinets, storage space, or other accessible locations shall also be appropriately marked.

10-2.2 Containers used for storage of peroxidizable compounds or materials that become hazardous upon prolonged storage shall be dated when opened. Retention shall be limited to a maximum of six months after opening, and then containers shall be disposed of in a safe manner.

Appendix A

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

A-1-4 Definitions.

Hazardous Chemical. For hazard ratings of many chemicals, see NFPA 49, *Hazardous Chemicals Data,* and NFPA 325M, *Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids.*

Incidental Test Facility. The term "incidental test facility" is intended to refer to sites where tests are required either before proceeding with the manufacturing process or for certification before continuation of the process is authorized. One or more separate testing sites may be required but in no case is any part of the manufacturing process part of the testing facility. Examples of incidental testing facilities are:

(a) metallurgical testing sites in an alloy metal manufacturing plant;

(b) chemical and pharmaceutical manufacturing process verification sites;

(c) plastic resin production sample testing sites.

Not included in the definition of "incidental test facility" are:

(a) research and development laboratories;

(b) incoming materials testing laboratories;

(c) pilot plants;

(d) production facilities, regardless of size or quantity produced;

(e) job shop operations.

All of these would be governed by Chapter 5 of NFPA 30, *Flammable and Combustible Liquids Code,* even though not integral to the manufacturing process, and other standards applicable to production facilities. Those sites defined as laboratories would be governed by this standard.

The size of an incidental test facility is governed by the nature of the work performed but in no case should a single incidental test facility have capabilities beyond those requiring a minimum-sized laboratory unit.

Maximum Allowable Working Pressure. For a more complete definition, see Section VIII of the Pressure Vessel Code of the American Society of Mechanical Engineers.

Storage Cabinet. Some local jurisdictions require bottom-venting of flammable liquids storage cabinets. While this is not required by NFPA 30, *Flammable and Combustible Liquids Code,* some manufacturers provide a plugged vent connection on one side of the cabinet, close to the base, to accommodate these local jurisdictions.

A-3-1 The types of construction in Table 3-1 are defined in NFPA 220, *Standard Types of Building Construction,* and are reprinted in Appendix B-4 of this standard. Also, for a discussion of fire-resistive construction and fire endurance of building materials and construction assemblies, see the NFPA *Fire Protection Handbook,* 15th Edition. For information on the fire protection ratings, installation, and maintenance of fire doors, see NFPA 80, *Standard for Fire Doors and Windows.*

A-3-3.2 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-3-4 Modern laboratory design concepts provide a wide range of selections in laboratory furniture and equipment. While such selections will be dictated by several factors, such as laboratory function, cost, servicibility, accessibility, repair, etc., 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. Included among such needs are:

(a) Flexibility in case work design which provides for optimum use of storage capacity without interfering with the normal needs of the laboratory. This may include desk areas which do not encourage underdesk storage, restraining techniques for items stored above eye level, ease of egress, provision for adequate 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.

(b) Easy access to typical laboratory utility services, including the adequate identification of all service panels, valves and electrical circuits and posting of any special or unique maintenance requirements.

(c) Walking surfaces should be such that slip hazards are minimized.

(d) Working surfaces should be designed to reduce the risks from accidental breakage.

A-4-2.1 The automatic fire extinguishing system should be an automatic sprinkler system. If extinguishment or control may be more effectively accomplished by a non-water automatic fire extinguishing system, it may be advisable to install such a system instead of automatic sprinklers.

A-4-2.1.2 It is suggested that automatic fire extinguishing systems activate both a local audible alarm and an audible or visible alarm at a constantly attended location.

A-4-3.1 All laboratory buildings should be provided with standpipes and 1½-in. hose connections for use by occupants. Hose connections should be fitted with hose lines and combination straight stream-fog nozzles. Waterflow through the standpipe system should activate an audible fire alarm system on the premises.

A-4-6.1.1 Emergency telephones are of value when connected directly to an emergency office and when located within the laboratory building so that they can be readily used by laboratory personnel. They are also valuable when available at an exterior location for use by evacuees or passers-by. An emergency telephone system should be interconnected with a mass notification system, such as a public address system.

The management of each laboratory work area covered by this standard should be responsible for developing and distributing an evacuation plan for the facility. The plan should be written with accompanying diagrams and distributed to each supervisor and posted in appropriate locations for all employees to read and study. In addition to fires and explosions, the evacuation plan should also consider hazardous incidents such as spills, leaks, or releases of flammable, toxic, or radioactive materials, and acts of nature such as tornadoes, hurricanes and floods. The evacuation plan should include, but not be limited to:

(a) Conditions under which evacuation will be necessary.

(b) Method of alarm transmission.

(c) Action to be taken by personnel upon receiving an alarm in addition to evacuation (e.g., turn off flames and other ignition sources).

(d) Primary and secondary routes to horizontal and vertical exits leading either to the exterior of the building or to safe refuge zones within the building as may be permitted if total evacuation is not necessary and the alarm system is appropriately zoned.

(e) Instructions necessary to prevent evacuees from hampering fire fighting operations or essential duties of emergency personnel (i.e., move away from the building to a predesignated area).

(f) Accountability to determine if everyone has left the facility. (Wardens or supervisors should be instructed to check all occupied spaces in their assigned area upon sounding of an alarm to ensure that everyone has heard the alarm and is evacuating. Personnel from particular groups, departments, floors, or areas should be instructed to gather in a predesignated area outside the building or in a safe refuge zone. Special procedures may have to be established for evacuation of handicapped persons. Wardens or supervisors should be responsible for accounting for all personnel in their areas, including guests and visitors.)

(g) Methods of notifying personnel when it is safe to reenter the facility. (Dependence on duly authorized persons, such as wardens, to pass this word will prevent someone from entering the facility prematurely.)

Laboratory management should conduct fire exit drills at least once a year to test the evacuation procedures by familiarizing personnel with exits, especially emergency exits not normally used, and their safe and efficient use. For required frequency of fire exit drills in educational occupancies, see NFPA *101, Life Safety Code*. (Fire exit drills differ from fire drills in that the latter are held for purposes of fire fighting practice by the fire brigade or other emergency organizations. Since a conflict exists between evacuation and fire fighting, management should appoint different persons to be responsible for each procedure, as one cannot effectively direct fire fighting operations and evacuation simultaneously.)

Fire alarm systems, where available, should be used in the conduct of fire exit drills. No one should be excused from participating in a fire exit drill.

A-4-6.1.2 Laboratory personnel should be thoroughly indoctrinated in procedures to follow in cases of clothing fires. The most important instruction, one which should be stressed until it becomes second nature to all personnel, is to immediately drop to the floor and roll. All personnel should recognize that, in case of ignition of another person's clothing, they should immediately knock that person to the floor and roll that person around to smother the flames. Too often a person will panic if clothing ignites and will run, resulting in more severe, often fatal burn injuries.

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

A-4-6.3 Successful prevention or extinguishment of fires and protection of personnel from injury due to fire or contingent conditions require an adequate maintenance program.

A-5-5.2 A protective coating, such as mineral oil, may be applied to transparent sight panels exposed to corrosive vapors.

A-6-3 Descriptions of Types of Laboratory Hoods.

Conventional Hoods. A square post hood without an air-foil directional vane across the bottom of the hood face, 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 may create turbulence at the hood face.

Many conventional hoods, because of their design, may create turbulence at the hood face which may 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 may become objectionably high as the sash is closed and, with sash completely closed, airflow may be insufficient to carry vapors away.

Bypass Air Hoods. A hood with streamlined entrance shapes around the face opening, and airfoil across the bottom of the hood opening, and air bypass grille which serves to maintain a relatively constant volume of exhaust air regardless of sash position.

Auxiliary Air Hoods. Same as bypass air hood with the addition of an auxiliary air bonnet to provide a direct source of make-up air in addition to the make-up air from the laboratory work area. Auxiliary air hoods are used to improve the airflow characteristics and to save conditioned air.

Special Purpose Hoods:

(a) *Radioisotope Hoods.* Designed primarily for use with radiochemicals;

(b) *Perchloric Acid Hoods.* Designed primarily for use with perchloric acid; and

(c) *Walk-in Hoods.* Designed primarily for extra headroom to accommodate tall equipment.

A-6-4.2 The overall building pressure should be positive to the outside atmosphere to prevent infiltration of unconditioned air into the building. This also ensures a positive flow of air through hoods and their ducts in event of exhaust fan failure. If a positive pressure cannot be maintained, the exhaust fans should be run continuously. Air conservation can be obtained by the use of multispeed fans that can be operated at low speed when the hood is not in use or by two-position dampers that reduce the air flow. Gravity-operated dampers can become inoperative due to corrosion and should not be used. Positive shut-off power-operated dampers are subject to malfunction and also are not recommended. If used, they should be of a type that will fail open if malfunction does occur (*see 6-11.3*).

Provisions should be made for immediate shut-down of recirculation of environmental air in the event of a spill or release of dangerous quantities of toxic or flammable materials.

A-6-5.4 Ducts should be sealed to prevent condensation, etc., from leaking into occupied areas.

A-6-8.6 Exhaust fans should be tested to ensure they do not rotate backwards in new installations or after repair on motors.

A-6-8.7 Exhaust stacks should extend at least 7 ft (2.14 m) above the roof to protect personnel on the roof. Exhaust stacks may need to be much higher to dissipate effluent effectively and studies may be necessary to determine adequate design.

A-6-9.1.2 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-6-9.1.3 The means of containing minor spills may consist of a ¼-in. (6.4-mm) 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-6-9.2 Hood sash greatly enhances the safety provided by laboratory hoods and it is recommended that hood design incorporate this feature. For example, 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; the sash can be closed to contain a fire or runaway reaction; the sash can be closed to contain experiments when the hood is left unattended.

Hoods without sashes or hoods with side or rear sash in addition to 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 may be desirable to save exhaust air and energy or to increase the maximum face velocity on existing hoods.

A-6-9.4.1 Locating services and controls external to the hood minimizes the potential hazards of corrosion and arcing.

A-6-10.1 A person walking past the hood may create sufficient turbulence to disrupt a face velocity of 100 fpm (30.5 m/min). In addition, open windows may completely negate or dramatically reduce the face velocity and can also affect negative differential air pressure.

A-6-12.1 If perchloric acid is heated above ambient temperature it will give off vapors which 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-6-12.2 A simple and sensitive test for perchlorates is available that uses a 0.1 percent solution of methylene blue in water. A few drops of the test solution in a small quantity (about 25 ml) of water washed from the duct to be tested will produce a violet precipitate if perchlorates are present.

An effective method for washing down duct work suspected of perchlorate contamination has been recommended by Breysse in the *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.

A-6-12.7 Perchloric acid hoods should be washed down after each use.

A-7-1 Before a hazardous chemical is ordered, controls should be established to assure that adequate facilities and procedures are available for receiving, storing, using, and disposing of the material. Information sources include:

NFPA 49, *Hazardous Chemicals Data*;

NFPA 491M, *Manual of Hazardous Chemical Reactions*;

NFPA 325M, *Fire Hazard Properties of Flammable Liquids, Gases and Volatile Solids*;

Flash Point Index of Trade-Name Liquids.

A-7-2.2.1 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. 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.

A-7-2.2.2 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.

A-7-2.2.5 Ventilation for transfer operations should be provided to prevent overexposure of personnel transferring flammable liquids. Control of solvent vapors is most effective if local exhaust ventilation is provided at or close to the point of transfer. Explosion venting is not required for separate inside storage areas if containers are no greater than 60 gal (227 L) and if transfer from containers larger than 1 gal (3.785 L) is by means of approved pumps or other devices drawing through a top opening.

A-7-2.2.6 Where practicable, transfer operations should be separated from the storage of flammable and combustible liquids because of the exposure of greater quantities to the hazards of transfer operations.

A-7-2.3 Flammable and combustible liquids that are not in use should be stored in safety cans, storage cabinets, or inside storage rooms. See NFPA 30, *Flammable and Combustible Liquids Code*, for quantity limitations of storage cabinets and inside storage rooms.

A-7-2.3.2 Class IA and IB flammable liquids in glass containers larger than the 1 pt (0.47 L) and 1 qt (0.97 L) sizes permitted by Table 7-2 should be kept in suitable containers of sufficient size to hold the contents of the glass containers.

A-7-2.3.4 For guidance, see NFPA 49, *Hazardous Chemicals Data*, and NFPA 491M, *Manual of Hazardous Chemical Reactions*.

A-7-3 Drain lines and traps from laboratory benches, hood work surfaces, mechanical equipment rooms, storage rooms, etc. should have water added at regular intervals to assure that traps will not be the source of flammable or toxic vapor release. Where self-priming traps are provided, an annual inspection for proper operation should be made. Mineral oil or similar liquids are sometimes added to traps to reduce evaporation of water.

A-8-1.1 For additional information, see Compressed Gas Association Pamphlet P-1, *Safe Handling of Compressed Gases in Containers*, and National Safety Council Data Sheet 1-668-80, *Cryogenic Fluid in the Laboratory*.

A-8-1.3 Some facilities also have shut-off valves in accessible locations outside of the spaces in which gases are being used.

A-8-1.5 It is recommended that each intermediate regulator and valve also be identified. The identification should conform to ANSI A13.1, *Standard Scheme for the Identification of Piping Systems*, or to some other recognized marking scheme.

A-8-2.4 Examples of such corrosive or unstable gases include:

(a) acid and alkaline gases;

(b) gases subject to polymerization;

(c) gases subject to explosive decomposition.

Cylinders of gases should be returned to the supplier when the expiration date of the maximum recommended retention period has been reached. 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 period, the following should be used: 36 months retention period for liquefied flammable gases, flammable gases, and oxygen; 6 months for gases having health hazard ratings of 3 or 4.

A-9-1.1.1 Suitable reference sources are NFPA 49, *Hazardous Chemicals Data*; NFPA 491M, *Manual of Hazardous Chemical Reactions*; *Flash Point Index of Trade Name Liquids*; and NFPA 325M, *Fire Hazard Properties of Flammable Liquids*.

A-9-1.1.3 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 may include, but are not limited to, differential thermal analysis, drop weight shock sensitivity, autoignition temperature, flash point, thermal stability under confinement, heat of combustion, and other appropriate tests.

A-9-1.4 Protection against ignition sources associated with typical laboratory apparatus may be achieved by distance, pressurization of motor or switch housings, or inerting techniques which may effectively prevent flammable vapor concentrations from contacting ignition sources.

A-9-1.6.2 Procedures may include chilling, quenching, cutoff of reactant supply, venting, dumping, and "short-stopping" or inhibiting.

A-9-2.2.2 The use of domestic refrigerators for the storage of typical laboratory solvents presents a significant hazard to the laboratory work area. Refrigerator temperatures are almost universally higher than the flash points of the flammable liquids most often stored in them. In addition to vapor accumulation, a domestic refrigerator contains readily available ignition sources, such as thermostats, light switches, and heater strips, all within or exposed to the refrigerated storage compartment. Furthermore, the compressor and its circuits are typically located at the bottom of the unit, where vapors from flammable liquid spills or leaks may easily accumulate.

Protection against the ignition of flammable vapors in refrigerated equipment is available through three types of laboratory refrigerators: "explosion-proof," "laboratory-safe" (or "explosion-safe"), and modified domestic models.

"Explosion-proof" refrigeration equipment is designed to protect against ignition of flammable vapors both inside and outside the refrigerated storage compartment. This type is intended and recommended for environments such as pilot plants or laboratory work areas where all electrical equipment is required to meet the requirements of Article 501 of NFPA 70, *National Electrical Code*.

The design concepts of the explosion-safe or laboratory-safe type of refrigerator are based on the 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 such design features 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 should an exothermic reaction 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 are such that they provide important safeguards not easily available through modification of domestic models.

Although not considered optimum protection, it is possible to modify domestic refrigerators to achieve some degree of protection. However, the modification process can be applied only to manual defrost refrigerators; the self-defrosting models cannot be successfully modified to provide even minimum safeguards against vapor ignition. The minimum procedures for modification include:

(a) Relocation of manual temperature controls to the exterior of the storage compartment, sealing all points where capillary tubing or wiring formerly entered the storage compartment.

(b) Removal of light switches and light assemblies and sealing of all resulting openings.

(c) Replacement of positive mechanical door latches with magnetic door gaskets.

Regardless of the approach used (explosion-proof, laboratory-safe, modified domestic, or unmodified domestic), every laboratory refrigerator should be clearly labeled to indicate whether or not it is safe for storage of flammable materials. Internal laboratory procedures should ensure that laboratory refrigerators are being properly used. Figure A-9-2.2.2 gives examples of labels which can be used on laboratory refrigerators.

Do not store flammable solvents in this refrigerator

Label Used for Unmodified Domestic Models

Notice: This is not an explosion-proof 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-9-2.2.2 Labels to be used in laboratory refrigerators.

A-9-2.6.1 For design of pressure vessels, see the ASME *Boiler and Pressure Vessel Code*, Section VIII, Rules for Construction of Pressure Vessels, Division 1.

A-10-1 Examples of severe or unusual hazards that may require posting of signs include:

(a) unstable chemicals,
(b) radioactive chemicals,
(c) pathogens,
(d) high pressure reactions,
(e) high powered lasers,
(f) water reactive materials,
(g) 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.

Appendix B Supplementary Definitions

The following definitions are taken from other NFPA documents and are critical to the understanding of this standard. . . and thus are considered a part of the requirements of this document.

B-1 The following definitions are taken from NFPA 30, *Flammable and Combustible Liquids Code*:

Flammable Liquid. A liquid having a flash point below 100°F (37.8°C) and having a vapor pressure not exceeding 40 lb per sq in. (absolute) at 100°F (37.8°C) shall be known as Class I liquid.

Class I liquids shall be subdivided as follows:

Class IA shall include those having flash points below 73°F (22.8°C) and having a boiling point below 100°F (37.8°C).

Class IB shall include those having flash points below 73°F (22.8°C) and having a boiling point at or above 100°F (37.8°C).

Class IC shall include those having flash points at or above 73°F (22.8°C) and below 100°F (37.8°C).

Combustible Liquid. A liquid having a flash point at or above 100°F (37.8°C).

Combustible liquids shall be subdivided as follows:

Class II liquids shall include those having flash points at or above 100°F (37.8°C) and below 140°F (60°C).

Class IIIA liquids shall include those having flash points at or above 140°F (60°C) and below 200°F (93.4°C).

Class IIIB liquids shall include those having flash points at or above 200°F (93.4°C).

B-2 The following definition is taken from NFPA 30, *Flammable and Combustible Liquids Code*:

The flash point of a liquid having a viscosity less than 45 SUS at 100°F (37.8°C) and a flash point below 200°F (93.4°C) shall be determined in accordance with ASTM D56-75, *Standard Method of Test for Flash Point by the Tag Closed Tester*.

The flash point of a liquid having a viscosity of 45 SUS or more at 100°F (37.8°C) or a flash point of 200°F (93.4°C) or higher shall be determined in accordance with ASTM D93-73, *Standard Method of Test for Flash Point by the Pensky-Martens Closed Tester*.

B-3 The following definitions are based on NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*:

B-3-1 Health Hazard. A health hazard is any property of a material which, either directly or indirectly, can cause injury or incapacitation, either temporary or permanent, from exposure by contact, inhalation, or ingestion.

B-3-1.1 Degrees of Health Hazard.

4 Materials which on very short exposure could cause death or major residual injury even though prompt medical treatment were given, including those which are too dangerous to be approached without specialized protective equipment. This degree should include:

Materials which can penetrate ordinary rubber protective clothing;

Materials which under normal conditions or under fire conditions give off gases which are extremely hazardous (i.e., toxic or corrosive) through inhalation or through contact with or absorption through the skin.

3 Materials which on short exposure could cause serious temporary or residual injury even though prompt medical treatment were given, including those requiring protection from all bodily contact. This degree should include:

Materials giving off highly toxic combustion products;

Materials corrosive to living tissue or toxic by skin absorption.

2 Materials which on intense or continued exposure could cause temporary incapacitation or possible residual injury unless prompt medical treatment is given, including those requiring use of respiratory protective equipment with independent air supply. This degree should include:

Materials giving off toxic combustion products;

Materials giving off highly irritating combustion products;

Materials which either under normal conditions or under fire conditions give off toxic vapors lacking warning properties.

1 Materials which on exposure would cause irritation but only minor residual injury even if no treatment is given, including those which require use of an approved canister type gas mask. This degree should include:

Materials which under fire conditions would give off irritating combustion products;

Materials which on the skin could cause irritation without destruction of tissue.

0 Materials which on exposure under fire conditions would offer no hazard beyond that of ordinary combustible material.

B-3-2 Flammability Hazard. Flammability describes the degree of susceptibility of materials to burning. The form or condition of the material, as well as its inherent properties, affects its flammability.

B-3-2.1 Degree of Flammability Hazard.

4 Materials which will rapidly or completely vaporize at atmospheric pressure and normal ambient temperature or which are readily dispersed in air, and which will burn readily. This degree should include:

Gases;

Cryogenic materials;

Any liquid or gaseous material which is a liquid while under pressure and having a flash point below 73°F (22.8°C) and having a boiling point below 100°F (37.8°C) (Class IA flammable liquids);

Materials which on account of their physical form or environmental conditions can form explosive mixtures with air and which are readily dispersed in air, such as dusts of combustible solids and mists of flammable or combustible liquid droplets.

3 Liquids and solids that can be ignited under almost all ambient temperature conditions. Materials in this degree produce hazardous atmospheres with air under almost all ambient temperatures or, though unaffected by ambient temperatures, are readily ignited under almost all conditions. This degree should include:

Liquids having a flash point below 73°F (22.8°C) and having a boiling point at or above 100°F (37.8°C) and those liquids having a flash point at or above 73°F (22.8°C) and below 100°F (37.8°C) (Class IB and Class IC flammable liquids);

Solid materials in the form of coarse dusts which may burn rapidly but which generally do not form explosive atmospheres with air;

Solid materials in a fibrous or shredded form which may burn rapidly and create flash fire hazards, such as cotton, sisal and hemp;

Materials which burn with extreme rapidity, usually by reason of self-contained oxygen (e.g., dry nitrocellulose and many organic peroxides);

Materials which ignite spontaneously when exposed to air.

2 Materials that must be moderately heated or exposed to relatively high ambient temperatures before ignition can occur. Materials in this degree would not under normal conditions form hazardous atmospheres with air, but under high ambient temperatures or under moderate heating may release vapor in sufficient quantities to produce hazardous atmospheres with air. This degree should include:

Liquids having a flash point above 100°F (37.8°C), but not exceeding 200°F (93.4°C);

Solids and semisolids which readily give off flammable vapors.

1 Materials that must be preheated before ignition can occur. Materials in this degree require considerable preheating, under all ambient temperature conditions, before ignition and combustion can occur. This degree should include:

Materials which will burn in air when exposed to a temperature of 1500°F (815.5°C) for a period of 5 minutes or less;

Liquids, solids, and semisolids having a flash point above 200°F (93.4°C).

This degree includes most ordinary combustible materials.

0 Materials that will not burn. This degree should include any material which will not burn in air when exposed to a temperature of 1500°F (815.5°C) for a period of 5 minutes.

B-3-3 Reactivity (Instability) Hazards. Reactivity describes the ability of a material to chemically react with other stable or unstable materials. For purposes of this hazard identification system, the other material is water, if reaction with water releases energy. Reactions with common materials other than water may release energy violently, but are beyond the scope of this identification system.

Unstable materials are those which, in the pure state or as commercially produced, will vigorously polymerize, decompose or condense; which become self-reactive; or which undergo other violent chemical changes.

Stable materials are those that normally have the capacity to resist changes in their chemical composition, despite exposure to air, water, and heat encountered in fire emergencies.

B-3-3.1 Degree of Reactivity (Instability) Hazard.

4 Materials which in themselves are readily capable of detonation or of explosive decomposition or explosive reaction at normal temperatures and pressures. This degree should include materials which are sensitive to mechanical or localized thermal shock at normal temperatures and pressures.

3 Materials which in themselves are capable of detonation or of explosive decomposition or explosive reaction but which require a strong initiating source or which must be heated under confinement before initiation. This degree should include materials which are sensitive to thermal or mechanical shock at elevated temperatures and pressures or which react explosively with water without requiring heat or confinement.

2 Materials which in themselves are normally unstable and readily undergo violent chemical change but do not detonate. This degree should include materials which can undergo chemical change with rapid release of energy at normal temperatures and pressures or which can undergo violent chemical change at elevated temperatures and pressures. It should also include those materials which may react violently with water or which may form potentially explosive mixtures with water.

1 Materials which in themselves are normally stable, but which can become unstable at elevated temperatures and pressures or which may react with water with some release of energy but not violently.

0 Materials which in themselves are normally stable, even under fire exposure conditions, and which are not reactive with water.

B-4 The following definitions are taken from NFPA 220, *Standard on Types of Building Construction*:

B-4-1 Noncombustible Material. A material which, in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors, when subjected to fire or heat. Materials reported as noncombustible, when tested in accordance with ASTM E-136, *Standard Method of Test for Noncombustibility of Elementary Materials*, shall be considered noncombustible materials.

B-4-2 Limited-Combustible. As applied to a building construction material, means a material, not complying with the definition of noncombustible material, which, in the form in which it is used, has a potential heat value not exceeding 3500 Btu per lb (8141 Kj/kg), and complies with one of the following paragraphs, (a) or (b). Materials subject to increase in combustibility or flame spread rating beyond the limits herein established through the effects of age, moisture, or other atmospheric condition shall be considered combustible.

(a) Materials having a structural base of noncombustible material, with a surfacing not exceeding a thickness of ⅛ of an in. (3.2 mm) which has a flame spread rating not greater than 50.

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

B-4-3 Potential Heat Value. The average value, in Btu per lb, obtained by testing a building material in accordance with NFPA 259, *Standard Test Method of Potential Heat of Building Materials*.

B-4-4 Flame Spread Index. Refers to numbers or classifications obtained according to NFPA 255, *Method of Test of Surface Burning Characteristics of Building Materials*.

B-4-5 Fire Endurance Rating. The time, in minutes or hours, that materials or assemblies have withstood a fire exposure as established in accordance with the test procedures of NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials*.

B-4-6 Classification of Construction Types.

B-4-6.1 Basic types of construction are defined below as Types I, II, III, IV or V. Each basic type, except for Type IV, includes two or more subclasses differentiated by a three digit arabic number. The arabic numbers designate the fire endurance rating requirements for certain structural elements as follows:

First Arabic Number. Exterior bearing walls.

Second Arabic Number. Structural frame or columns and girders, supporting loads for more than one floor.

Third Arabic Number. Floor construction.

B-4-6.2 Basic Construction Types.

Type I (443-332). Type I construction is that type in which the structural members, including walls, columns, beams, floors, and roofs, are of approved noncombustible or limited-combustible materials and have fire endurance ratings not less than those set forth in Table B-4.

Type II (222-111-000). Type II construction is that type not qualifying as Type I construction in which the structural members, including walls, columns, beams, floors, and roofs are of approved noncombustible or limited-combustible materials and have fire endurance ratings not less than those set forth in Table B-4.

Type III (211-200). Type III construction is that type in which exterior walls and structural members which are portions of exterior walls are of approved noncombustible or limited-combustible materials, and interior structural members, including walls, columns, beams, floors, and roofs, are wholly or partly of wood of smaller dimensions than required for Type IV construction or of approved noncombustible, limited-combustible, or other approved combustible materials. In addition, structural members have fire endurance ratings not less than those set forth in Table B-4.

Type IV (2HH).[1] Type IV construction is that type

[1]All dimensions for sawn and laminated lumber are nominal.

Table B-4 Fire Resistance Requirements for Type I through Type V Construction

	Type I		Type II			Type III		Type IV	Type V	
	443	332	222	111	000	211	200	2HH	111	000
EXTERIOR BEARING WALLS —										
Supporting more than one floor, columns or other bearing walls	4	3	2	1	0[1]	2	2	2	1	0[1]
Supporting one floor only	4	3	2	1	0[1]	2	2	2	1	0[1]
Supporting a roof only	4	3	1	1	0[1]	2	2	2	1	0[1]
INTERIOR BEARING WALLS —										
Supporting more than one floor, columns or other bearing walls	4	3	2	1	0	1	0	2	1	0
Supporting one floor only	3	2	2	1	0	1	0	1	1	0
Supporting a roof only	3	2	1	1	0	1	0	1	1	0
COLUMNS —										
Supporting more than one floor, bearing walls or other columns	4	3	2	1	0	1	0	H[2]	1	0
Supporting one floor only	3	2	2	1	0	1	0	H[2]	1	0
Supporting a roof only	3	2	1	1	0	1	0	H[2]	1	0
BEAMS, GIRDERS, TRUSSES & ARCHES —										
Supporting more than one floor, bearing walls or columns	4	3	2	1	0	1	0	H[2]	1	0
Supporting one floor only	3	2	2	1	0	1	0	H[2]	1	0
Supporting a roof only	3	2	1	1	0	1	0	H[2]	1	0
FLOOR CONSTRUCTION	3	2	2	1	0	1	0	H[2]	1	0
ROOF CONSTRUCTION	2	1½	1	1	0	1	0	H[2]	1	0
EXTERIOR NONBEARING WALLS	0[1]	0[1]	0[1]	0[1]	0[1]	0[1]	0[1]	0[1]	0[1]	0[1]

(hatched) Those members listed that are permitted to be of approved combustible material.

[1] Requirements for fire resistance of exterior walls, the provision of spandrel wall sections, and the limitation or protection of wall openings are not related to construction type. They need to be specified in other standards and codes, where appropriate, and may be required in addition to the requirements of this Standard for the construction type.

[2] "H" indicates heavy timber members; see text for requirements.

in which exterior and interior walls and structural members which are portions of such walls are of approved noncombustible or limited-combustible materials. Other interior structural members including columns, beams, arches, floors and roofs are of solid or laminated wood without concealed spaces and comply with the provisions shown in (a) through (e) below. In addition, structural members have fire endurance ratings not less than those set forth in Table B-4.

Exception No. 1: Interior columns, arches, beams, girders, and trusses of approved materials other than wood are permitted provided they are protected to provide a fire endurance rating of not less than 1 hour.

Exception No. 2: Certain concealed spaces are permitted by the Exception to (c) below.

(a) Wood columns supporting floor loads shall be not less than 8 in. (203 mm) in any dimension; wood columns supporting roof loads only shall be not less than 6 in. (152 mm) in least dimension and not less than 8 in. (203 mm) in depth.

(b) Wood beams and girders supporting floor loads shall be not less than 6 in. (152 mm) in width and not less than 10 in. (254 mm) in depth; wood beams and girders and other roof framing, supporting roof loads only, shall be not less than 4 in. (102 mm) in width and not less than 6 in. (152 mm) in depth.

(c) Framed or glued laminated arches which spring from grade or the floor line and timber trusses which support floor loads shall be not less than 8 in. (203 mm) in width or depth. Framed or glued laminated arches for roof construction which spring from grade or the floor line and do not support floor loads shall have members not less than 6 in. (152 mm) in width and not less than 8 in. (203 mm) in depth for the lower half of the height and not less than 6 in. (152 mm) in depth for the upper half. Framed or glued laminated arches for roof construction which spring from the top of walls or wall abutments and timber trusses which do not support floor loads shall have members not less than 4 in. (102 mm) in width and not less than 6 in. (152 mm) in depth.

Exception: Spaced members may be composed of two or more pieces not less than 3 in. (76 mm) in thickness when blocked solidly throughout their intervening spaces or when such spaces are tightly closed by a continuous wood cover plate not less than two in. (51 mm) in thickness, secured to the underside of the members.

Splice plates shall be not less than 3 in. (76 mm) in thickness.

(d) Floors shall be constructed of splined or tongued and grooved plank not less than 3 in. (76 mm) in thickness covered with 1-in. (25-mm) tongue and groove flooring, laid crosswise or diagonally to the plank, or with ½-in. (12.7-mm) plywood, or of laminated planks not less than 4 in. (102 mm) in width, set on edge close together, spiked at intervals of 18 in. (457 mm) and covered with 1-in. (25-mm) tongue and groove flooring laid crosswise or diagonally to the plank or with ½-in. (12.7-mm) plywood.

(e) Roof decks shall be of splined or tongued and grooved plank not less than 2 in. (51 mm) in thickness; or of laminated planks not less than 3 in. (76 mm) in width, set on edge close together, and laid as required for floors; or of 1⅛-in. (28.6-mm) thick interior plywood (exterior glue) or of approved noncombustible or limited-combustible materials of equal fire durability.

Type V (111-000). Type V construction is that type in which exterior walls, bearing walls, and floors and roofs and their supports are wholly or partly of wood or other approved combustible material smaller than required for Type IV construction. In addition, structural members have fire resistance ratings not less than those set forth in Table B-4.

Appendix C Supplementary Information on Explosion Hazards and Protection

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

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

C-2 Explosion. An explosion is 1) a violent bursting, as of a pressurized vessel; or 2) an extremely rapid chemical reaction with the associated production of noise, heat and violent expansion of gases. Reactive explosions are further categorized as deflagrations, detonations and thermal explosions.

C-2.1 Container Failure. When a container is pressurized beyond its burst strength, it may violently tear asunder (explode). A container failure can produce subsonic, sonic, or supersonic shock waves, depending on the cause of the internal pressure.

C-2.1.1 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-2.1.2 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-2.1.3 Small volume liquid systems pressurized to over 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-2.1.4 Liquid systems containing entrained air or gas will store more potential energy and are, therefore, more hazardous than totally liquid systems, because the gas becomes the driving force behind the liquid.

C-2.1.5 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 level.

C-2.1.6 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-2.2 A deflagration is a rapid combustion or decomposition reaction in which the reaction zone (flame front) progresses below the speed of sound through the unburned medium.

C-2.2.1 The reaction rate is proportional to the increasing pressure of the reaction. A deflagration may under some conditions accelerate and build into a detonation. The deflagration-to-detonation transition (D-D-T) is influenced by confinement that allows compression waves to advance and create higher pressures which continue to increase the deflagration rates. This is commonly called "pressure piling."

C-2.3 A detonation is a rapid combustion reaction which takes place at or above the speed of sound in the unburned medium.

C-2.3.1 A detonation will cause a high pressure shock wave to propagate outwardly, through the surrounding environment, at velocities above the speed of sound.

C-2.4 A thermal explosion is a self-accelerating exothermic decomposition which occurs throughout the entire mass with no separate, distinct reaction zone.

C-2.4.1 A thermal explosion may accelerate into a detonation.

C-2.4.2 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. The Frank-Kamenetsky theory is useful in evaluating the critical mass in the thermal explosion of solids.

C-3 Effects of Explosions.

C-3.1 Personnel Exposure. Personnel exposed to the effects of an explosion are susceptible to injury from:

(a) missiles and explosion-dispersed materials;

(b) thermal and corrosive burns;

(c) inhalation of explosion products;

(d) overpressure; including incident, reflection-reinforced incident, and sustained overpressure;

(e) body blow-down 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 Tables C-3.1(a) and (b).

Table C-3.1(a) Blast Effects from Detonations
Range in ft for Indicated Explosive Yield (TNT Equivalents)

Blast Effect	0.1 gm	1.0 gm	10 gm	100 gm	Criteria
1% Eardrum Rupture	1.1	2.4	5.2	11	P_i = 3.4 psi
50% Eardrum Rupture	0.47	1.0	2.2	4.7	P_i = 16 psi
No Blowdown	0.31	1.3	6.9	~30	$I_i + I_q$ = 1.25 psi • msec V_{max} = 0.3 ft/sec
50% Blowdown	<0.1	0.29	1.1	4.1	$I_i + I_q$ = 8.3 psi • msec V_{max} = 2.0 ft/sec
1% Serious Displacement Injury	<0.1	<0.2	<0.5	~1.1	$I_i + I_q$ = 54 psi • msec V_{max} = 13 ft/sec
Threshold Lung Hemorrhage	<0.1	<0.2	~0.5	1.8	$I_i + I_q$ = 26 psi • msec
Severe Lung Hemorrhage	<0.1	<0.2	<0.5	~1.1	$I_i + I_q$ = 52 psi • msec
1% Mortality	<0.1	<0.2	<0.5	<1	$I_i + I_q$ = 85 psi • msec
50% Mortality	<0.1	<0.2	<0.5	<1	$I_i + I_q$ = 130 psi • msec
50% Large (16-25 ft^2) Windows Broken	0.26	1.1	5.7	~30	I_r = 3 psi • msec
50% Small (1.3-6 ft^2) Windows Broken	0.17	0.40	1.9	9.9	I_r = 8 psi • msec

P_i = the peak incident overpressure (psi).
V_{max} = the maximum translational velocity for an initially standing man (ft/sec).
I_i = the impulse in the incident wave (psi • msec).
I_q = the dynamic pressure impulse in the incident wave (psi • msec).
I_r = the impulse in the incident wave upon reflection against a surface perpendicular to its path of travel (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 (milliseconds).

Table C-3.1(b)
Criteria for Estimating Missile Injuries

Kind of Missile	Critical Organ or Event	Related Impact Velocity (ft/sec)
Nonpenetrating		
10 lb. object	Cerebral	
	Concussion	
	Threshold	15
	Skull fracture	
	Threshold	15
	Near 100%	23
Penetrating*		
10 gm glass fragments	Skin laceration	
	Threshold	50
	Serious Wounds	
	Threshold	100
	50%	180
	100%	300

*Eye damage, lethality or paralysis may result from penetrating missiles at relatively low velocities striking eyes, major blood vessels, major nerve centers or vital organs.

For SI Units: 1 ft/sec = 0.305 m/sec.

C-3.2 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-3.2.1 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 may 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 grams, the reinforcement phenomena is negligible because of the rapid decay of both the incident pressure wave and the reflected pressure wave with distance.

C-3.2.2 Thermal explosions and deflagrations having impulses with rates of pressure rise greater than 20 milliseconds require peak pressures of approximately 3 times those of detonations in order to produce similar damage.

C-3.2.3 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 grams would not be expected to create significant sustained overpressures, except in small enclosures. (For small explosions, burns, inhalation of toxic gases and missile injuries usually exceed blast wave injuries.)

C-4 Hazard Analysis.

C-4.1 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 at an appropriate level of management is recommended.

C-4.2 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 may 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, may generate pressure waves which, in themselves, do not endanger personnel, but the resulting fragments may blind, otherwise injure, or kill the experimenter. An explosion which 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 may become a missile. The possibility of flames and dispersion of hot, corrosive, or toxic materials likewise should be considered.

C-4.3 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, etc.; 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; explosive limits, quantities, oxygen enrichment, etc., 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 upon statistical data. In general, there will be insufficient data to develop mathematical probabilities.

C-4.4 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: numbers and locations of personnel; injury and fatality potentials; repair or replacement cost of equipment; ability of the building or room or equipment to withstand the explosion, and the cost to restore the facility and equipment; adverse impact on research and development and business interruption costs as a result of loss of use of the facility.

C-4.5 Figure C-4.5 provides guidance on distinguishing between high pressure and low pressure reactions.

The following items apply to the classification of reactions in vessels as either high pressure or low pressure.

C-4.5.1 Reactions which produce pressures below the curve in Figure C-4.5 are classified as low pressure reactions.

Exception: Experimental reactions involving materials that are known to be inherently unstable, such as reactions with acetylenic compounds and certain oxidations, such as halogenations or nitrations, should be considered high pressure reactions, even though they may fall below the curve in Figure C-4.5.

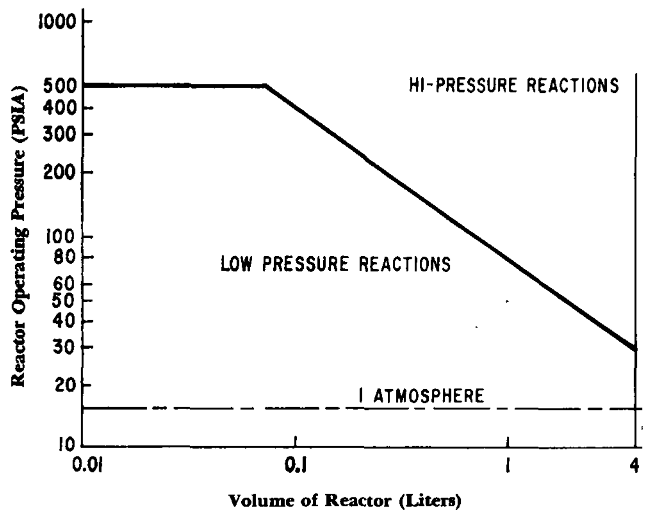

Figure C-4.5

C-4.5.2 Reactions which produce pressures above the curve in Figure C-4.5 should be classified as high pressure reactions.

Exception: Routine reactions where pressures and temperatures are expected between certain predetermined limits based on long experience or routine work may be considered low pressure reactions, if the reaction vessel is built of suitable materials, has an adequate safety factor, and is provided with pressure relief in the form of a properly designed safety relief valve or a rupture disc, which discharges to a safe location.

C-4.5.3 Items (a) through (d) contain recommendations for protecting against explosion hazards of reactions conducted above atmospheric pressures.

(a) 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. (*See NFPA 68, Guide for Explosion Venting.*)

(b) Reaction vessels should be built of suitable materials of construction and should have an adequate safety factor.

(c) All reaction vessels should be provided with a pressure relief valve or a rupture disc.

(d) Low pressure reactions should be conducted in or behind portable barricades.

C-5 Explosion Hazard Protection.

C-5.1 It is important to remember that a conventional laboratory hood is not designed to provide explosion protection.

C-5.2 The design of explosion hazard protection measures should be based on the following considerations:

(a) Blast effects:

1. Impulse
2. Rate and duration of pressure rise
3. Peak pressure
4. Duration of overpressure
5. Velocity of the propagating pressure wave
6. Residual overpressure and underpressure

(b) Missiles:

1. Physical properties of the material
2. Mass
3. Shape
4. Velocity

C-5.3 Protection can be provided by one or more of the following methods:

(a) providing special preventive or protective measures for reactions, equipment, or the reactants themselves (such as explosion suppression, high speed fire detection with deluge sprinklers, explosion venting directed to a safe location, or explosion-resistant enclosures);

(b) using remote control to minimize personnel exposure;

(c) conducting experiments in a detached or isolated building, or outdoors;

(d) providing explosion-resistant walls or barricades around the laboratory;

(e) limiting the quantities of flammable or reactive chemicals used in or exposed by the experiments;

(f) limiting the quantities of reactants of unknown characteristics to fractional gram amounts until the properties of intermediate and final products are well established;

(g) 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 must be of explosion-resistant construction.

(h) disallowing the use of explosion hazard areas for other nonexplosion hazard uses;

(i) locating offices, conference rooms, lunch rooms, etc., remote from explosion hazard area.

C-5.4 Explosion-Resistant Hoods and Shields.[1] Laboratory personnel may be protected by specially designed explosion-resistant hoods or shields for TNT equivalencies up to 1.0 grams. For slightly greater TNT equivalencies, specially designed hoods provided with explosion venting are required. For TNT equivalencies greater than 2.0 grams, explosion-resistant construction, isolation or other protective methods should be used.

[1]Conventional laboratory hoods are not designed to provide explosion protection.

C-5.4.1 When explosion-resistant hoods or shields are used, they should be designed, located, supported, and anchored so as to:

(a) withstand the effects of the explosion;

(b) vent overpressures, injurious substances, flames, and heat to a safe location;

(c) contain missiles and fragments;

(d) prevent the formation of secondary missiles caused by failure of hood or shield components.

C-5.4.2 Commercially available explosion shields should be evaluated against the criteria of C-5.4.1 for the specific hazard.

C-5.4.3 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-5.4.4 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, while 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 may 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 towards 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-5.5 Explosion-Resistant Construction. As explained in C-5.4, explosion-resistant construction may be required for TNT equivalencies greater than 2.0 grams. 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 1,000 to 4,000 ft/sec (305 to 1220 m/sec) normally may be expected.

C-5.5.1 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.

(a) Detonations of small quantities of explosive materials usually involve very short periods of time (tenths of milliseconds) and high average pressure.