NFPA 30

Flammable and Combustible Liquids Code

1990 Edition

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An American National Standard
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National Fire Protection Association
1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101

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

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

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

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NATIONAL FIRE PROTECTION ASSOCIATION

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This edition of NFPA 30, *Flammable and Combustible Liquids Code*, was prepared by the Technical Committee on Flammable and Combustible Liquids, released by the Correlating Committee on Flammable Liquids, and acted on by the National Fire Protection Association, Inc. at its Annual Meeting held May 21-24, 1990 in San Antonio, TX. It was issued by the Standards Council on July 20, 1990, with an effective date of August 17, 1990, and supersedes all previous editions.

The 1990 edition of this document has been approved by the American National Standards Institute.

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

Origin and Development of NFPA 30

From 1913 to 1957, this standard was written in the form of a municipal ordinance known as the *Suggested Ordinance for the Storage, Handling and Use of Flammable Liquids*. In 1957, the format was changed from a municipal ordinance to a Code, although the technical provisions were retained. During the 71-year existence of this suggested ordinance and code, numerous editions have been published as conditions and experiences have dictated.

Recent editions of NFPA 30 include 1977, 1981, 1984, 1987, and this 1990 edition. In 1984, the chapter on automotive and marine service stations was removed from NFPA 30 and rewritten as an individual code, NFPA 30A, *Automotive and Marine Service Station Code*. In 1987, Chapter 5 (Industrial Plants), Chapter 6 (Bulk Plants and Terminals), Chapter 7 (Processing Plants), and Chapter 8 (Refineries, Chemical Plants, and Distilleries) were combined into a single chapter entitled "Operations."

This 1990 edition incorporates the following major changes:

- Addition of a Statement of Equivalency (1-1.5).
- Elimination of all references to flammable aerosols (now covered by NFPA 30B, *Code for the Manufacture and Storage of Aerosol Products*).
- Guidance on abandonment and reuse of storage tanks (2-3.8).
- Security requirements for tanks in unsupervised areas (2-9.3).
- Overfill protection for underground tanks (2-10.3).
- Liquidtightness of tanks (2-8.6) and piping (3-2.2).
- Criteria for plastic containers (4-2.1).
- Clarification of allowable portable tank construction, i.e., metal only (4-2.1, Table 4-2.3).

- Construction, use, and siting of hazardous materials storage lockers (4-4.1, new Section 4-9).
- Revised requirements for storage of Class I and Class II liquids in plastic containers in general purpose warehouses (4-5.6.4).
- Drainage systems for liquid warehouses (4-5.7.14).
- More detailed guidance for ventilation of process areas and estimation of quantity of fugitive emissions (5-3.3.1 and Appendix F).

NOTICE

Following release by the NFPA Standards Council of this 1990 edition of NFPA 30, *Flammable and Combustible Liquids Code*, an appeal was filed with the NFPA Board of Directors.

The appeal requests that the effective date of 4-5.6.4 be changed to September 1, 1990 and that an exception be added allowing Class I and II corrosive flammable liquids of 1 gallon or less in plastic containers to be stored in general purpose warehouses until September 1, 1991.

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

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

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

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NFPA 30

Flammable and Combustible Liquids Code

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

Information on referenced publications can be found in Chapter 6 and Appendix G.

Foreword

This standard, known as the *Flammable and Combustible Liquids Code*, is recommended for use as the basis of legal regulations. Its provisions are intended to reduce the hazard to a degree consistent with reasonable public safety, without undue interference with public convenience and necessity that require the use of flammable and combustible liquids. Thus, compliance with this standard does not eliminate all hazards in the use of flammable and combustible liquids. (*See the Flammable and Combustible Liquids Code Handbook for additional explanatory information.*)

Chapter 1 General Provisions

1-1 Scope and Application.

1-1.1 This code applies to all flammable and combustible liquids, including waste liquids, except those that are solid at 100°F (37.8°C) or above and those that are liquefied gases or cryogenic liquids.

1-1.2 Requirements for the safe storage and use of the great variety of flammable and combustible liquids commonly available depend primarily on their fire characteristics, particularly the flash point, which is the basis for the several classifications of liquids as defined in Section 1-2. It should be noted that the classification of a liquid can be changed by contamination. For example, placing a Class II liquid into a tank that last contained a Class I liquid can alter its classification, as can exposing a Class II liquid to the vapors of a Class I liquid via an interconnecting vapor line (*see 2-3.6.4 and 2-4.5.6*). Care shall be exercised in such cases to apply the requirements appropriate to the actual classification. (NFPA 325M, *Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*, contains flash point and other fire hazard data. NFPA 49, *Hazardous Chemicals Data*, and NFPA 321, *Standard on Basic Classification of Flammable and Combustible Liquids*, also contain information regarding this subject.)

1-1.3 The volatility of liquids is increased by heating. When Class II or Class III liquids are exposed to storage conditions, use conditions, or process operations where they are naturally or artificially heated to or above their flash points, additional requirements may be necessary. These requirements include consideration for such items as ventilation, exposure to ignition sources, diking, and electrical area classification.

1-1.4 Additional requirements may be necessary for the safe storage and use of liquids that have unusual burning characteristics, that are subject to self-ignition when exposed to the air, that are highly reactive with other substances, that are subject to explosive decomposition, or that have other special properties that dictate safeguards over and above those specified for a normal liquid of similar flash point classification.

1-1.5 Equivalency.

1-1.5.1 Nothing in this code is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this code, provided technical documentation is submitted to the authority having jurisdiction to demonstrate equivalency and the system, method, or device is approved for the intended purpose.

1-1.5.2 In certain installations the provisions of this code may be altered at the discretion of the authority having jurisdiction after consideration of special features such as topographical conditions, barricades, walls, adequacy of building exits, nature of occupancies, proximity to buildings or adjoining property, and character of construction of such buildings, capacity and construction of proposed tanks, and character of liquids to be stored, the nature of the process, the degree of private fire protection to be provided, and the adequacy of the facilities of the fire department to cope with flammable or combustible liquid fires.

1-1.5.3 Other regulations, such as for environmental protection, may impose requirements that are not anticipated by this code. Where acceptable to the authority having jurisdiction, alternate arrangements affording protection at least equivalent to that required by this code may be used.

1-1.6 Existing plants, equipment, buildings, structures, and installations for the storage, handling, or use of flammable or combustible liquids that are not in strict compliance with the terms of this code may be continued in use at the discretion of the authority having jurisdiction provided they do not constitute a recognized hazard to life or adjoining property. The existence of a situation that might result in an explosion or sudden escalation of a fire, such as inadequate ventilation of confined spaces, lack of adequate emergency venting of a tank, failure to fireproof the supports of elevated tanks, or lack of drainage or dikes to control spills, may constitute such a hazard.

1-1.7 This code shall not apply to:

1-1.7.1 Transportation of flammable and combustible liquids. These requirements are contained in the U.S. Department of Transportation regulations or in NFPA 385, *Standard for Tank Vehicles for Flammable and Combustible Liquids*.

1-1.7.2 Storage, handling, and use of fuel oil tanks and containers connected with oil burning equipment. These requirements are covered separately in NFPA 31, *Standard for the Installation of Oil Burning Equipment*.

1-1.7.3 Liquefied gases. (*See definition.*)

1-1.7.4 Cryogenic liquids. (*See definition.*)

1-1.7.5 Storage of flammable and combustible liquids on farms and isolated construction projects. These requirements are covered separately in NFPA 395, *Standard for the Storage of Flammable and Combustible Liquids on Farms and Isolated Construction Projects.*

1-1.7.6 Liquids without flash points that can be flammable under some conditions, such as certain halogenated hydrocarbons and mixtures containing halogenated hydrocarbons. (*See NFPA 321, Standard on Basic Classification of Flammable and Combustible Liquids.*)

1-1.7.7 Storage and handling of aerosol products. These requirements are covered separately in NFPA 30B, *Code for the Manufacture and Storage of Aerosol Products.*

1-1.7.8 Mists, sprays, or foams.

1-1.8 Installations made in accordance with the applicable requirements of standards of the National Fire Protection Association: NFPA 30A, *Automatic and Marine Service Station Code*, NFPA 32, *Standard for Drycleaning Plants*; NFPA 33, *Standard for Spray Application Using Flammable and Combustible Materials*; NFPA 34, *Standard for Dipping and Coating Processes Using Flammable or Combustible Liquids*; NFPA 35, *Standard for the Manufacture of Organic Coatings*; NFPA 36, *Standard for Solvent Extraction Plants*; NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*; NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*; and Chapter 10 of NFPA 99, *Standard for Health Care Facilities*, shall be deemed to be in compliance with this code.

1-1.9 Metrication. If a value for measurement as given in this standard is followed by an equivalent value in other units, the first stated is regarded as the requirement. The given equivalent value may be approximate.

1-2 Definitions.

Apartment House. A building or that portion of a building containing more than two dwelling units.

Approved. Acceptable to the "authority having jurisdiction."

NOTE: The National Fire Protection Association does not approve, inspect or certify any installations, procedures, equipment, or material 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.

Assembly Occupancy. All buildings or portions of buildings used for gathering 50 or more persons for such purposes as deliberation, worship, entertainment, dining, amusement, or awaiting transportation.

Atmospheric Tank. A storage tank that has been designed to operate at pressures from atmospheric through 0.5 psig (760 mm Hg through 786 mm Hg) measured at the top of the tank.

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."

Barrel. A volume of 42 U.S. gal (158.9 L).

Basement. A story of a building or structure having $1/2$ or more of its height below ground level and to which access for fire fighting purposes is unduly restricted.

Boiling Point. The temperature at which a liquid exerts a vapor pressure of 14.7 psia (760 mm Hg). Where an accurate boiling point is unavailable for the material in question, or for mixtures that do not have a constant boiling point, for purposes of this code the 10 percent point of a distillation performed in accordance with ASTM D 86-82, *Standard Method of Test for Distillation of Petroleum Products*, may be used as the boiling point of the liquid.

Boil-Over. An event in the burning of certain oils in an open top tank when, after a long period of quiescent burning, there is a sudden increase in fire intensity associated with expulsion of burning oil from the tank. Boil-over occurs when the residues from surface burning become more dense than the unburned oil and sink below the surface to form a hot layer, which progresses downward much faster than the regression of the liquid surface. When this hot layer, called a "heat wave," reaches water or water-in-oil emulsion in the bottom of the tank, the water is first superheated and subsequently boils almost explosively, overflowing the tank. Oils subject to boil-over consist of components having a wide range of boiling points, including both light ends and viscous residues. These characteristics are present in most crude oils and can be produced in synthetic mixtures.

NOTE: A boil-over is an entirely different phenomenon from a slop-over or froth-over. Slop-over involves a minor frothing that occurs when water is sprayed onto the hot

surface of a burning oil. Froth-over is not associated with a fire but results when water is present or enters a tank containing hot viscous oil. Upon mixing, the sudden conversion of water to steam causes a portion of the tank contents to overflow.

Bulk Plant or Terminal. That portion of a property where liquids are received by tank vessel, pipelines, tank car, or tank vehicle and are stored or blended in bulk for the purpose of distributing such liquids by tank vessel, pipeline, tank car, tank vehicle, portable tank, or container.

Chemical Plant. A large integrated plant or that portion of such a plant other than a refinery or distillery where liquids are produced by chemical reactions or used in chemical reactions.

Closed Container. A container as herein defined, so sealed by means of a lid or other device that neither liquid nor vapor will escape from it at ordinary temperatures.

Combustible Liquids. (*See Liquid.*)

Container. Any vessel of 60 U.S. gal (227 L) or less capacity used for transporting or storing liquids.

Crude Petroleum. Hydrocarbon mixtures that have a flash point below 150°F (65.6°C) and that have not been processed in a refinery.

Cryogenic Liquid. A refrigerated liquid gas having a boiling point below −130°F (−90°C) at atmospheric pressure.

Distillery. A plant or that portion of a plant where liquids produced by fermentation are concentrated and where the concentrated products may also be mixed, stored, or packaged.

Dwelling. A building occupied exclusively for residence purposes and having not more than two dwelling units or as a boarding or rooming house serving not more than 15 persons with meals or sleeping accommodations or both.

Dwelling Unit. One or more rooms arranged for the use of one or more individuals living together as a single housekeeping unit, with cooking, living, sanitary, and sleeping facilities.

Educational Occupancy. The occupancy or use of a building or structure or any portion thereof by persons assembled for the purpose of learning or of receiving educational instruction.

Fire Area. An area of a building separated from the remainder of the building by construction having a fire resistance of at least 1 hr and having all communicating openings properly protected by an assembly having a fire resistance rating of at least 1 hr.

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 procedure and apparatus as follows:

(a) The flash point of a liquid having a viscosity less than 45 SUS at 100°F (37.8°C) and a flash point below 200°F (93°C) shall be determined in accordance with ASTM D 56, *Standard Method of Test for Flash Point by the Tag Closed Cup Tester.*

(b) The flash point of a liquid having a viscosity of 45 SUS or more at 100°F (37.8°C) or a flash point of 200°F (93°C) or higher shall be determined in accordance with ASTM D 93, *Standard Method of Test for Flash Point by the Pensky-Martens Closed Tester.*

(c) As an alternate, ASTM D 3278, *Standard Method of Tests for Flash Point of Liquids by Setaflash Closed Tester,* may be used for paints, enamels, lacquers, varnishes, and related products and their components having flash points between 32°F (0°C) and 230°F (110°C) and having a viscosity lower than 150 stokes at 77°F (25°C).

(d) As an alternate, ASTM D 3828, *Standard Test Methods for Flash Point by Setaflash Closed Tester,* may be used for materials other than those for which specific Setaflash Methods exist.

Fugitive Emissions. Releases of flammable vapor that continuously occur from process equipment during normal operations. These include leaks from pump seals, valve packing, flange gaskets, compressor seals, process drains, etc.

Hazardous Material or Hazardous Chemical. Material presenting dangers beyond the fire problems relating to flash point and boiling point. These dangers may arise from but are not limited to toxicity, reactivity, instability, or corrosivity.

Hazardous Materials Storage Locker. A relocatable prefabricated structure, manufactured primarily at a site other than the final location of the structure and transported completely assembled or in a ready-to-assemble package to the final location. It is intended to meet local, state, and federal requirements for outside storage of hazardous materials.

Hazardous Reaction or Hazardous Chemical Reaction. Reactions that result in dangers beyond the fire problems relating to flash point and boiling point of either the reactants or of the products. These dangers may include but are not limited to toxic effects, reaction speed (including detonation), exothermic reaction, or production of unstable or reactive materials.

Hotel. Buildings or groups of buildings under the same management in which there are sleeping accommodations for hire, primarily used by transients who are lodged with or without meals, including but not limited to inns, clubs, motels, and apartment hotels.

Incidental Liquid Use or Storage. Use or storage as a subordinate activity to that which established the occupancy or area classification.

Institutional Occupancy. The occupancy or use of a building or structure or any portion thereof by persons harbored or detained to receive medical, charitable, or other care or treatment or by persons involuntarily detained.

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.

Liquefied Gas. A gas that, under its charged pressure, is partially liquid at 70°F (21°C).

Liquid. For the purpose of this code, any material that has a fluidity greater than that of 300 penetration asphalt when tested in accordance with ASTM D 5, *Test for Penetration for Bituminous Materials*. **When not otherwise identified, the term *liquid* shall mean both flammable and combustible liquids.**

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°C).

Class IIIB liquids shall include those having flash points at or above 200°F (93°C).

Flammable Liquid. A liquid having a flash point below 100°F (37.8°C) and having a vapor pressure not exceeding 40 psia (2 068 mm Hg) at 100°F (37.8°C) shall be known as a 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).

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.

Low-Pressure Tank. A storage tank designed to withstand an internal pressure above 0.5 psig (3.5 kPa) but not more than 15 psig (103.4 kPa) measured at the top of the tank.

Mercantile Occupancy. The occupancy or use of a building or structure or any portion thereof for the displaying, selling, or buying of goods, wares, or merchandise.

Occupancy Classification. The system of defining the predominant operating characteristic of a portion of a building or plant for purposes of applying relevant sections of this code. This may include but is not limited to distillation, oxidation, cracking, and polymerization.

Office Occupancy. The occupancy or use of a building or structure or any portion thereof for the transaction of business or the rendering or receiving of professional services.

Operating Unit (Vessel) or Process Unit (Vessel). The equipment in which a unit operation or unit process is conducted. (*See also definition of "Unit Operation or Unit Process."*)

Operations. A general term that includes but is not limited to the use, transfer, storage, and processing of liquids.

Outdoor Occupancy Classification. Similar to occupancy classification except that it applies to outdoor operations not enclosed in a building or shelter.

Portable Tank. Any closed vessel having a liquid capacity over 60 U.S. gallons (227 L) and not intended for fixed installation.

Pressure Vessel. Any fired or unfired vessel within the scope of the applicable section of the ASME *Boiler and Pressure Vessel Code*.

Process or Processing. An integrated sequence of operations. The sequence may be inclusive of both physical and chemical operations, unless the term is modified to restrict it to one or the other. The sequence may involve, but is not limited to, preparation, separation, purification, or change in state, energy content, or composition.

Protection for Exposures. Fire protection for structures on property adjacent to liquid storage. Fire protection for such structures shall be acceptable when located either within the jurisdiction of any public fire department or adjacent to plants having private fire brigades capable of providing cooling water streams on structures on property adjacent to liquid storage.

Refinery. A plant in which flammable or combustible liquids are produced on a commercial scale from crude petroleum, natural gasoline, or other hydrocarbon sources.

Safety Can. An approved container, of not more than 5 gal (18.9 L) capacity, having a spring-closing lid and spout cover and so designed that it will safely relieve internal pressure when subjected to fire exposure.

Secondary Containment Tank. A tank having an inner and outer wall with an interstitial space (annulus) between and having means for monitoring the interstitial space for a leak in either wall. Secondary containment tanks are of either Type I or Type II construction.

Type I. A primary tank wrapped by an exterior shell that is in direct contact with it. The exterior shell may or may not wrap the full 360 degree circumference of the primary tank.

Type II. A primary tank wrapped by an exterior shell that is physically separated from it by stand-offs and wraps the full 360 degree circumference of the primary tank.

Separate Inside Storage Area. A room or building used for the storage of liquids in containers or portable tanks, separated from other types of occupancies. Such areas may include:

Inside Room. A room totally enclosed within a building and having no exterior walls.

Cut-Off Room. A room within a building and having at least one exterior wall.

Attached Building. A building having only one common wall with another building having other types of occupancies.

Service Stations.

Automotive Service Station. That portion of a property where liquids used as motor fuels are stored and dispensed from fixed equipment into the fuel tanks of motor vehicles and shall include any facilities available for the sale and service of tires, batteries, and accessories and for minor automotive maintenance work. Major automotive repairs, painting, and body and fender work are excluded.

Marine Service Station. That portion of a property where liquids used as fuels are stored and dispensed from fixed equipment on shore, piers, wharves, or floating docks into the fuel tanks of self-propelled craft, including all facilities used in connection therewith.

Service Station Located inside Buildings. That portion of an automotive service station located within the perimeter of a building or building structure that also contains other occupancies. The service station may be enclosed or partially enclosed by the building walls, floors, ceilings, or partitions or may be open to the outside. The service station dispensing area shall mean that area of the service station required for dispensing of fuels to motor vehicles. Dispensing of fuel at manufacturing, assembly, and testing operations is not included within this definition.

Stable Liquid. Any liquid not defined as unstable.

Storage Tank. Any vessel having a liquid capacity exceeding 60 gal (227 L) and intended for fixed installation.

Unit Operation or Unit Process. A segment of a physical or chemical process that may or may not be integrated with other segments to constitute the manufacturing sequence.

Unstable Liquid. A liquid that, in the pure state or as commercially produced or transported, will vigorously polymerize, decompose, undergo condensation reaction, or become self-reactive under conditions of shock, pressure, or temperature.

Vapor Pressure. The pressure, measured in psia, exerted by a volatile liquid as determined by ASTM D 323, *Standard Method of Test for Vapor Pressure of Petroleum Products (Reid Method).*

Vapor Processing Equipment. Those components of a vapor processing system designed to process vapors or liquids captured during filling operations at service stations, bulk plants, or terminals.

Vapor Processing System. A system designed to capture and process vapors displaced during filling operations at service stations, bulk plants, or terminals by use of mechanical and/or chemical means. Examples are systems using blower-assist for capturing vapors and refrigeration, absorption, and combustion systems for processing vapors.

Vapor Recovery System. A system designed to capture and retain, without processing, vapors displaced during filling operations at service stations, bulk plants, or terminals. Examples are balanced-pressure vapor displacement systems and vacuum-assist systems without vapor processing.

Ventilation. As specified in this code, ventilation is for the prevention of fire and explosion. It is considered adequate if it is sufficient to prevent accumulation of significant quantities of vapor-air mixtures in concentrations over one-fourth of the lower flammable limit.

Warehouses.

General-Purpose Warehouse. A separate, detached building or portion of a building used only for warehousing-type operations.

NOTE: Warehousing operations referred to above are those operations not accessible to the public and include general purpose, merchandise, distribution, and industrial warehouse-type operations.

Liquid Warehouse. A separate, detached building or attached building used for warehousing-type operations for liquids.

Wharf. Any dock, pier, bulkhead, or other structure over or contiguous to navigable water with direct physical access from land, the primary function of which is the transfer of liquid cargo in bulk between shore installations and any tank vessel, such as a ship, barge, lighter boat, or other mobile floating craft.

1-3 Storage. Liquids shall be stored in tanks or in containers in accordance with Chapter 2 or Chapter 4.

1-4 Pressure Vessel. All new pressure vessels containing liquids shall comply with 1-4.1, 1-4.2, or 1-4.3, as applicable.

1-4.1 Fired pressure vessels shall be designed and constructed in accordance with Section I (Power Boilers), or Section VIII, Division 1 or Division 2 (Pressure Vessels), as applicable, of the ASME *Boiler and Pressure Vessel Code.*

1-4.2 Unfired pressure vessels shall be designed and constructed in accordance with Section VIII, Division 1 or Division 2, of the ASME *Boiler and Pressure Vessel Code.*

1-4.3 Fired and unfired pressure vessels that do not conform to 1-4.1 or 1-4.2 may be used provided approval has been obtained from the state or other governmental jurisdiction in which they are to be used. Such pressure vessels are generally referred to as "State Special."

1-5 Exits. Egress from buildings and areas covered by this code shall be in accordance with NFPA *101,® Life Safety Code.®*

Chapter 2 Tank Storage

2-1 Scope. This chapter shall apply to aboveground, underground, and inside storage of liquids in fixed tanks and in portable tanks whose capacity exceeds 660 gal (2500 L).

2-2 Design and Construction of Tanks.

2-2.1 Materials. Tanks shall be designed and built in accordance with recognized good engineering standards for the material of construction being used and shall be of steel or approved noncombustible material, with the following limitations and exceptions:

(a) The material of tank construction shall be compatible with the liquid to be stored. In case of doubt about the properties of the liquid to be stored, the supplier, producer of the liquid, or other competent authority shall be consulted.

(b) Tanks constructed of combustible materials shall be subject to the approval of the authority having jurisdiction and limited to:

1. Installation underground, or

2. Use where required by the properties of the liquid stored, or

3. Storage of Class IIIB liquids aboveground in areas not exposed to a spill or leak of Class I or Class II liquid, or

4. Storage of Class IIIB liquids inside a building protected by an approved automatic fire extinguishing system.

(c) Unlined concrete tanks may be used for storing liquids having a gravity of 40 degrees API or heavier. Concrete tanks with special linings may be used for other services provided the design is in accordance with sound engineering practice.

(d) Tanks may have combustible or noncombustible linings. The choice of a suitable protective lining shall depend upon the properties of the liquid stored.

(e) Special engineering consideration may be required if the specific gravity of the liquid to be stored exceeds that of water or if the tank is designed to contain liquids at a liquid temperature below 0°F (-17.8°C).

2-2.2 Fabrication.

2-2.2.1 Tanks may be of any shape or type consistent with sound engineering design.

2-2.2.2 Metal tanks shall be welded, riveted, and caulked, or bolted, or constructed by use of a combination of these methods.

2-2.3 Atmospheric Tanks.

2-2.3.1 Atmospheric tanks, including those incorporating secondary containment, shall be built in accordance with recognized standards of design *or* approved equivalents. Atmospheric tanks shall be built, installed, and used within the scopes of their approvals or within the scopes of any of the following:

(a) Underwriters Laboratories Inc., *Standard for Steel Aboveground Tanks for Flammable and Combustible Liquids*, UL 142; *Standard for Steel Underground Tanks for Flammable and Combustible Liquids*, UL 58; or *Standard for Steel Inside Tanks for Oil Burner Fuel*, UL 80.

(b) American Petroleum Institute Standard No. 650, *Welded Steel Tanks for Oil Storage*, Sixth Edition.

(c) American Petroleum Institute Specifications 12B, *Bolted Tanks for Storage of Production Liquids*, Twelfth Edition; 12D, *Field Welded Tanks for Storage of Production Liquids*, Eighth Edition; or 12F, *Shop Welded Tanks for Storage of Production Liquids*, Seventh Edition.

(d) American Society for Testing and Materials, *Standard Specification for Glass-Fiber Reinforced Polyester Underground Petroleum Storage Tanks*, ASTM D 4021.

(e) Underwriters Laboratories Inc., *Standard for Glass-Fiber Reinforced Plastic Underground Storage Tanks for Petroleum Products*, UL 1316.

2-2.3.2 Low-pressure tanks and pressure vessels may be used as atmospheric tanks.

2-2.3.3 Atmospheric tanks shall not be used for the storage of a liquid at a temperature at or above its boiling point.

2-2.4 Low-Pressure Tanks.

2-2.4.1 The normal operating pressure of the tank shall not exceed the design pressure of the tank.

2-2.4.2 Low-pressure tanks shall be built in accordance with recognized standards of design. Low-pressure tanks may be built in accordance with:

(a) American Petroleum Institute Standard No. 620, *Recommended Rules for the Design and Construction of Large, Welded, Low-Pressure Storage Tanks*, Fifth Edition.

(b) The principles of the *Code for Unfired Pressure Vessels*, Section VIII, Division I of the ASME *Boiler and Pressure Vessel Code*.

2-2.4.3 Tanks built according to Underwriters Laboratories Inc. requirements in 2-2.3.1 may be used for operating pressures not exceeding 1 psig (6.9 kPa) and shall be limited to 2.5 psig (17.2 kPa) under emergency venting conditions.

2-2.4.4 Pressure vessels may be used as low-pressure tanks.

2-2.5 Pressure Vessels.

2-2.5.1 The normal operating pressure of the vessel shall not exceed the design pressure of the vessel.

2-2.5.2 Storage tanks designed to withstand pressures above 15 psig (103.4 kPa) shall meet the requirements of Section 1-4.

2-2.6 Provisions for Internal Corrosion. When tanks are not designed in accordance with the American Petroleum Institute, American Society of Mechanical Engineers, or the Underwriters Laboratories Inc. Standards, or if corrosion is anticipated beyond that provided for in the design formulas used, additional metal thickness or suitable protective coatings or linings shall be provided to compensate for the corrosion loss expected during the design life of the tank.

2-3 Installation of Outside Aboveground Tanks.

2-3.1 Location with Respect to Property Lines, Public Ways, and Important Buildings on the Same Property.

2-3.1.1 Every aboveground tank for the storage of Class I, Class II, or Class IIIA liquids (except as provided in 2-3.1.2), and those liquids with boil-over characteristics and unstable liquids, operating at pressures not in excess of 2.5 psig (17.2 kPa) and designed with a weak roof-to-shell seam (*see 2-3.5.3*), or equipped with emergency venting devices that will not permit pressures to exceed 2.5 psig (17.2 kPa), shall be located in accordance with Table 2-1. Where tank spacing is contingent on a weak roof-to-shell seam design, the user shall present evidence certifying such construction to the authority having jurisdiction, upon request.

(a) For the purpose of Section 2-3, a floating roof tank is defined as one that incorporates either:

1. A pontoon or double-deck metal floating roof in an open-top tank in accordance with API Standard 650, or

2. A fixed metal roof with ventilation at the top and roof eaves in accordance with API Standard 650 and containing a metal floating roof or cover meeting any one of the following requirements:

a. A pontoon or double-deck metal floating roof meeting the requirements of API Standard 650.

b. A metal floating cover supported by liquidtight metal floating devices that provide sufficient buoyancy to prevent the liquid surface from being exposed when half of the flotation is lost.

(b) An internal metal floating pan, roof, or cover that does not meet the requirements of (a) 2., or one that uses plastic foam (except for seals) for flotation, even if encapsulated in metal or fiberglass, shall be considered a fixed roof tank.

2-3.1.2 Vertical tanks having a weak roof-to-shell seam (*see 2-3.5.3*) and storing Class IIIA liquids may be located at one-half the distances specified in Table 2-1, provided the tanks are not within a diked area or drainage path for a tank storing a Class I or Class II liquid.

2-3.1.3 Every aboveground tank for the storage of Class I, Class II, or Class IIIA liquids, except those liquids with boil-over characteristics and unstable liquids, operating at pressures exceeding 2.5 psig (17.2 kPa) or equipped with emergency venting that will permit pressures to exceed 2.5 psig (17.2 kPa), shall be located in accordance with Table 2-2.

Table 2-1 Stable Liquids [Operating Pressure 2.5 psig (17.2 kPa) or Less]

Type of Tank	Protection	Minimum Distance in Feet from Property Line that Is or Can Be Built Upon, Including the Opposite Side of a Public Way and Shall Be Not Less than 5 Feet	Minimum Distance in Feet from Nearest Side of Any Public Way or from Nearest Important Building on the Same Property and Shall Be Not Less than 5 Feet
Floating Roof [See 2-3.1.1(a)]	Protection for Exposures*	1/2 times diameter of tank	1/6 times diameter of tank
	None	Diameter of tank but need not exceed 175 feet	1/6 times diameter of tank
Vertical with Weak Roof-to-Shell Seam (See 2-3.5.3)	Approved foam or inerting system** on tanks not exceeding 150 feet in diameter***	1/2 times diameter of tank	1/6 times diameter of tank
	Protection for Exposures*	Diameter of tank	1/3 times diameter of tank
	None	2 times diameter of tank but need not exceed 350 feet	1/3 times diameter of tank
Horizontal and Vertical with Emergency Relief Venting to Limit Pressures to 2.5 psig	Approved inerting system** on the tank or approved foam system on vertical tanks	1/2 times Table 2-6	1/2 times Table 2-6
	Protection for Exposures*	Table 2-6	Table 2-6
	None	2 times Table 2-6	Table 2-6

* See definition of "Protection for Exposures."
**See NFPA 69, *Standard on Explosion Prevention Systems*.
***For tanks over 150 ft in diameter, use "Protection for Exposures" or "None," as applicable.
SI Units: 1 ft = 0.30 m.

2-3.1.4 Every aboveground tank for storage of liquids with boil-over characteristics shall be located in accordance with Table 2-3. Liquids with boil-over characteristics shall not be stored in fixed roof tanks larger than 150 ft (45.7 m) in diameter, unless an approved inerting system is provided on the tank.

2-3.1.5 Every aboveground tank for the storage of unstable liquids shall be located in accordance with Table 2-4.

2-3.1.6 Every aboveground tank for the storage of Class IIIB liquids, excluding unstable liquids, shall be located in accordance with Table 2-5, except when located within a diked area or drainage path for a tank(s) storing a Class I or Class II liquid. When a Class IIIB liquid storage tank is within the diked area or drainage path for a Class I or Class II liquid, 2-3.1.1 or 2-3.1.2 shall apply.

2-3.1.7 Where two tank properties of diverse ownership have a common boundary, the authority having jurisdiction may, with the written consent of the owners of the two properties, substitute the distances provided in 2-3.2.1 through 2-3.2.6 for the minimum distances set forth in 2-3.1.

2-3.1.8 Where end failure of horizontal pressure tanks and vessels can expose property, the tank shall be placed with the longitudinal axis parallel to the nearest important exposure.

2-3.2 Spacing (Shell-to-Shell) between Any Two Adjacent Aboveground Tanks.

2-3.2.1 Tanks storing Class I, II, or IIIA stable liquids shall be separated in accordance with Table 2-7, except as provided in 2-3.2.2.

Table 2-2 Stable Liquids [Operating Pressure Greater than 2.5 psig (17.2 kPa)]

Type of Tank	Protection	Minimum Distance in Feet from Property Line that Is or Can Be Built Upon, Including the Opposite Side of a Public Way	Minimum Distance in Feet from Nearest Side of Any Public Way or from Nearest Important Building on the Same Property
Any Type	Protection for Exposures*	1½ times Table 2-6 but shall not be less than 25 feet	1½ times Table 2-6 but shall not be less than 25 feet
	None	3 times Table 2-6 but shall not be less than 50 feet	1½ times Table 2-6 but shall not be less than 25 feet

* See definition of "Protection for Exposures."
SI Units: 1 ft = 0.30 m.

Table 2-3 Boil-Over Liquids

Type of Tank	Protection	Minimum Distance in Feet from Property Line that Is or Can Be Built Upon, Including the Opposite Side of a Public Way, and Shall Be Not Less than 5 Feet	Minimum Distance in Feet from Nearest Side of Any Public Way or from Nearest Important Building on the Same Property and Shall Be Not Less than 5 Feet
Floating Roof [See 2-3.1.1(a)]	Protection for Exposures*	½ times diameter of tank	⅙ times diameter of tank
	None	Diameter of tank	⅙ times diameter of tank
Fixed Roof (See 2-3.1.4)	Approved foam or inerting system**	Diameter of tank	⅓ times diameter of tank
	Protection for Exposures*	2 times diameter of tank	⅔ times diameter of tank
	None	4 times diameter of tank but need not exceed 350 feet	⅔ times diameter of tank

*See definition of "Protection for Exposures."
**See NFPA 69, *Standard on Explosion Prevention Systems.*
SI Units: 1 ft = 0.30 m.

Table 2-4 Unstable Liquids

Type of Tank	Protection	Minimum Distance in Feet from Property Line that Is or Can Be Built Upon, Including the Opposite Side of a Public Way	Minimum Distance in Feet from Nearest Side of Any Public Way or from Nearest Important Building on the Same Property
Horizontal and Vertical Tanks with Emergency Relief Venting to Permit Pressure Not in Excess of 2.5 psig	Tank protected with any one of the following: Approved water spray, Approved inerting,* Approved insulation and refrigeration, Approved barricade	Table 2-6 but not less than 25 feet	Not less than 25 feet
	Protection for Exposures**	2½ times Table 2-6 but not less than 50 feet	Not less than 50 feet
	None	5 times Table 2-6 but not less than 100 feet	Not less than 100 feet
Horizontal and Vertical Tanks with Emergency Relief Venting to Permit Pressure over 2.5 psig	Tank protected with any one of the following: Approved water spray, Approved inerting,* Approved insulation and refrigeration, Approved barricade	2 times Table 2-6 but not less than 50 feet	Not less than 50 feet
	Protection for Exposures**	4 times Table 2-6 but not less than 100 feet	Not less than 100 feet
	None	8 times Table 2-6 but not less than 150 feet	Not less than 150 feet

* See NFPA 69, *Standard on Explosion Prevention Systems.*
** See definition of "Protection for Exposures."
SI Units: 1 ft = 0.30 m.

Table 2-5 Class IIIB Liquids

Capacity Gallons	Minimum Distance in Feet from Property Line that Is or Can Be Built Upon, Including the Opposite Side of a Public Way	Minimum Distance in Feet from Nearest Side of Any Public Way or from Nearest Important Building on the Same Property
12,000 or less	5	5
12,001 to 30,000	10	5
30,001 to 50,000	10	10
50,001 to 100,000	15	10
100,001 or more	15	15

SI Units: 1 ft = 0.30 m; 1 gal = 3.8 L.

Table 2-6 Reference Table for Use in Tables 2-1 to 2-4

Capacity Tank Gallons	Minimum Distance in Feet from Property Line that Is or Can Be Built Upon, Including the Opposite Side of a Public Way	Minimum Distance in Feet from Nearest Side of Any Public Way or from Nearest Important Building on the Same Property
275 or less	5	5
276 to 750	10	5
751 to 12,000	15	5
12,001 to 30,000	20	5
30,001 to 50,000	30	10
50,001 to 100,000	50	15
100,001 to 500,000	80	25
500,001 to 1,000,000	100	35
1,000,001 to 2,000,000	135	45
2,000,001 to 3,000,000	165	55
3,000,001 or more	175	60

SI Units: 1 ft = 0.30 m; 1 gal = 3.8 L.

Table 2-7 Minimum Tank Spacing (Shell-to-Shell)

		Fixed or Horizontal Tanks	
	Floating Roof Tanks	**Class I or II Liquids**	**Class IIIA Liquids**
All tanks not over 150 feet in diameter	1/6 sum of adjacent tank diameters but not less than 3 feet	1/6 sum of adjacent tank diameters but not less than 3 feet	1/6 sum of adjacent tank diameters but not less than 3 feet
Tanks larger than 150 feet in diameter			
If remote impounding is in accordance with 2-3.3.2	1/6 sum of adjacent tank diameters	1/4 sum of adjacent tank diameters	1/6 sum of adjacent tank diameters
If impounding is around tanks in accordance with 2-3.3.3	1/4 sum of adjacent tank diameters	1/3 sum of adjacent tank diameters	1/4 sum of adjacent tank diameters

SI Units: 1 ft = 0.30 m.

2-3.2.2 Crude petroleum tanks having individual capacities not exceeding 126,000 gal (3,000 barrels), when located at production facilities in isolated locations, need not be separated by more than 3 ft (0.90 m).

2-3.2.3 Tanks used only for storing Class IIIB liquids may be spaced no less than 3 ft (0.90 m) apart unless within a diked area or drainage path for a tank storing a Class I or II liquid, in which case the provisions of Table 2-7 apply.

2-3.2.4 For unstable liquids, the distance between such tanks shall not be less than one-half the sum of their diameters.

2-3.2.5 When tanks are in a diked area containing Class I or Class II liquids, or in the drainage path of Class I or Class II liquids, and are compacted in three or more rows or in an irregular pattern, greater spacing or other means may be required by the authority having jurisdiction to make tanks in the interior of the pattern accessible for fire fighting purposes.

2-3.2.6 The minimum horizontal separation between an LP-Gas container and a Class I, Class II, or Class IIIA liquid storage tank shall be 20 ft (6 m), except in the case of a Class I, Class II, or Class IIIA liquid tank operating at pressures exceeding 2.5 psig (17.2 kPa) or equipped with emergency venting that will permit pressures to exceed 2.5 psig (17.2 kPa), in which case the provisions of 2-3.2.1 and 2-3.2.2 shall apply. Suitable measures shall be taken to prevent the accumulation of Class I, Class II, or Class IIIA liquids under adjacent LP-Gas containers such as by dikes, diversion curbs, or grading. When flammable or combustible liquid storage tanks are within a diked area, the LP-Gas containers shall be outside the diked area and at least 10 ft (3 m) away from the centerline of the wall of the diked area. The foregoing provisions shall not apply when LP-Gas containers of 125 gal (475 L) or less capacity are installed adjacent to fuel oil supply tanks of 660 gal (2498 L) or less capacity. No horizontal separation is required between aboveground LP-Gas containers and underground flammable and combustible liquid tanks installed in accordance with Section 2-4.

2-3.3 Control of Spillage from Aboveground Tanks.

2-3.3.1 Facilities shall be provided so that any accidental discharge of any Class I, II, or IIIA liquids will be prevented from endangering important facilities, and adjoining property, or reaching waterways, as provided for in 2-3.3.2 or 2-3.3.3. Tanks storing Class IIIB liquids do not require special drainage or diking provisions for fire protection purposes.

2-3.3.2 Remote Impounding. Where protection of adjoining property or waterways is by means of drainage to a remote impounding area, so that impounded liquid will not be held against tanks, such systems shall comply with the following:

(a) A slope of not less than 1 percent away from the tank shall be provided for at least 50 ft (15 m) toward the impounding area.

(b) The impounding area shall have a capacity not less than that of the largest tank that can drain into it.

(c) The route of the drainage system shall be so located that, if the liquids in the drainage system are ignited, the fire will not seriously expose tanks or adjoining property.

(d) The confines of the impounding area shall be located so that, when filled to capacity, the liquid level will not be closer than 50 ft (15 m) from any property line that is or can be built upon, or from any tank.

2-3.3.3 Impounding around Tanks by Diking. When protection of adjoining property or waterways is by means of impounding by diking around the tanks, such system shall comply with the following:

(a) A slope of not less than 1 percent away from the tank shall be provided for at least 50 ft (15 m) or to the dike base, whichever is less.

(b) The volumetric capacity of the diked area shall not be less than the greatest amount of liquid that can be released from the largest tank within the diked area, assuming a full tank. To allow for volume occupied by tanks, the capacity of the diked area enclosing more than one tank shall be calculated after deducting the volume of the tanks, other than the largest tank, below the height of the dike.

(c) To permit access, the outside base of the dike at ground level shall be no closer than 10 ft (3 m) to any property line that is or can be built upon.

(d) Walls of the diked area shall be of earth, steel, concrete, or solid masonry designed to be liquidtight and to withstand a full hydrostatic head. Earthen walls 3 ft (0.90 m) or more in height shall have a flat section at the top not less than 2 ft (0.60 m) wide. The slope of an earthen wall shall be consistent with the angle of repose of the material of which the wall is constructed. Diked areas for tanks containing Class I liquids located in extremely porous soils may require special treatment to prevent seepage of hazardous quantities of liquids to low-lying areas or waterways in case of spills.

(e) Except as provided in (f) below, the walls of the diked area shall be restricted to an average interior height of 6 ft (1.8 m) above interior grade.

(f) Dikes may be higher than an average of 6 ft (1.8 m) above interior grade where provisions are made for normal access and necessary emergency access to tanks, valves, and other equipment, and safe egress from the diked enclosure.

1. Where the average height of the dike containing Class I liquids is over 12 ft (3.6 m) high, measured from interior grade, or where the distance between any tank and the top inside edge of the dike wall is less than the height of the dike wall, provisions shall be made for normal operation of valves and for access to tank roof(s) without entering below the top of the dike. These provisions may be met through the use of remote-operated valves, elevated walkways, or similar arrangements.

2. Piping passing through dike walls shall be designed to prevent excessive stresses as a result of settlement or fire exposure.

3. The minimum distance between tanks and toe of the interior dike walls shall be 5 ft (1.5 m).

(g) Each diked area containing two or more tanks shall be subdivided, preferably by drainage channels or at least by intermediate dikes, in order to prevent spills from endangering adjacent tanks within the diked area as follows:

1. When storing normally stable liquids in vertical cone roof tanks constructed with weak roof-to-shell seam or floating roof tanks, or when storing crude petroleum in producing areas in any type of tank, one subdivision for each tank in excess of 10,000 bbl and one subdivision for each group of tanks (no tank exceeding 10,000 bbl capacity) having an aggregate capacity not exceeding 15,000 bbl.

2. When storing normally stable liquids in tanks not covered in subsection (1), one subdivision for each tank in excess of 2,380 bbl (378 500 L) and one subdivision for each group of tanks [no tank exceeding 2,380 bbl (378 500 L) capacity] having an aggregate capacity not exceeding 3,570 bbl (567 750 L).

3. When storing unstable liquids in any type of tank, one subdivision for each tank except that tanks installed in accordance with the drainage requirements of NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, shall require no additional subdivision. Since unstable liquids will react more rapidly when heated than when at ambient temperatures, subdivision by drainage channels is the preferred method.

4. Whenever two or more tanks storing Class I liquids, any one of which is over 150 ft (45 m) in diameter, are located in a common diked area, intermediate dikes shall be provided between adjacent tanks to hold at least 10 percent of the capacity of the tank so enclosed, not including the volume displaced by the tank.

5. The drainage channels or intermediate dikes shall be located between tanks so as to take full advantage of the available space with due regard for the individual tank capacities. Intermediate dikes, where used, shall be not less than 18 in. (45 cm) in height.

(h) Where provision is made for draining water from diked areas, such drains shall be controlled in a manner so as to prevent flammable or combustible liquids from entering natural water courses, public sewers, or public drains, if their presence would constitute a hazard. Control of drainage shall be accessible under fire conditions from outside the dike.

(i) Storage of combustible materials, empty or full drums, or barrels, shall not be permitted within the diked area.

2-3.4 Normal Venting for Aboveground Tanks.

2-3.4.1 Atmospheric storage tanks shall be adequately vented to prevent the development of vacuum or pressure sufficient to distort the roof of a cone roof tank or exceeding the design pressure in the case of other atmospheric tanks, as a result of filling or emptying, and atmospheric temperature changes.

2-3.4.2 Normal vents shall be sized in accordance with either: (1) the American Petroleum Institute Standard No. 2000, *Venting Atmospheric and Low-Pressure Storage Tanks*, or (2) other accepted standard; or shall be at least as large as the filling or withdrawal connection, whichever is larger, but in no case less than 1¼ in. (3 cm) nominal inside diameter.

2-3.4.3 Low-pressure tanks and pressure vessels shall be adequately vented to prevent development of pressure or vacuum, as a result of filling or emptying and atmospheric temperature changes, from exceeding the design pressure of the tank or vessel. Protection shall also be provided to prevent overpressure from any pump discharging into the tank or vessel when the pump discharge pressure can exceed the design pressure of the tank or vessel.

2-3.4.4 If any tank or pressure vessel has more than one fill or withdrawal connection and simultaneous filling or withdrawal can be made, the vent size shall be based on the maximum anticipated simultaneous flow.

2-3.4.5 The outlet of all vents and vent drains on tanks equipped with venting to permit pressures exceeding 2.5 psig (17.2 kPa) shall be arranged to discharge in such a way as to prevent localized overheating of, or flame impingement on, any part of the tank, in the event vapors from such vents are ignited.

2-3.4.6 Tanks and pressure vessels storing Class IA liquids shall be equipped with venting devices that shall be normally closed except when venting to pressure or vacuum conditions. Tanks and pressure vessels storing Class IB and IC liquids shall be equipped with venting devices that shall be normally closed except when venting under pressure or vacuum conditions, or with listed flame arrestors. Tanks of 3,000 bbl (476 910 L) capacity or less containing crude petroleum in crude-producing areas, and outside aboveground atmospheric tanks under 23.8 bbl (3785 L) capacity containing other than Class IA liquids may have open vents. (*See 2-3.6.2.*)

2-3.4.7 Flame arrestors or venting devices required in 2-3.4.6 may be omitted for IB and IC liquids where conditions are such that their use may, in case of obstruction, result in tank damage. Liquid properties justifying the omission of such devices include, but are not limited to, condensation, corrosiveness, crystallization, polymerization, freezing, or plugging. When any of these conditions exist, consideration may be given to heating, use of devices employing special materials of construction, the use of liquid seals, or inerting (*see NFPA 69, Standard on Explosion Prevention Systems*).

2-3.5 Emergency Relief Venting for Fire Exposure for Aboveground Tanks.

2-3.5.1 Except as provided in 2-3.5.2, every aboveground storage tank shall have some form of construction or device that will relieve excessive internal pressure caused by exposure fires.

2-3.5.2 Tanks larger than 285 bbl (45 306 L) capacity storing Class IIIB liquids and not within the diked area or the drainage path of Class I or Class II liquids do not require emergency relief venting.

2-3.5.3 In a vertical tank, the construction referred to in 2-3.5.1 may take the form of a floating roof, lifter roof, a weak roof-to-shell seam, or other approved pressure-relieving construction. The weak roof-to-shell seam shall be constructed to fail preferential to any other seam. Design methods that will provide a weak roof-to-shell seam construction are contained in API 650, *Welded Steel Tanks for Oil Storage*, and UL 142, *Standard for Steel Aboveground Tanks for Flammable and Combustible Liquids.*

2-3.5.4 Where entire dependence for emergency relief is placed upon pressure-relieving devices, the total venting capacity of both normal and emergency vents shall be enough to prevent rupture of the shell or bottom of the tank if vertical, or of the shell or heads if horizontal. If unstable liquids are stored, the effects of heat or gas resulting from polymerization, decomposition, condensation, or self-reactivity shall be taken into account. The total capacity of both normal and emergency venting devices shall be not less than that derived from Table 2-8 except as provided in 2-3.5.6 or 2-3.5.7. Such device may be a self-closing manhole cover, or one using long bolts that permit the cover to lift under internal pressure, or an additional or larger relief valve or valves. The wetted area of the tank shall be calculated on the basis of 55 percent of the total exposed area of a sphere or spheroid, 75 percent of the total exposed area of a horizontal tank, and the first 30 ft (9 m) above grade of the exposed shell area of a vertical tank. (*See Appendix B for the square footage of typical tank sizes.*)

Table 2-8 Wetted Area versus Cubic Feet Free Air per Hour* (14.7 psia and 60°F) (101.3 kPa and 15.6°C)

Sq Ft	CFH	Sq Ft	CFH	Sq Ft	CFH
20	21,100	200	211,000	1,000	524,000
30	31,600	250	239,000	1,200	557,000
40	42,100	300	265,000	1,400	587,000
50	52,700	350	288,000	1,600	614,000
60	63,200	400	312,000	1,800	639,000
70	73,700	500	354,000	2,000	662,000
80	84,200	600	392,000	2,400	704,000
90	94,800	700	428,000	2,800	742,000
100	105,000	800	462,000	and over	
120	126,000	900	493,000		
140	147,000	1,000	524,000		
160	168,000				
180	190,000				
200	211,000				

SI Units: 10 ft^2 = 0.93 m^2; 36 ft^3 = 1.0 m^3
*Interpolate for intermediate values.

2-3.5.5 For tanks and storage vessels designed for pressures over 1 psig (6.9 kPa), the total rate of venting shall be determined in accordance with Table 2-8, except that when the exposed wetted area of the surface is greater than 2,800 sq ft (260 m^2), the total rate of venting shall be in accordance with Table 2-9 or calculated by the following formula:

$$CFH = 1{,}107\ A^{0.82}$$

Where:

CFH = venting requirement, in cubic feet of free air per hour

A = exposed wetted surface, in square feet

The foregoing formula is based on $Q = 21{,}000\ A^{0.82}$

Table 2-9 Wetted Area Over 2,800 sq ft and Pressures Over 1 psig

Sq Ft	CFH	Sq Ft	CFH
2,800	742,000	9,000	1,930,000
3,000	786,000	10,000	2,110,000
3,500	892,000	15,000	2,940,000
4,000	995,000	20,000	3,720,000
4,500	1,100,000	25,000	4,470,000
5,000	1,250,000	30,000	5,190,000
6,000	1,390,000	35,000	5,900,000
7,000	1,570,000	40,000	6,570,000
8,000	1,760,000		

SI Units: 10 ft^2 = 0.93 m^2; 36 ft^3 = 1.0 m^3

2-3.5.6 The total emergency relief venting capacity for any specific stable liquid can be determined by the following formula:

$$\text{Cubic feet of free air per hour} = V \frac{1{,}337}{L\sqrt{M}}$$

V = cubic feet of free air per hour from Table 2-8
L = latent heat of vaporization of specific liquid in Btu per pound
M = molecular weight of specific liquids

2-3.5.7 For tanks containing stable liquids, the required airflow rate of 2-3.5.4 or 2-3.5.6 may be multiplied by the appropriate factor listed in the following schedule when protection is provided as indicated. Only one factor shall be used for any one tank.

0.5 for drainage in accordance with 2-3.3.2 for tanks over 200 sq ft (18.6 m^2) of wetted area

0.3 for water spray in accordance with NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, and drainage in accordance with 2-3.3.2

0.3 for insulation in accordance with 2-3.5.7(a)

0.15 for water spray with insulation in accordance with 2-3.5.7(a) and drainage in accordance with 2-3.3.2 (*see Appendix B*)

(a) Insulation systems for which credit is taken shall meet the following performance criteria:

1. Remain in place under fire exposure conditions.
2. Withstand dislodgment when subjected to hose stream impingement during fire exposure. This requirement may be waived where use of solid hose streams is not contemplated or would not be practical.
3. Maintain a maximum conductance value of 4.0 Btu per hour per square foot per degree Fahrenheit (Btu/hr/sq ft/°F) when the outer insulation jacket or cover is at a temperature of 1,660°F (904.4°C) and when the mean temperature of the insulation is 1,000°F (537.8°C).

2-3.5.8 The outlet of all vents and vent drains on tanks equipped with emergency venting to permit pressures exceeding 2.5 psig (17.2 kPa) shall be arranged to discharge in such a way as to prevent localized overheating of or flame impingement on any part of the tank, in the event vapors from such vents are ignited.

2-3.5.9 Each commercial tank venting device shall have stamped on it the opening pressure, the pressure at which the valve reaches the full open position, and the flow capacity at the latter pressure. If the start to open pressure is less than 2.5 psig (17.2 kPa) and the pressure at full open position is greater than 2.5 psig (17.2 kPa), the flow capacity at 2.5 psig (17.2 kPa) shall also be stamped on the venting device. The flow capacity shall be expressed in cubic feet per hour of air at 60°F (15.6°C) and 14.7 psia (760 mm Hg).

(a) The flow capacity of tank venting devices under 8 in. (20 cm) in nominal pipe size shall be determined by actual test of each type and size of vent. These flow tests may be conducted by the manufacturer if certified by a qualified, impartial observer or may be conducted by a qualified, impartial outside agency. The flow capacity of tank venting devices 8 in. (20 cm) nominal pipe size and larger, including manhole covers with long bolts or equivalent, may be calculated provided that the opening pressure is actually measured, the rating pressure and corresponding free orifice area are stated, the word "calculated" appears on the nameplate, and the computation is based on a flow coefficient of 0.5 applied to the rated orifice area.

(b) A suitable formula for this calculation is:

$$CFH = 1{,}667\ C_f A\sqrt{P_t - P_a}$$

where CFH = venting requirement in cubic feet of free air per hour
C_f = 0.5 [the flow coefficient]
A = the orifice area in sq in.
P_t = the absolute pressure inside the tank in inches of water
P_a = the absolute atmospheric pressure outside the tank in inches of water

2-3.6 Vent Piping for Aboveground Tanks.

2-3.6.1 Vent piping shall be constructed in accordance with Chapter 3.

2-3.6.2 Where vent pipe outlets for tanks storing Class I liquids are adjacent to buildings or public ways, they shall be located so that the vapors are released at a safe point outside of buildings and not less than 12 ft (3.6 m) above the adjacent ground level. In order to aid their dispersion, vapors shall be discharged upward or horizontally away from closely adjacent walls. Vent outlets shall be located so that flammable vapors will not be trapped by eaves or other obstructions and shall be at least 5 ft (1.5 m) from building openings.

2-3.6.3 The manifolding of tank vent piping shall be avoided except where required for special purposes such as vapor recovery, vapor conservation, or air pollution control. When tank vent piping is manifolded, pipe sizes shall be such as to discharge, within the pressure limitations of the system, the vapors they may be required to handle when manifolded tanks are subject to the same fire exposure.

2-3.6.4 Vent piping for tanks storing Class I liquids shall not be manifolded with vent piping for tanks storing Class II or Class III liquids unless positive means are provided to prevent the vapors from Class I liquids from entering tanks storing Class II or Class III liquids, to prevent contamination (*see 1-1.2*) and possible change in classification of the less volatile liquid.

2-3.7 Tank Openings Other than Vents for Aboveground Tanks.

2-3.7.1 Each connection to an aboveground tank through which liquid can normally flow shall be provided with an internal or an external valve located as close as practical to the shell of the tank.

2-3.7.2 Each connection below the liquid level through which liquid does not normally flow shall be provided with a liquidtight closure. This may be a valve, plug, or blind, or a combination of these.

2-3.7.3 Openings for gaging on tanks storing Class I liquids shall be provided with a vaportight cap or cover. Such covers shall be closed when not gaging.

2-3.7.4 Fill pipes that enter the top of a tank shall terminate within 6 in. (15 cm) of the bottom of the tank. Fill pipes shall be installed or arranged so that vibration is minimized.

Exception: Fill pipes in tanks handling liquids that have a minimum potential for the accumulation of static electricity or fill pipes in tanks whose vapor space, under normal operating conditions, is not in the flammable range or is inerted need not meet this requirement. (Examples include most crude oils, residual oils, asphalts, and water-miscible liquids.)

2-3.7.5 Filling and emptying connections for Class I, Class II, and Class IIIA liquids that are made and broken shall be located outside of buildings at a location free from any source of ignition and not less than 5 ft (1.5 m) away from any building opening. Such connections for any liquid shall be closed and liquidtight when not in use and shall be properly identified.

2-3.8 Abandonment or Reuse of Aboveground Tanks.

2-3.8.1 Tanks taken out of service or abandoned shall be emptied of liquid, rendered vapor-free, and safeguarded against trespassing. (*For further information see, API 2015, Cleaning Petroleum Storage Tanks; API 2015A, A Guide for Controlling the Lead Hazard Associated with Tank Entry and Cleaning; and API 2015B, Cleaning Open Top and Covered Floating Roof Tanks.*)

2-3.8.2 Only those used tanks that comply with the applicable sections of this code and are approved by the authority having jurisdiction shall be installed for flammable or combustible liquids service.

2-4 Installation of Underground Tanks.

2-4.1 Location. Excavation for underground storage tanks shall be made with due care to avoid undermining of foundations of existing structures. Underground tanks or tanks under buildings shall be so located with respect to existing building foundations and supports that the loads carried by the latter cannot be transmitted to the tank. The distance from any part of a tank storing Class I liquids to the nearest wall of any basement or pit shall be not less than 1 ft (0.30 m), and to any property line that can be built upon, not less than 3 ft (0.90 m). The distance from any part of a tank storing Class II or Class III liquids to the nearest wall of any basement, pit, or property line shall be not less than 1 ft (0.30 m).

2-4.2 Burial Depth and Cover.

2-4.2.1 All underground tanks shall be installed in accordance with the manufacturer's instructions, where available, and shall be set on firm foundations and surrounded with at least 6 in. (15 cm) of noncorrosive inert material such as clean sand or gravel well tamped in place. The tank shall be placed in the hole with care, since dropping or rolling the tank into the hole can break a weld, puncture or damage the tank, or scrape off the protective coating of coated tanks. [*See Petroleum Equipment Institute (PEI) RP-100-86, Recommended Practice for the Installation of Underground Liquid Storage Systems, for further information.*]

2-4.2.2 All underground tanks shall be covered with a minimum of 2 ft (0.60 m) of earth, or shall be covered with not less than 1 ft (0.30 m) of earth on top of which shall be placed a slab of reinforced concrete not less than 4 in. (10 cm) thick. When they are, or are likely to be, subjected to traffic, they shall be protected against damage from vehicles passing over them by at least 3 ft (0.90 m) of earth cover, or 18 in. (45.7 cm) of well-tamped earth plus either 6 in. (15 cm) of reinforced concrete or 8 in. (20 cm) of asphaltic concrete. When asphaltic or reinforced concrete paving is used as part of the protection, it shall extend at least 1 ft (0.30 m) horizontally beyond the outline of the tank in all directions.

2-4.2.3 For underground tanks built in accordance with 2-2.3.1, the burial depth shall be such that the static head imposed at the bottom of the tank will not exceed 10 psig (68.9 kPa) if the fill or vent pipe are filled with liquid. If the depth of cover is greater than the tank diameter, the tank manufacturer shall be consulted to determine if reinforcement is required.

2-4.3 External Corrosion Protection. Tanks and their piping shall be protected by either:

(a) A properly engineered, installed, and maintained cathodic protection system in accordance with recognized standards of design, such as:

1. American Petroleum Institute Publication 1632, *Cathodic Protection of Underground Petroleum Storage Tanks and Piping Systems.*

2. Underwriters Laboratories of Canada ULC-S603.1-M, *Standard for Galvanic Corrosion Protection Systems for Steel Underground Tanks for Flammable and Combustible Liquids.*

3. Steel Tank Institute Standard No. sti-P_3®, *sti-P_3® Specification and Manual for Corrosion Protection of Underground Steel Storage Tanks.*

4. National Association of Corrosion Engineers Standard RP-01-69 (1983 Rev.), Recommended Practice, *Control of External Corrosion of Underground or Submerged Metallic Piping Systems.*

5. National Association of Corrosion Engineers Standard RP-02-85, Recommended Practice, *Control of External Corrosion on Metallic Buried, Partially Buried, or Submerged Liquid Storage Systems.*

(b) Approved or listed corrosion-resistant materials or systems, which may include special alloys, fiberglass reinforced plastic, or fiberglass reinforced plastic coatings.

2-4.3.1 Selection of the type of protection to be employed shall be based upon the corrosion history of the area and the judgement of a qualified engineer. The authority having jurisdiction may waive the requirements for corrosion protection where evidence is provided that such protection is not necessary. (*See API Publication 1615, Installation of Underground Petroleum Storage Systems, for further information.*)

2-4.4 Abandonment, Reuse, or Change of Service of Underground Tanks.

2-4.4.1 Underground tanks taken out of service shall be safeguarded or disposed of in a safe manner. (*See Appendix C.*)

2-4.4.2 Only those used tanks that comply with the applicable sections of this code and are approved by the authority having jurisdiction shall be installed for flammable or combustible liquids service.

2-4.4.3 Tanks that undergo any change of stored product shall meet the requirements of Section 2-2.

2-4.5 Vents for Underground Tanks.

2-4.5.1 Location and Arrangement of Vents for Class I Liquids. Vent pipes from underground storage tanks storing Class I liquids shall be so located that the discharge point is outside of buildings, higher than the fill pipe opening, and not less than 12 ft (3.6 m) above the adjacent ground level. Vent pipes shall not be obstructed by devices provided for vapor recovery or other purposes unless the tank and associated piping and equipment are otherwise protected to limit back-pressure development to less than the maximum working pressure of the tank and equipment by the provision of pressure-vacuum vents, rupture discs, or other tank venting devices installed in the tank vent lines. Vent outlets and devices shall be protected to minimize the possibility of blockage from weather, dirt, or insect nests, shall be so located and directed that flammable vapors will not accumulate or travel to an unsafe location, enter building openings, or be trapped under eaves, and shall be at least 5 ft from building openings. Tanks containing Class IA liquids shall be equipped with pressure and vacuum venting devices that shall be normally closed except when venting under pressure or vacuum conditions. Tanks storing Class IB or Class IC liquids shall be equipped with pressure-vacuum vents or with listed flame arrestors. Tanks storing gasoline are exempt from the requirements for pressure and vacuum venting devices, except as required to prevent excessive back pressure, or flame arrestors, provided the vent does not exceed 3 in. (7.6 cm) nominal inside diameter. (*See also 2-1.1 of NFPA 30A, Automotive and Marine Service Station Code.*)

2-4.5.2 Vent Capacity. Tank venting systems shall be provided with sufficient capacity to prevent blowback of vapor or liquid at the fill opening while the tank is being filled. Vent pipes shall not be less than 1¼ in. (3 cm) nominal inside diameter. The required venting capacity depends upon the filling or withdrawal rate, whichever is greater, and the vent line length. Unrestricted vent piping sized in accordance with Table 2-10 will prevent back-pressure development in tanks from exceeding 2.5 psig (17.2 kPa). Where tank venting devices are installed in vent lines, their flow capacities shall be determined in accordance with 2-3.5.9.

Table 2-10 Vent Line Diameters

Maximum Flow GPM	Pipe Length* 50 Ft	100 Ft	200 Ft
100	1¼-inch	1¼-inch	1¼-inch
200	1¼-inch	1¼-inch	1¼-inch
300	1¼-inch	1¼-inch	1½-inch
400	1¼-inch	1½-inch	2-inch
500	1½-inch	1½-inch	2-inch
600	1½-inch	2-inch	2-inch
700	2-inch	2-inch	2-inch
800	2-inch	2-inch	3-inch
900	2-inch	2-inch	3-inch
1,000	2-inch	2-inch	3-inch

SI Units: 1 in. = 2.5 cm; 1 ft = 0.30 m; 1 gal = 3.8 L.
*Vent lines of 50 ft, 100 ft, and 200 ft of pipe plus 7 ells.

2-4.5.3 Location and Arrangement of Vents for Class II or Class IIIA Liquids. Vent pipes from tanks storing Class II or Class IIIA liquids shall terminate outside of the building and higher than the fill pipe opening. Vent outlets shall be above normal snow level. They may be fitted with return bends, coarse screens, or other devices to minimize ingress of foreign material.

2-4.5.4 Vent piping shall be constructed in accordance with Chapter 3. Tank vent pipes and vapor return piping shall be installed without sags or traps in which liquid can collect. Condensate tanks, if utilized, shall be installed and maintained so as to preclude the blocking of the vapor return piping by liquid. The vent pipes and condensate tanks shall be located so that they will not be subjected to physical damage. The tank end of the vent pipe shall enter the tank through the top.

2-4.5.5 When tank vent piping is manifolded, pipe sizes shall be such as to discharge, within the pressure limitations of the system, the vapors they can be required to handle when manifolded tanks are filled simultaneously. Float-type check valves installed in tank openings connected to manifolded vent piping to prevent product contamination may be used provided that the tank pressure will not exceed that permitted by 2-4.2.3 when the valves close.

Exception: For service stations, the capacity of manifolded vent piping shall be sufficient to discharge vapors generated when two manifolded tanks are simultaneously filled.

2-4.5.6 Vent piping for tanks storing Class I liquids shall not be manifolded with vent piping for tanks storing Class II or Class III liquids unless positive means are provided to prevent the vapors from Class I liquids from entering tanks storing Class II or Class III liquids, to prevent contamination (*see 1-1.2*) and possible change in classification of the less volatile liquid.

2-4.6 Tank Openings Other than Vents for Underground Tanks.

2-4.6.1 Connections for all tank openings shall be liquidtight.

2-4.6.2 Openings for manual gaging, if independent of the fill pipe, shall be provided with a liquidtight cap or cover. Covers shall be kept closed when not gaging. If inside a building, each such opening shall be protected against liquid overflow and possible vapor release by means of a spring-loaded check valve or other approved device.

2-4.6.3 Fill and discharge lines shall enter tanks only through the top. Fill lines shall be sloped toward the tank. Underground tanks for Class I liquids having a capacity of more than 1,000 gal (3785.L) shall be equipped with a tight fill device for connecting the fill hose to the tank.

2-4.6.4 Fill pipes that enter the top of a tank shall terminate within 6 in. (15 cm) of the bottom of the tank. Fill pipes shall be installed or arranged so that vibration is minimized.

Exception: Fill pipes in tanks handling liquids that have a minimum potential for the accumulation of static electricity or fill pipes in tanks whose vapor space, under normal operating conditions, is not in the flammable range or is inerted need not meet this requirement. (Examples include most crude oils, residual oils, asphalts, and water-miscible liquids.)

2-4.6.5 Filling and emptying and vapor recovery connections for Class I, Class II, or Class IIIA liquids that are made and broken shall be located outside of buildings at a location free from any source of ignition and not less than 5 ft (1.5 m) away from any building opening. Such connections shall be closed and liquidtight when not in use and shall be properly identified.

2-4.6.6 Tank openings provided for purposes of vapor recovery shall be protected against possible vapor release by means of a spring-loaded check valve or dry-break connection, or other approved device, unless the opening is pipe-connected to a vapor processing system. Openings designed for combined fill and vapor recovery shall also be protected against vapor release unless connection of the liquid delivery line to the fill pipe simultaneously connects the vapor recovery line. All connections shall be vaportight.

2-5 Installation of Tanks Inside of Buildings.

2-5.1 Location. Tanks shall not be permitted inside of buildings.

Exception: If the storage of liquids in outside aboveground or underground tanks is not practical because of government regulations, temperature considerations, or production considerations, tanks may be permitted inside of buildings or structures in accordance with the applicable provisions of Chapter 2, Tank Storage. Production considerations that may necessitate storage inside of buildings include but are not limited to high viscosity, purity, sterility, hydroscopicity, sensitivity to temperature change, and need to store temporarily pending completion of sample analysis.

2-5.1.1 Storage tanks inside of buildings shall be permitted only in areas at or above grade have adequate drainage and are separated from other parts of the building by construction having a fire resistance rating of at least 2 hr. Day tanks, running tanks, and surge tanks are permitted in process areas. Openings to other rooms or buildings shall be provided with noncombustible liquidtight raised sills or ramps at least 4 in. (10 cm) in height, or the floor in the storage area shall be at least 4 in. (10 cm) below the surrounding floor. As a minimum, each opening shall be provided with a listed, self-closing $1\frac{1}{2}$-hr (B) fire door installed in accordance with NFPA 80, *Standard for Fire Doors and Windows*, or a listed fire damper installed where required by NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, or NFPA 91, *Standard for the Installation of Blower and Exhaust Systems for Dust, Stock, and Vapor Removal or Conveying*. The room shall be liquidtight where the walls join the floor.

2-5.2 Vents. Vents for tanks inside of buildings shall be as required in 2-3.4, 2-3.5, 2-3.6.2, and 2-4.5, except that emergency venting by the use of weak roof seams on tanks shall not be permitted. Automatic sprinkler systems designed in accordance with the requirements of NFPA 13, *Standard for the Installation of Sprinkler Systems*, may be accepted by the authority having jurisdiction as equivalent to water spray systems for purposes of calculating the required airflow rates for emergency vents in 2-3.5.7. Except for tanks containing Class IIIB liquids, vents shall terminate outside the buildings.

2-5.3 Vent Piping. Vent piping shall be constructed in accordance with Chapter 3.

2-5.4 Tank Openings Other than Vents for Tanks Inside Buildings.

2-5.4.1 Connections for all tank openings shall be liquidtight.

2-5.4.2 Each connection to a tank inside of buildings through which liquid can normally flow shall be provided with an internal or an external valve located as close as practical to the shell of the tank.

2-5.4.3 Tanks for storage of Class I or Class II liquids inside buildings shall be provided with either:

(a) A normally closed remotely activated valve,

(b) An automatic-closing heat-activated valve, or

(c) Another approved device on each liquid transfer connection below the liquid level, except for connections used for emergency disposal, to provide for quick cutoff of flow in the event of fire in the vicinity of the tank.

This function can be incorporated in the valve required in 2-5.4.2 and, if a separate valve, shall be located adjacent to the valve required in 2-5.4.2.

2-5.4.4 Openings for manual gaging of Class I or Class II liquids, if independent of the fill pipe, shall be provided with a vaportight cap or cover. Openings shall be kept closed when not gaging. Each such opening for any liquid shall be protected against liquid overflow and possible

vapor release by means of a spring-loaded check valve or other approved device. Substitutes for manual gaging include, but are not limited to, heavy-duty flat gage glasses, magnetic, hydraulic, or hydrostatic remote reading devices, and sealed float gages.

2-5.4.5 Fill pipes that enter the top of a tank shall terminate within 6 in. (15 cm) of the bottom of the tank. Fill pipes shall be installed or arranged so that vibration is minimized.

Exception: Fill pipes in tanks handling liquids that have a minimum potential for the accumulation of static electricity or fill pipes in tanks whose vapor space, under normal operating conditions, is not in the flammable range or is inerted need not meet this requirement. (Examples include most crude oils, residual oils, asphalts, and water-miscible liquids.)

2-5.4.6 The fill pipe inside of the tank shall be installed to avoid excessive vibration of the pipe.

2-5.4.7 The inlet of the fill pipe and the outlet of a vapor recovery line for which connections are made and broken shall be located outside of buildings at a location free from any source of ignition and not less than 5 ft (1.5 m) away from any building opening. Such connections shall be closed and tight when not in use and shall be properly identified.

2-5.4.8 Tanks storing Class I, Class II, and Class IIIA liquids inside buildings shall be equipped with a device, or other means shall be provided, to prevent overflow into the building. Suitable devices include, but are not limited to, a float valve, a preset meter on the fill line, a valve actuated by the weight of the tank contents, a low head pump incapable of producing overflow, or a liquidtight overflow pipe at least one pipe size larger than the fill pipe discharging by gravity back to the outside source of liquid or to an approved location.

2-5.4.9 Tank openings provided for purposes of vapor recovery shall be protected against possible vapor release by means of a spring-loaded check valve or dry-break connections, or other approved device, unless the opening is pipe-connected to a vapor processing system. Openings designed for combined fill and vapor recovery shall also be protected against vapor release unless connection of the liquid delivery line to the fill pipe simultaneously connects the vapor recovery line. All connections shall be vaportight.

2-6 Supports, Foundations, and Anchorage for All Tank Locations.

2-6.1 Tanks shall rest on the ground or on foundations made of concrete, masonry, piling, or steel. Tank foundations shall be designed to minimize the possibility of uneven settling of the tank and to minimize corrosion in any part of the tank resting on the foundation. (Appendix E of API Standard 650, *Specification for Welded Steel Tanks for Oil Storage*, and Appendix B of API Standard 620, *Recommended Rules for the Design and Construction of Large, Welded, Low-Pressure Storage Tanks*, provide information on tank foundations.)

2-6.2 When tanks are supported above the foundations, tank supports shall be installed on firm foundations. Supports for tanks storing Class I, Class II, or Class IIIA liquids shall be of concrete, masonry, or protected steel. Single wood timber supports (not cribbing) laid horizontally may be used for outside aboveground tanks if not more than 12 in. (0.30 m) high at their lowest point.

2-6.3 Steel supports or exposed piling for tanks storing Class I, Class II, or Class IIIA liquids shall be protected by materials having a fire resistance rating of not less than 2 hours, except that steel saddles need not be protected if less than 12 in. (0.30 m) high at their lowest point. At the discretion of the authority having jurisdiction, water spray protection in accordance with NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, or NFPA 13, *Standard for the Installation of Sprinkler Systems*, or equivalent may be used.

2-6.4 The design of the supporting structure for tanks such as spheres shall require special engineering consideration. (Appendix N of the API Standard 620, *Recommended Rules for the Design and Construction of Large, Welded, Low-Pressure Storage Tanks*, contains information regarding supporting structures.)

2-6.5 Every tank shall be so supported as to prevent the excessive concentration of loads on the supporting portion of the shell.

2-6.6 Tanks in Areas Subject to Flooding.

2-6.6.1 Where a tank is located in an area subject to flooding, provisions shall be taken to prevent tanks, either full or empty, from floating during a rise in water level up to the established maximum flood stage.

2-6.6.2 Aboveground Tanks.

2-6.6.2.1 Each vertical tank shall be located so that its top extends above the maximum flood stage by at least 30 percent of its allowable storage capacity.

2-6.6.2.2 Horizontal tanks located so that more than 70 percent of the tank's storage capacity will be submerged at the established flood stage shall be anchored; shall be attached to a foundation of concrete or of steel and concrete of sufficient weight to provide adequate load for the tank when filled with flammable or combustible liquid and submerged by flood water to the established flood stage; or shall be adequately secured from floating by other means. Tank vents or other openings that are not liquidtight shall be extended above maximum flood stage water level.

2-6.6.2.3 A dependable water supply shall be available for filling an empty or partially filled tank, except that where filling the tank with water is impractical or hazardous because of the tank's contents, tanks shall be protected by other means against movement or collapse.

2-6.6.2.4 Spherical or spheroid tanks shall be protected by applicable methods as specified for either vertical or horizontal tanks.

2-6.6.3 Underground Tanks.

2-6.6.3.1 At locations where there is an ample and dependable water supply available, underground tanks containing flammable or combustible liquids, so placed that more than 70 percent of their storage capacity will be submerged at the maximum flood stage, shall be so anchored, weighted, or secured as to prevent movement when filled or loaded with water and submerged by flood water to the established flood stage. Tank vents or other openings that are not liquidtight shall be extended above maximum flood stage water level.

2-6.6.3.2 At locations where there is no ample and dependable water supply or where filling of underground tanks with water is impractical because of the contents, each tank shall be safeguarded against movement when empty and submerged by high ground water or flood water by anchoring or by securing by other means. Each such tank shall be so constructed and installed that it will safely resist external pressures if submerged.

2-6.6.4 Water Loading. The filling of a tank to be protected by water loading shall be started as soon as flood waters are predicted to reach a dangerous flood stage. Where independently fueled water pumps are relied upon, sufficient fuel shall be available at all times to permit continuing operations until all tanks are filled. Tank valves shall be locked in a closed position when water loading has been completed.

2-6.6.5 Operating Instructions.

2-6.6.5.1 Operating instructions or procedures to be followed in a flood emergency shall be readily available.

2-6.6.5.2 Personnel relied upon to carry out flood emergency procedures shall be informed of the location and operation of valves and other equipment necessary to effect the intent of these requirements.

2-6.7 In areas subject to earthquakes, the tank supports and connections shall be designed to resist damage as a result of such shocks.

2-7 Sources of Ignition. In locations where flammable vapors may be present, precautions shall be taken to prevent ignition by eliminating or controlling sources of ignition. Sources of ignition may include open flames, lightning, smoking, cutting and welding, hot surfaces, frictional heat, sparks (static, electrical, and mechanical), spontaneous ignition, chemical and physicochemical reactions, and radiant heat. (NFPA 77, *Recommended Practice on Static Electricity*, and NFPA 78, *Lightning Protection Code*, provide information on such protection.)

2-8 Testing and Maintenance.

2-8.1 All tanks, whether shop-built or field-erected, shall be tested before they are placed in service in accordance with the applicable paragraphs of the code under which they were built. The ASME Code stamp or the Listing Mark of Underwriters Laboratories Inc. on a tank shall be evidence of compliance with this test. Tanks not marked in accordance with the above codes shall be tested before they are placed in service in accordance with good engineering principles and reference shall be made to the sections on testing in the codes listed in 2-2.3.1, 2-2.4.2, or 2-2.5.2.

2-8.2 When the vertical length of the fill and vent pipes is such that when filled with liquid the static head imposed on the bottom of the tank exceeds 10 psi (68.9 kPa), the tank and related piping shall be tested hydrostatically to a pressure equal to the static head thus imposed. In special cases where the height of the vent above the top of the tank is excessive, the hydrostatic test pressure shall be determined by using recognized engineering practice.

2-8.3 In addition to the test called for in 2-8.1 and 2-8.2, all tanks and connections shall be tested for tightness. Except for underground tanks, this tightness shall be made at operating pressure with air, inert gas, or water prior to placing the tank in service. In the case of field-erected tanks, the test called for in 2-8.1 or 2-8.2 may be considered to be the test for tank tightness. Single wall underground tanks and piping, before being covered, enclosed, or placed in use, shall be tested for tightness hydrostatically or with air pressure at not less than 3 psi (20.6 kPa) and not more than 5 psi (34.5 kPa). For testing of secondary containment tanks, see 2-8.3.1. (*See Section 3-7 for testing pressure piping.*) Air pressure shall not be used to test tanks that contain flammable or combustible liquids or vapors.

2-8.3.1 Secondary containment tanks (Types I and II) shall have the primary (inner) tank tested according to 2-8.3 and the interstitial space (annulus) tested using air at 3 to 5 psig (20.6 to 34.5 kPa) or vacuum at 5.3 in. Hg (17.9 kPa). The pressure or vacuum shall be held for one hour. Care shall be taken to ensure that the interstitial space is not overpressured or subjected to excessive vacuum.

2-8.4 Before the tank is initially placed in service, all leaks or deformations shall be corrected in an acceptable manner. Mechanical caulking is not permitted for correcting leaks in welded tanks except pinhole leaks in the roof.

2-8.5 Tanks to be operated at pressures below their design pressure may be tested by the applicable provisions of 2-8.1 or 2-8.2 based upon the pressure developed under full emergency venting of the tank.

2-8.6 Each tank shall be maintained liquidtight. Each tank that is leaking shall be emptied of liquid or repaired in a manner acceptable to the authority having jurisdiction.

2-8.7 Each underground tank that has been repaired or altered, or is suspected of leaking, shall be tested in a manner approved by the authority having jurisdiction. (*See NFPA 329, Recommended Practice for Handling Underground Leakage of Flammable and Combustible Liquids, for information on testing methods.*)

2-9 Fire Protection and Identification.

2-9.1 A fire extinguishing system in accordance with an applicable NFPA standard shall be provided or be available for vertical atmospheric fixed roof storage tanks larger than 50,000 gal (189 250 L) capacity, storing Class I liquids, if located in a congested area where there is an unusual exposure hazard to the tank from adjacent property or to adjacent property from the tank. Fixed roof tanks storing Class II or III liquids at temperatures below their flash points and floating roof tanks storing any liquid generally do not require protection when installed in compliance with Section 2-3.

2-9.2 The application of NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*, to storage tanks containing liquids shall not be required except when the contents have a health or reactivity degree of hazard of 2 or more or a flammability rating of 4. The marking need not be applied directly to the tank but shall be located where it can readily be seen, such as on the shoulder of an accessway or walkway to the tank or tanks or on the piping outside of the diked area. If more than one tank is involved, the markings shall be so located that each tank can readily be identified.

2-9.3 Unsupervised, isolated aboveground storage tanks shall be secured and marked in such a manner as to identify the fire hazards of the tank and its contents to the general public. The area in which the tank is located shall be protected from tampering or trespassing, where necessary.

2-10 Prevention of Overfilling of Tanks.

2-10.1 Aboveground tanks at terminals receiving transfer of Class I liquids from mainline pipelines or marine vessels shall follow formal written procedures to prevent overfilling of tanks utilizing one of the following methods of protection:

(a) Tanks gaged at frequent intervals by personnel continuously on the premises during product receipt with frequent acknowledged communication maintained with the supplier so that flow can be promptly shut down or diverted.

(b) Tanks equipped with a high-level detection device that is independent of any tank gaging equipment. Alarms shall be located where personnel who are on duty throughout product transfer can promptly arrange for flow stoppage or diversion.

(c) Tanks equipped with an independent high-level detection system that will automatically shut down or divert flow.

(d) Alternatives to instrumentation described in (b) and (c) where approved by the authority having jurisdiction as affording equivalent protection.

2-10.1.1 Instrumentation systems covered in 2-10.1(b) and (c) shall be electrically supervised or equivalent.

2-10.2 Formal written procedures required in 2-10.1 shall include:

(a) Instructions covering methods to check for proper line up and receipt of initial delivery to tank designated to receive shipment.

(b) Provision for training and monitoring the performance of operating personnel by terminal supervision.

(c) Schedules and procedures for inspection and testing of gaging equipment and high-level instrumentation and related systems. Inspection and testing intervals shall be acceptable to the authority having jurisdiction, but shall not exceed one year.

2-10.3 An underground storage tank shall be equipped with overfill prevention equipment that will:

(a) Automatically shut off the flow of liquid into the tank when the tank is no more than 95 percent full; or

(b) Alert the transfer operator when the tank is no more than 90 percent full by restricting the flow of liquid into the tank or triggering a high-level alarm;

(c) Or other methods approved by the authority having jurisdiction.

2-11 Leakage Detection and Inventory Records for Underground Tanks. Accurate inventory records or a leak detection program shall be maintained on all Class I liquid storage tanks for indication of possible leakage from the tanks or associated piping. (*See NFPA 329, Recommended Practice for Handling Underground Leakage of Flammable and Combustible Liquids, for information on testing methods.*)

Chapter 3 Piping Systems

3-1 Scope.

3-1.1 This chapter shall apply to piping systems consisting of pipe, tubing, flanges, bolting, gaskets, valves, fittings, flexible connectors, the pressure containing parts of other components such as expansion joints and strainers, and devices that serve such purposes as mixing, separating, snubbing, distributing, metering, or controlling flow.

3-1.2 This chapter does not apply to any of the following:

(a) Tubing or casing on any oil or gas wells and any piping connected directly thereto.

(b) Motor vehicle, aircraft, boat, or portable or stationary engine.

(c) Piping within the scope of any applicable boiler and pressure vessel code.

3-2 General.

3-2.1 The design, fabrication, assembly, test, and inspection of piping systems containing liquids shall be suitable for the expected working pressures and structural stresses. Conformity with the applicable sections of ANSI B31, *American National Standard Code for Pressure Piping*, and the provisions of this chapter shall be considered prima facie evidence of compliance with the foregoing provisions.

3-2.2 Piping systems shall be maintained liquidtight. A piping system that has leaks that constitute a hazard shall be emptied of liquid or repaired in a manner acceptable to the authority having jurisdiction.

3-3 Materials for Piping, Valves, and Fittings.

3-3.1 Pipe, valves, faucets, fittings, and other pressure-containing parts as covered in 3-1.1 shall meet the material specifications and pressure and temperature limitations of ANSI B31.3-1980, *Petroleum Refinery Piping*, or ANSI B31.4-1979, *Liquid Petroleum Transportation Piping Systems*, except as provided by 3-3.2, 3-3.3, and 3-3.4. Plastic or similar materials, as permitted by 3-3.4, shall be designed to specifications embodying recognized engineering principles and shall be compatible with the fluid service.

3-3.2 Nodular iron shall conform to ASTM A 395, *Ferritic Ductile Iron Pressure Retaining Castings for Use at Elevated Temperatures*.

3-3.3 Valves at storage tanks, as required by 2-3.7.1 and 2-5.4.2, and their connections to the tank shall be of steel or nodular iron except as provided in 3-3.3.1 or 3-3.3.2.

3-3.3.1 Valves at storage tanks may be other than steel or nodular iron when the chemical characteristics of the liquid stored are not compatible with steel or when installed internally to the tank. When installed externally to the tank, the material shall have a ductility and melting point comparable to steel or nodular iron so as to withstand reasonable stresses and temperatures involved in fire exposure or otherwise be protected, such as by materials having a fire-resistance rating of not less than 2 hours.

3-3.3.2 Cast iron, brass, copper, aluminum, malleable iron, and similar materials may be used on tanks described in 2-3.2.2 or for tanks storing Class IIIB liquids when the tank is located outdoors and not within a diked area or drainage path of a tank storing a Class I, Class II, or Class IIIA liquid.

3-3.4 Low melting point materials such as aluminum, copper, and brass, materials that soften on fire exposure such as plastics, or nonductile material such as cast iron may be used underground for all liquids within the pressure and temperature limits of ANSI B31, *American National Standard Code for Pressure Piping*. If such materials are used outdoors in aboveground piping systems handling Class I, Class II, or Class IIIA liquids or within buildings handling any liquid they shall be either: (a) suitably protected against fire exposure, (b) so located that any leakage resulting from the failure would not unduly expose persons, important buildings, or structures, or (c) located where leakage can readily be controlled by operation of an accessible remotely located valve(s).

3-3.5 Piping, valves, and fittings may have combustible or noncombustible linings.

3-4 Pipe Joints.

3-4.1 Joints shall be made liquidtight and shall be either welded, flanged, or threaded, except that listed flexible connectors may be used when installed in accordance with 3-4.2. Threaded joints shall be made up tight with a suitable thread sealant or lubricant. Joints in piping systems handling Class I liquids shall be welded when located in concealed spaces within buildings.

3-4.2 Pipe joints dependent upon the friction characteristics or resiliency of combustible materials for mechanical continuity or liquidtightness of piping shall not be used inside buildings. They may be used outside of buildings above or below ground. If used aboveground outside of buildings, the piping shall either be secured to prevent disengagement at the fitting, or the piping system shall be so designed that any spill resulting from disengagement could not unduly expose persons, important buildings, or structures and could be readily controlled by remote valves.

3-5 Supports. Piping systems shall be substantially supported and protected against physical damage and excessive stresses arising from settlement, vibration, expansion, or contraction. The installation of nonmetallic piping shall be in accordance with the manufacturer's instructions.

3-6* Protection against Corrosion. All piping systems for liquids, both aboveground and underground, that are subject to external corrosion shall be protected. Underground piping systems shall be protected in accordance with 2-4.3.

3-7 Valves. Piping systems shall contain a sufficient number of valves to operate the system properly and to protect the plant. Piping systems in connection with pumps shall contain a sufficient number of valves to control properly the flow of liquid in normal operation and in the event of physical damage. Each connection to piping by which equipment such as tank cars, tank vehicles, or marine vessels discharge liquids into storage tanks shall be provided with a check valve for automatic protection against back-flow if the piping arrangement is such that back-flow from the system is possible. (*See also 2-3.7.1.*)

3-7.1 If loading and unloading is done through a common pipe system, a check valve is not required. However, a block valve shall be provided. This valve shall be located so that it is readily accessible or shall be remotely operable.

3-8 Testing. Unless tested in accordance with the applicable sections of ANSI B31, *American National Standard Code for Pressure Piping*, all piping, before being covered, enclosed, or placed in use, shall be hydrostatically tested to 150 percent of the maximum anticipated pressure of the system, or pneumatically tested to 110 percent of the maximum anticipated pressure of the system but not less than 5 psi (34.5 kPa) gage at the highest point of the system. This test shall be maintained for a sufficient time to complete visual inspection of all joints and connections, but for at least 10 minutes.

3-9* Identification. Each loading and unloading riser for liquid storage shall be identified by color code or marking to identify the product for which the tank is used.

Chapter 4 Container and Portable Tank Storage

4-1 Scope.

4-1.1 This chapter shall apply to the storage of liquids in drums or other containers not exceeding 60 gal (227 L) individual capacity and portable tanks not exceeding 660 gal (2498 L) individual capacity and limited transfers incidental thereto. For portable tanks exceeding 660 gal (2498 L), Chapter 2 shall apply.

4-1.2 This chapter shall not apply to the following:

(a) Storage of containers in bulk plants, service stations, refineries, chemical plants, and distilleries.

(b) Liquids in the fuel tanks of motor vehicles, aircraft, boats, or portable or stationary engines.

(c) Beverages, when packaged in individual containers not exceeding a capacity of one gallon.

(d) Medicines, foodstuffs, cosmetics, and other consumer products containing not more than 50 percent by volume of water-miscible liquids and with the remainder of the solution not being flammable when packaged in individual containers not exceeding one gallon in size.

(e) The storage of liquids that have no fire point when tested by ASTM D 92-78, *Cleveland Open Cup Test Method*, up to the boiling point of the liquid or up to a temperature at which the sample being tested shows an obvious physical change.

(f) The storage of distilled spirits and wines in wooden barrels or casks.

4-1.3 For the purpose of this chapter, unstable liquids shall be treated as Class IA liquids.

4-2 Design, Construction, and Capacity of Containers.

4-2.1 Only approved containers and portable tanks shall be used. Metal containers and metal portable tanks meeting the requirements of, and containing products authorized by, Chapter I, Title 49 of the *Code of Federal Regulations* (DOT Regulations), or NFPA 386, *Standard for Portable Shipping Tanks for Flammable and Combustible Liquids*, shall be acceptable. Plastic containers meeting the requirements of, and used for petroleum products within the scope of, one or more of the following specifications shall be acceptable:

(a) ANSI/ASTM D 3435-80, *Plastic Containers (Jerry Cans) for Petroleum Products.*

(b) ASTM F 852-86, *Standard for Portable Gasoline Containers for Consumer Use.*

(c) ASTM F 976-86, *Standard for Portable Kerosine Containers for Consumer Use.*

(d) ANSI/UL 1313-83, *Nonmetallic Safety Cans for Petroleum Products.*

4-2.2 Each portable tank shall be provided with one or more devices installed in the top with sufficient emergency venting capacity to limit internal pressure under fire exposure conditions to 10 psig (68.9 kPa), or 30 percent of the bursting pressure of the tank, whichever is greater. The total venting capacity shall be not less than that specified in 2-3.5.4 or 2-3.5.6. At least one pressure-actuated vent having a minimum capacity of 6,000 cu ft (170 m^3) of free air per hour [14.7 psia (760 mm Hg) and 60°F (15.6°C)] shall be used. It shall be set to open at not less than 5 psig (34.5 kPa). If fusible vents are used, they shall be actuated by elements that operate at a temperature not exceeding 300°F (148.9°C). When used for paints, drying oils, and similar materials where plugging of the pressure-actuated vent can occur, fusible vents or vents of the type that soften to failure at a maximum of 300°F (148.9°C) under fire exposure may be used for the entire emergency venting requirement.

4-2.3 The maximum allowable size of containers and metal portable tanks shall not exceed that specified in Table 4-2.3, except as provided for in 4-2.3.1 and 4-2.3.2.

Table 4-2.3 Maximum Allowable Size of Containers and Metal Portable Tanks

	Flammable Liquids			Combustible Liquids	
Container Type	**Class IA**	**Class IB**	**Class IC**	**Class II**	**Class III**
Glass	1 pt	1 qt	1 gal	1 gal	5 gal
Metal (other than DOT drums) or approved plastic	1 gal	5 gal	5 gal	5 gal	5 gal
Safety Cans	2 gal	5 gal	5 gal	5 gal	5 gal
Metel Drum (DOT Spec.)	60 gal	60 gal	60 gal	60 gal	60 gal
Approved Metal Portable Tanks	660 gal	660 gal	660 gal	660 gal	660 gal
Polyethylene DOT Spec. 34, or as authorized by DOT Exemption	1 gal	5 gal	5 gal	60 gal	60 gal

SI Units: 1 pt = 0.473 L; 1 qt = 0.95 L; 1 gal = 3.8 L.

4-2.3.1 Medicines, beverages, foodstuffs, cosmetics, and other common consumer products, when packaged according to commonly accepted practices for retail sales, shall be exempt from the requirements of 4-2.1 and 4-2.3.

4-2.3.2 DOT Type III polyethylene nonreusable containers, constructed and tested in accordance with DOT specification 2U, treated if necessary to prevent permeation, may be used for storage of Class II and Class III liquids, in all capacities not to exceed 2½ gal (9.5 L).

4-2.3.3 Class IA and Class IB liquids may be stored in glass containers of not more than one gallon capacity if the required liquid purity (such as ACS analytical reagent grade or higher) would be affected by storage in metal containers or if the liquid would cause excessive corrosion of the metal container.

4-3 Design, Construction, and Capacity of Storage Cabinets.

4-3.1 Not more than 120 gal (454 L) of Class I, Class II, and Class IIIA liquids may be stored in a storage cabinet. Of this total, not more than 60 gal (227 L) may be of Class I and Class II liquids, and not more than three (3) such cabinets may be located in a single fire area, except that, in an industrial occupancy, additional cabinets may be located

in the same fire area if the additional cabinet, or group of not more than three (3) cabinets, is separated from other cabinets or group of cabinets by at least 100 ft (30 m).

4-3.2* Storage cabinets shall be designed and constructed to limit the internal temperature at the center, 1 in. (2.5 cm) from the top, to not more than 325°F (162.8°C) when subjected to a 10-minute fire test with burners simulating a room fire exposure using the standard time-temperature curve as given in NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials*. All joints and seams shall remain tight and the door shall remain securely closed during the fire test. Cabinets shall be marked in conspicuous lettering: "FLAMMABLE — KEEP FIRE AWAY."

The cabinet is not required to be vented for fire protection purposes; however, the following shall apply:

(a) If the cabinet is vented for whatever reasons, the cabinet shall be vented outdoors in such a manner that will not compromise the specified performance of the cabinet, as acceptable to the authority having jurisdiction.

(b) If the cabinet is not vented, the vent openings shall be sealed with the bungs supplied with the cabinet or with bungs specified by the manufacturer of the cabinet.

4-3.2.1 Metal cabinets constructed in the following manner are acceptable. The bottom, top, door, and sides of cabinet shall be at least No. 18 gage sheet steel and double walled with 1½ in. (3.8 cm) air space. Joints shall be riveted, welded, or made tight by some equally effective means. The door shall be provided with a three-point latch arrangement and the door sill shall be raised at least 2 in. (5 cm) above the bottom of the cabinet to retain spilled liquid within the cabinet.

4-3.2.2 Wooden cabinets constructed in the following manner are acceptable. The bottom, sides, and top shall be constructed of exterior grade plywood at least 1 in. (2.5 cm) in thickness, which shall not break down or delaminate under fire conditions. All joints shall be rabbetted and shall be fastened in two directions with wood screws. When more than one door is used, there shall be a rabbetted overlap of not less than 1 in. (2.5 cm). Doors shall be equipped with a means of latching, and hinges shall be constructed and mounted in such a manner as to not lose their holding capacity when subjected to fire exposure. A raised sill or pan capable of containing a 2-in. (5-cm) depth of liquid shall be provided at the bottom of the cabinet to retain spilled liquid within the cabinet.

4-3.2.3 Listed cabinets that have been constructed and tested in accordance with 4-3.2 shall be acceptable.

4-4 Design, Construction, and Operation of Separate Inside Storage Areas. (*See Section 1-2, "Definitions."*) (*For additional information, see Appendix D.*)

4-4.1 Inside Rooms and Hazardous Materials Storage Lockers Used Inside. Inside rooms and hazardous materials storage lockers that are used as inside rooms shall meet the requirements set forth in 4-4.1.1 through 4-4.1.9, as applicable.

4-4.1.1 Inside rooms shall be constructed to meet the selected fire-resistance rating as specified in 4-4.1.4. Such construction shall comply with the test specifications given in NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials*. Except for drains, floors shall be liquidtight, and the room shall be liquidtight where the walls join the floor. Where an automatic fire protection system is provided, as indicated in 4-4.1.4, the system shall be designed and installed in accordance with the appropriate NFPA standard for the type of system selected.

4-4.1.2 Openings in interior walls to adjacent rooms or buildings shall be provided with:

(a) Normally closed, listed 1½ hr (B) fire doors for interior walls with fire-resistance rating of 2 hours or less. Where interior walls are required to have greater than 2 hour fire-resistance rating, the listed fire doors shall be compatible with the wall rating. Doors may be arranged to stay open during material handling operations if doors are designed to close automatically in a fire emergency by provision of listed closure devices. Fire doors shall be installed in accordance with NFPA 80, *Standard for Fire Doors and Windows*.

(b) Noncombustible, liquidtight raised sills or ramps at least 4 in. (10 cm) in height or otherwise designed to prevent the flow of liquids to the adjoining areas. A permissible alternative to the sill or ramp is an open-grated trench, which drains to a safe location, across the width of the opening inside of room.

4-4.1.3 Wood at least 1 in. (2.5 cm) nominal thickness may be used for shelving, racks, dunnage, scuffboards, floor overlay, and similar installations.

4-4.1.4 Storage in inside rooms shall comply with the following:

Automatic Fire Protection* Provided	Fire Resistance	Maximum Floor Area	Total Allowable Quantities—Gallons/ Sq Ft/Floor Area
Yes	2 hr	500 sq ft	10
No	2 hr	500 sq ft	4**
Yes	1 hr	150 sq ft	5
No	1 hr	150 sq ft	2

SI Units: 1 sq ft = 0.09 m^2; 1 gal = 3.8 L.

*Fire protection system shall be sprinkler, water spray, carbon dioxide, dry chemical, halon, or other approved system.

**Total allowable quantities of Class IA and IB liquids shall not exceed that permitted in Table 4-4.2.7 and the provisions of 4-4.2.10.

4-4.1.5 Electrical wiring and equipment located in inside rooms used for Class I liquids shall be suitable for Class I, Division 2 classified locations; for Class II and Class III liquids, shall be suitable for general use. (NFPA 70, *National Electrical Code®*, provides information on the design and installation of electrical equipment.)

4-4.1.6 Every inside room shall be provided with either a gravity or a continuous mechanical exhaust ventilation system. Mechanical ventilation shall be used if Class I liquids are dispensed within the room.

(a) Exhaust air shall be taken from a point near a wall on one side of the room and within 12 in. (30 cm) of the floor with one or more make-up inlets located on the opposite side of the room within 12 in. (30 cm) of the floor. The location of both the exhaust and inlet air openings shall be arranged to provide, as far as practicable, air

movements across all portions of the floor to prevent accumulation of flammable vapors. Exhaust from the room shall be directly to the exterior of the building without recirculation.

Exception: Recirculation is permitted where it is monitored continuously using a fail-safe system that is designed to automatically sound an alarm, stop recirculation, and provide full exhaust to the outside in the event that vapor-air mixtures in concentration over one-fourth of the lower flammable limit are detected.

If ducts are used, they shall not be used for any other purpose and shall comply with NFPA 91, *Standard for the Installation of Blower and Exhaust Systems for Dust, Stock, and Vapor Removal or Conveying*. If make-up air to a mechanical system is taken from within the building, the opening shall be equipped with a fire door or damper, as required in NFPA 91, *Standard for the Installation of Blower and Exhaust Systems for Dust, Stock, and Vapor Removal or Conveying*. For gravity systems, the make-up air shall be supplied from outside the building.

(b) Mechanical ventilation systems shall provide at least one cubic foot per minute of exhaust per square foot of floor area (1 m^3 per min per 3 m^2), but not less than 150 cfm (4 m^3 per min). The mechanical ventilation system for dispensing areas shall be equipped with an airflow switch or other equally reliable method that is interlocked to sound an audible alarm upon failure of the ventilation system.

4-4.1.7 In every inside room, an aisle at least 3 ft (0.90 m) wide shall be maintained so that no container is more than 12 ft (3.6 m) from the aisle. Containers over 30 gal (113.5 L) capacity storing Class I or Class II liquids shall not be stored more than one container high.

4-4.1.8 Where dispensing is being done in inside rooms, operations shall comply with the provisions of Chapter 5.

4-4.1.9 Basement Storage Areas. Class I liquids shall not be permitted in inside storage rooms in basement areas.

4-4.2 Cutoff Rooms and Attached Buildings.

4-4.2.1 Construction design of exterior walls shall provide ready accessibility for fire fighting operations through provision of access openings, windows, or lightweight noncombustible wall panels. Where Class IA or IB liquids are dispensed, or where Class IA liquids are stored in containers larger than one gallon, the exterior wall or roof construction shall be designed to include explosion-venting features, such as lightweight wall assemblies, lightweight roof assemblies, roof hatches, or windows of the explosion-venting type. (NFPA 68, *Guide for Venting of Deflagrations*, provides information on this subject.)

4-4.2.2 Where other portions of buildings or other properties are exposed, each opening in the exposing wall shall be protected with a listed 1½ hr (D) fire door installed in accordance with NFPA 80, *Standard for Fire Doors and Windows*, and the walls shall have a fire-resistance rating of not less than 2 hr.

4-4.2.3 Except as noted in 4-4.2.6, interior walls, ceiling, and floors shall have a fire-resistance rating of not less than 2 hr where floor area of the room or building exceeds 300 sq ft (27 m^2) or a fire-resistance rating of not less than one hour for a floor area of 300 sq ft (27 m^2) or less. Such construction shall comply with the test specifications given in NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials*. Walls shall be liquidtight at the floor level.

4-4.2.4 Openings in interior walls to adjacent rooms or buildings shall be in accordance with 4-4.1.2(a).

4-4.2.5 Curbs, scuppers, special drains, or other suitable means shall be provided to prevent the flow of liquids under emergency conditions into adjacent building areas except where the individual container capacity is 5 gal (18.9 L) or less or if the liquids stored are only Class III liquids. The drainage system, if used, shall have sufficient capacity to carry off expected discharge of water from fire protection systems and hose streams.

4-4.2.6 Roofs of attached buildings, one story in height, may be lightweight, noncombustible construction if the separating interior wall as specified in 4-4.2.3 has a minimum 3-ft (0.90-m) parapet.

4-4.2.7 Unprotected storage in cutoff rooms and attached buildings shall comply with Table 4-4.2.7. (*See 4-4.2.10 for mixed storage of liquids.*)

Table 4-4.2.7 Indoor Unprotected Storage of Liquids in Containers and Portable Tanks

	Container Storage			Portable Tank Storage		
Class	Max. Pile Height (ft)	Max. Quant. per Pile (gal)	Max. Total Quant. (gal)*	Max. Pile Height (ft)	Max. Quant. per Pile (gal)	Max. Total Quant. (gal)*
IA	5	660	660	—	Not Permitted	—
IB	5	1,375	1,375	7	2,000	2,000
IC	5	2,750	2,750	7	4,000	4,000
II	10	4,125	8,250	7	5,500	11,000
IIIA	15	13,750	27,500	7	22,000	44,000
IIIB	15	13,750	55,000	7	22,000	88,000

SI Units: 1 ft = 0.30 m; 1 gal = 3.8 L.

*Applies only to cutoff rooms and attached buildings.

4-4.2.8 Protected storage in cutoff rooms and attached buildings shall comply with Section 4-6 as applicable. (*See 4-4.2.10 for mixed storage of liquids.*)

4-4.2.9 Wood at least 1-in. (2.5-cm) nominal thickness may be used for shelving, racks, dunnage, scuffboards, floor overlay, and similar installations.

4-4.2.10 Where two or more classes of liquids are stored in a single pile or rack section, the maximum quantities and height of storage permitted in that pile or rack section shall be the smallest of the two or more separate quantities and heights. The maximum total quantities permitted shall be limited to a sum of proportional amounts that each class of liquid present bears to the maximum total permitted for its respective class; sum of proportional amounts not to exceed 100 percent.

4-4.2.11 Dispensing operations of Class I or Class II liquids are not permitted in cutoff rooms or attached buildings exceeding 1000 sq ft (93 m^2) floor area. In rooms where dispensing of Class I liquids is permitted, electrical systems shall comply with 4-4.1.5, except that within 3 ft (0.90 m) of a dispensing nozzle area, the electrical system shall be suitable for Class I, Division 1; ventilation shall be provided per 4-4.1.6; and operations shall comply with the provisions of Chapter 5.

4-4.2.12 Basement Storage Areas. Class I liquids shall not be permitted in the basement areas of cutoff rooms and attached buildings. Class II and Class IIIA liquids may be stored in basements provided that automatic sprinkler protection and other fire protection facilities are provided in accordance with Section 4-6.

4-5 Indoor Storage.

4-5.1 Basic Conditions.

4-5.1.1 The storage of any liquids shall not physically obstruct a means of egress. Class I liquids in other than separate inside storage areas or warehouses shall be so placed that a fire in the liquid storage would not preclude egress from the area.

4-5.1.2 The storage of liquids in containers or portable tanks shall comply with 4-5.2 through 4-5.7, as applicable. Where separate inside storage areas are required, they shall conform to Section 4-4. Where other factors substantially increase or decrease the hazard, the authority having jurisdiction may modify the quantities specified.

4-5.1.3 Liquids used for building maintenance painting or other similar infrequent maintenance purposes may be stored temporarily in closed containers outside of storage cabinets or separate inside storage areas, if limited in amount, not to exceed a 10-day supply at anticipated rates of consumption.

4-5.1.4 Class I liquids shall not be stored in a basement, except as provided in 4-5.5.

4-5.2 Dwellings and Residential Buildings Containing Not More than Three Dwelling Units and Accompanying Attached and Detached Garages. Storage in excess of 25 gal (94.6 L) of Class I and Class II liquids combined shall be prohibited. In addition, storage in excess of 60 gal (227 L) of Class IIIA liquid shall be prohibited.

4-5.3 Assembly Occupancies, Buildings Containing More than Three Dwelling Units, and Hotels. Storage in excess of 10 gal (37.8 L) of Class I and Class II liquids combined or 60 gal (227 L) of Class IIIA liquids shall be in containers stored in storage cabinets, in safety cans, or in a separate inside storage area not having an opening communicating with that portion of the building used by the public.

4-5.4 Office, Educational, and Institutional Occupancies. Storage shall be limited to that required for operation of office equipment, maintenance, demonstration, and laboratory work. This storage shall comply with the provisions of 4-5.4.1 through 4-5.4.4 except that the storage for industrial and educational laboratory work shall comply with NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals.*

4-5.4.1 Containers for Class I liquids outside of a separate inside storage area shall not exceed a capacity of 1 gal (3.8 L) except that safety cans can be of 2 gal (7.6 L) capacity.

4-5.4.2 Not more than 10 gal (37.8 L) of Class I and Class II liquids combined shall be stored in a single fire area outside of a storage cabinet or a separate inside storage area unless in safety cans.

4-5.4.3 Not more than 25 gal (94.6 L) of Class I and Class II liquids combined shall be stored in a single fire area in safety cans outside of a separate inside storage area or storage cabinet.

4-5.4.4 Not more than 60 gal (227 L) of Class IIIA liquids shall be stored outside of a separate inside storage area or storage cabinet.

4-5.5 Mercantile Occupancies, Retail Stores, and Other Related Areas Accessible to the Public.

4-5.5.1* In display areas that are accessible to the public, the storage of Class I, Class II, and Class IIIA liquids shall be limited to quantities needed for display and normal merchandising purposes but shall not exceed the limits as given by the following (*also see Table A-4-5.5.1*):

(a) In protected display areas, the total aggregate quantity of Class I, II, and IIIA liquids shall not exceed 2 gal per sq ft (81 L per m^2) of gross floor area, but, except for basement display areas, the quantity of Class IA liquids shall not exceed 1 gal per sq ft (40 L per m^2) of gross floor area. In basement display areas, the storage of Class IA liquids shall be prohibited.

(b) In unprotected display areas on other than the ground floor, the total aggregate quantity of Class IB, IC, II, and IIIA liquids shall not exceed 1 gal per sq ft (40 L per m^2) of gross floor area, and the storage of

Class IA liquids shall be prohibited. In unprotected ground floor display areas, the total aggregate quantity of Class I, II, and IIIA liquids shall not exceed 2 gal per sq ft (81 L per m^2) of gross floor area, but the quantity of Class IA liquids shall not exceed 1 gal per sq ft (40 L per m^2) of gross floor area.

"Protected" shall mean protected with automatic sprinklers installed at least in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, requirements for Ordinary Hazard Group 2 Occupancies. The gross floor area used for computing the maximum quantity permitted shall be considered as that portion of the floor actually being used for merchandising liquids and immediately adjacent aisles.

4-5.5.2 The aggregate quantity of additional stock in areas not accessible to the public shall not exceed the greater of that which would be permitted if the area were accessible to the public, or 60 gal (227 L) of Class IA, 120 gal (454 L) of Class IB, 180 gal (681 L) of Class IC, 240 gal (908 L) of Class II, or 660 gal (2498 L) of Class IIIA liquids, or 240 gal (908 L) in any combination of Class I and Class II liquids subject to the limitations of the individual class. These quantities may be doubled for areas protected as defined in 4-5.5.1. Storage of Class IA liquids shall be prohibited in basement storage areas.

4-5.5.3 Quantities in excess of those permitted in 4-5.5.2 shall be stored in accordance with other appropriate sections of this code.

4-5.5.4 Containers shall not be stacked more than 3 ft (0.90 m) or 2 containers high, whichever is the greater, unless on fixed shelving or otherwise satisfactorily secured.

4-5.5.5 Shelving shall be of stable construction and of sufficient depth and arrangement such that containers displayed thereon shall not easily be displaced.

4-5.5.6 Leaking containers shall be removed immediately to an adequately ventilated area, and the contents transferred to an undamaged container.

4-5.6 General-Purpose Warehouses. (*See 1-2, "Definitions."*)

4-5.6.1 General-purpose warehouses shall be separate, detached buildings or shall be separated from other type occupancies by a standard 4-hr fire wall, or, if approved, a fire partition having a fire-resistance rating of not less than 2 hr. Each opening in a fire wall shall be protected with an automatic-closing, listed 3-hr (A) fire door with the fusible link or other automatic actuating mechanism located in the opening or on both sides of the opening. Each opening in a fire partition shall be protected with an automatic-closing, listed 1½-hr (B) fire door. The doors shall be installed in accordance with NFPA 80, *Standard for Fire Doors and Windows*.

4-5.6.2 Warehousing operations that involve storage of liquids shall be restricted to separate inside storage areas or to liquid warehouses in accordance with Section 4-4 or 4-5.7, as applicable, except as provided in 4-5.6.3.

4-5.6.3 Class IB and IC liquids in containers of 1 gal (3.8 L) or less capacity, Class II liquids in containers of 5 gal (18.9 L) or less capacity, and Class III liquids in containers of 60 gal (227 L) or less capacity may be stored in warehouses handling combustible commodities, as defined in the scope of NFPA 231, *Standard for General Storage*, provided that the storage area is protected with automatic sprinklers in accordance with the provisions of this standard for 20 ft (6 m) storage of Class IV commodities and the quantities and height of liquid storage are limited to:

(a) Class IA liquids — not permitted,

(b) Class IB & IC 660 gal (2498 L) — 5 ft (1.5 m) high,

(c) Class II 1375 gal (5204 L) — 5 ft (1.5 m) high,

(d) Class IIIA 2750 gal (10 409 L) — 10 ft (3.0 m) high,

(e) Class IIIB 13,750 gal (52 044 L) — 15 ft (4.6 m) high.

The liquid storage shall also conform to 4-5.6.4, 4-5.6.5, 4-5.6.6, 4-5.6.7, and 4-5.6.8.

4-5.6.4 Liquids in Plastic Containers. Effective September 1, 1991, Class I and Class II liquids in plastic containers shall not be stored in general-purpose warehouses, but shall be stored in separate inside rooms or liquid warehouses in accordance with Section 4-4 or 4-5.7, as applicable.

Exception No. 1: Liquids in plastic containers may be stored in general-purpose warehouses in accordance with protection and storage limitations specified in 4-5.6.3 as follows:

(a) Products containing not more than 50 percent by volume of water-miscible liquids and with the remainder of the solution being not flammable when packaged in individual containers,

(b) Water-miscible liquids containing more than 50 percent by volume in individual containers not exceeding 16 oz. capacity.

Exception No. 2: Class I and Class II liquids in plastic containers may be stored in a general purpose warehouse if the packaging systems are listed and labeled for use with these materials. Other provisions of 4-5.6 shall also apply.*

4-5.6.5 Basement Storage Areas. Class I liquids shall not be permitted in the basement areas of buildings. Class II and Class IIIA liquids may be stored in basements provided that automatic sprinkler protection and other fire protection facilities are provided in accordance with Section 4-6.

4-5.6.6 Palletized, Solid Pile, or Rack Storage. Liquids in containers may be stored on pallets, in solid piles, or on racks subject to the quantity and height limits of 4-5.6.3 provided the protection is in accordance with Section 4-6, as applicable.

4-5.6.7 Separation and Aisles. Palletized or solid pile storage shall be arranged so that piles permitted in 4-5.6.3 are separated from each other by at least 4-ft (1.2-m) aisles. Aisles shall be provided so that no container is more than 12 ft (3.6 m) from an aisle. Where liquids are stored on racks, a minimum 4-ft (1.2-m) wide aisle shall be provided

between adjacent rows of racks and adjacent storage of liquids. Main aisles shall be a minimum of 8 ft (2.4 m) wide. Where ordinary combustible commodities are stored in the same area as liquids in containers, the minimum distance between the two types of storage shall be 8 ft (2.4 m).

4-5.6.8 Mixed Storage. Liquids shall not be stored in the same pile or in the same rack sections as ordinary combustible commodities. Where liquids are packaged together with ordinary combustibles, as in kits, the storage shall be considered on the basis of whichever commodity predominates. When two or more classes of liquids are stored in a single pile or single rack section, the maximum quantities permitted in the pile or rack section shall be the smallest of the two or more separate maximum quantities, and the height of storage permitted in that pile or rack section shall be the least of the two or more separate heights. The maximum total quantities permitted shall be limited to the sum of proportional amounts that each class of liquid present bears to the maximum total permitted for its respective class. The sum of proportional amounts shall not exceed 100 percent.

4-5.7 Liquid Warehouses. (*See 1-2, "Definitions."*)

4-5.7.1 Liquid warehouses shall be separate, detached buildings or shall be separated from other type occupancies by standard 4-hr fire walls, with communicating openings protected on each side of the wall with automatic-closing, listed 3-hr (A) fire doors. Fire doors shall be installed in accordance with NFPA 80, *Standard for Fire Doors and Windows.*

4-5.7.2 If the warehouse building is located more than 10 ft (3 m) but less than 50 ft (15 m) from an important building or line of adjoining property that can be built upon, the exposing wall shall have a fire-resistance rating of at least 2 hr with each opening protected with a listed 1½-hr (D) fire door.

4-5.7.3 If the warehouse is located 10 ft (3 m) or less from an important building or line of adjoining property that can be built upon, the exposing wall shall have a fire-resistance rating of 4 hr with each opening protected with a listed 3-hr (A) fire door.

4-5.7.4 An attached warehouse, having communicating openings in the required 4-hr fire wall separation from the adjacent building area, shall have these openings protected by:

(a) Normally closed, listed 3-hr (A) fire doors on each side of the wall. These doors may be arranged to stay open during material handling operations, only if the doors are designed to close automatically in a fire emergency by provision of listed closure devices.

(b) Noncombustible, liquidtight raised sills or ramps, at least 4 in. (10 cm) in height, or other design features to prevent flow of liquids to the adjoining area.

4-5.7.5 Fire doors shall be installed in accordance with NFPA 80, *Standard for Fire Doors and Windows.*

4-5.7.6 The total quantity of liquids within a liquid warehouse shall not be restricted. The maximum pile heights and maximum quantity per pile, arranged as palletized and/or solid pile storage, shall comply with Table 4-4.2.7 if unprotected, or Table 4-6.1(a) if protected in accordance with Section 4-6. The storage heights of containers on protected racks shall comply with Table 4-6.1 (b), as applicable.

Exception: An unprotected liquid warehouse located a minimum of 100 ft (30 m) from exposed buildings or adjoining property that can be built upon is not required to conform to Table 4-4.2.7, if there is protection for exposures. Where protection for exposures is not provided, a minimum 200 ft (61 m) distance is required.

4-5.7.7 Class I liquids shall not be permitted in the basement areas of liquid warehouses. Class II and Class IIIA liquids may be stored in basements provided that automatic sprinkler protection and other fire protection facilities are provided in accordance with Section 4-6.

4-5.7.8 Limited amounts of combustible commodities, as defined in the scope of NFPA 231, *Standard for General Storage*, and NFPA 231C, *Standard for Rack Storage of Materials*, may be stored in liquid warehouses if protection is provided in accordance with Section 4-6 and if the ordinary combustibles, other than those used for packaging the liquids, are separated a minimum of 8 ft (2.4 m) horizontally, by aisles or open racks, from the liquids in storage.

4-5.7.9 Empty or idle combustible pallet storage shall be limited to a maximum pile size of 2500 sq ft (232 m^2) and to a maximum storage height of 6 ft (1.8 m). Idle pallet storage shall be separated from liquids by at least 8-ft (2.4-m) wide aisles. However, pallet storage in accordance with NFPA 231, *Standard for General Storage*, shall be acceptable.

4-5.7.10 Containers in piles shall be separated by pallets or dunnage to provide stability and to prevent excessive stress on container walls. Portable tanks stored over one tier high shall be designed to nest securely, without dunnage. (*See NFPA 386, Standard for Portable Shipping Tanks for Flammable and Combustible Liquids, for information on portable tank design.*) Materials handling equipment shall be suitable to handle containers and tanks safely at the upper tier level.

4-5.7.11 No container or portable tank shall be stored closer than 36 in. (0.90 m) to the nearest beam, chord, girder, or other roof member in an unprotected warehouse.

4-5.7.12 Solid pile and palletized storage shall be arranged so that piles are separated from each other by at least 4 ft (1.2 m). Aisles shall be provided so that no container or tank is more than 12 ft (3.6 m) from an aisle. Where storage on racks exists as permitted in this code, a minimum 4-ft (1.2-m) wide aisle shall be provided between adjacent rows of racks and any adjacent storage of liquids. Main aisles shall be a minimum of 8 ft (2.4 m) wide, and access shall be maintained to all doors required for egress.

4-5.7.13 Mixed Storage. When two or more classes of liquids are stored in a single pile, the maximum quantity permitted in that pile shall be the smallest of the two or more

separate maximum quantities and the heights of storage permitted in that pile shall be the least of the two or more separate heights as given in Tables 4-4.2.7 or 4-6.1 (a), as applicable. When two or more classes of liquids are stored in the same racks as permitted in this code, the maximum height of storage permitted shall be the least of the two or more separate heights given in Table 4-6.1 (b).

4-5.7.14 For new liquid warehouses, where automatic sprinkler protection is provided, curbs, scuppers, special drains, or other suitable means shall be provided to prevent the flow of liquids, under emergency conditions throughout the building. The drainage system, if used, shall have sufficient capacity to carry off expected discharge of water from fire protection systems and hose streams.

4-6 Protection Requirements for Protected Storage of Liquids.

4-6.1 Containers and portable tanks storing flammable and combustible liquids may be stored in the quantities and arrangements specified in Tables 4-6.1(a) and 4-6.1(b), provided the storage is protected in accordance with 4-6.2 and 4-6.5, as applicable.

Table 4-6.1(a) Storage Arrangements for Protected Palletized or Solid Pile Storage of Liquids in Containers and Portable Tanks

Class	Storage Level	Max. Storage Height (ft)		Max. Quantity per Pile (gal.)		Max. Quantity (gal)**	
		Containers	Port. Tanks	Containers	Port. Tanks	Containers	Port. Tanks
IA	Ground Floor	5	—	3,000	—	12,000	—
	Upper Floors	5	—	2,000	—	8,000	—
	Basements	——Not Permitted——		—	—	—	—
IB	Ground Floor	6½	7	5,000	20,000	15,000	40,000
	Upper Floors	6½	7	3,000	10,000	12,000	20,000
	Basements	——Not Permitted——		—	—	—	—
IC	Ground Floor	6½*	7	5,000	20,000	15,000	40,000
	Upper Floors	6½*	7	3,000	10,000	12,000	20,000
	Basements	——Not Permitted——		—	—	—	—
II	Ground Floor	10	14	10,000	40,000	25,000	80,000
	Upper Floors	10	14	10,000	40,000	25,000	80,000
	Basements	5	7	7,500	20,000	7,500	20,000
III	Ground Floor	20	14	15,000	60,000	55,000	100,000
	Upper Floors	20	14	15,000	60,000	55,000	100,000
	Basements	10	7	10,000	20,000	25,000	40,000

SI Units: 1 ft = 0.30 m; 1 gal = 3.8 L.

*These height limitationsmay be increased to 10 ft for containers of 5 gal or less in capacity.

**Applies only to cutoff rooms and attached buildings.

NOTE: See Section 4-6 for protection requirements as applicable to this type of storage.

Table 4-6.1(b) Storage Arrangements for Protected Rack Storage of Liquids in Containers

Class	Type Rack	Storage Level	Max. Storage Height (ft)	Max. Quantity (gal)[2,3]
			Containers	Containers
IA	Double Row or Single Row	Ground Floor	25	7,500
		Upper Floor	15	4,500
		Basements	Not Permitted	—
IB	Double Row or Single Row	Ground Floor	25	15,000
IC		Upper Floor	15	9,000
		Basements	Not Permitted	—
II	Double Row or Single Row	Ground Floor	25	24,000
		Upper Floor	25	24,000
		Basements	15	9,000
III	Multi-Row Double Row or Single Row	Ground Floor	40	55,000
		Upper Floor	20	55,000
		Basements	20	25,000

SI Units: 1 ft = 0.30 m; 1 gal = 3.8 L.

NOTE 1: See Section 4-6 for protection requirements as applicable to this type of storage.

NOTE 2: Maximum quantity allowed on racks in cutoff rooms and attached buildings (*see 4-4.2*).

NOTE 3: Maximum quantity allowed per rack section in liquid warehouses (*see 4-5.7*).

4-6.1.1 Other quantities and arrangements may be used where suitably protected and approved by the authority having jurisdiction.

4-6.2 Where automatic sprinklers are used, they shall be installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, and approved by the authority having jurisdiction. (*For additional information, see Appendix D.*)

4-6.2.1 Other systems such as automatic foam-water systems, automatic water-spray systems, or other combinations of systems may be considered acceptable if approved by the authority having jurisdiction. (*For additional information, see Appendix D.*)

4-6.3 Racks storing Class I or Class II liquids shall be either single-row or double-row as described in NFPA 231C, *Standard for Rack Storage of Materials.*

4-6.4 Ordinary combustibles other than those used for packaging the liquids shall not be stored in the same rack section as liquids and shall be separated a minimum of 8 ft (2.4 m) horizontally, by aisles or open racks, from liquids stored in racks.

4-6.5 In-rack sprinklers shall be installed in accordance with the provisions of NFPA 231C, *Standard for Rack Storage of Materials*, except as modified by 4-6.2. Alternate lines of in-rack sprinklers shall be staggered. Multiple levels of in-rack sprinkler heads shall be provided with water shields unless otherwise separated by horizontal barriers or unless the sprinkler heads are listed for such installations.

4-7 Fire Control.

4-7.1 Suitable fire extinguishers or preconnected hose lines, either 1½-in. (3.8-cm) lined or 1-in. (2.5-cm) hard rubber, shall be provided where liquids are stored. Where 1½-in. (3.8-cm) fire hose is used, it shall be installed in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*.

4-7.1.1 At least one portable fire extinguisher having a rating of not less than 20-B shall be located outside of, but not more than 10 ft (3 m) from, the door opening into any separate inside storage area.

4-7.1.2 At least one portable fire extinguisher having a rating of not less than 20-B shall be located not less than 10 ft (3 m), nor more than 50 ft (15 m), from any Class I or Class II liquid storage area located outside of a separate inside storage area.

4-7.1.3 In protected general purpose and liquid warehouses, hand hose lines shall be provided in sufficient number to reach all liquid storage areas.

4-7.1.4 The water supply shall be sufficient to meet the fixed fire protection demand, plus a total of at least 500 gal (1892 L) per minute for inside and outside hose lines. [*See Tables D-4-6.2(a), (b), and (c).*]

4-7.2 Control of Ignition Sources. Precautions shall be taken to prevent the ignition of flammable vapors. Sources of ignition include but are not limited to: open flames; lightning; smoking; cutting and welding; hot surfaces; frictional heat; static, electrical, and mechanical sparks; spontaneous ignition, including heat-producing chemical reactions; and radiant heat.

4-7.3 Dispensing of Class I and Class II liquids in general-purpose or liquid warehouses shall not be permitted unless the dispensing area is suitably cut off from other ordinary combustible or liquid storage areas, as specified in Section 4-4, and otherwise conforms with the applicable provisions of Section 4-4.

4-7.4 Materials with a water reactivity degree of 2 or higher as outlined in NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*, shall not be stored in the same area with other liquids.

4-7.5 Power-operated industrial trucks used to move containers of Class I liquids shall be selected, maintained, and operated in accordance with NFPA 505, *Firesafety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation*.

4-8 Outdoor Storage.

4-8.1 Outdoor storage of liquids in containers and portable tanks shall be in accordance with Table 4-8, as qualified by 4-8.1.1 through 4-8.1.4 and 4-8.2, 4-8.3, and 4-8.4.

4-8.1.1 When two or more classes of materials are stored in a single pile, the maximum gallonage in that pile shall be the smallest of the two or more separate gallonages.

4-8.1.2 No container or portable tank in a pile shall be more than 200 ft (60 m) from a 12-ft (3.6-m) wide access way to permit approach of fire control apparatus under all weather conditions.

Table 4-8 Outdoor Liquid Storage in Containers and Portable Tanks

	1		2		3	4	5
Class	Container Storage-Max. per Pile		Portable Tank Storage Max. per Pile Gallons (l)		Distance between Piles or Racks (ft)	Distance to Property Line that Can Be Built Upon (ft)(2)(3)	Distance to Street, Alley, or a Public Way (ft)(3)
	Gallons (1) (4)	Height (ft)	Gallons (1) (4)	Height (ft)			
IA	1,100	10	2,200	7	5	50	10
IB	2,200	12	4,400	14	5	50	10
IC	4,400	12	8,800	14	5	50	10
II	8,800	12	17,600	14	5	25	5
III	22,000	18	44,000	14	5	10	5

SI Units: 1 ft = 0.30 m; 1 gal = 3.8 L.

NOTES: (1) See 4-8.1.1 regarding mixed class storage.
(2) See 4-8.1.3 regarding protection for exposures.
(3) See 4-8.1.4 for smaller pile sizes.
(4) For storage in racks, the quantity limits per pile do not apply, but the rack arrangement shall be limited to a maximum of 50 feet in length and 2 rows or 9 feet in depth.

4-8.1.3 The distances listed in Table 4-8 apply to properties that have protection for exposures as defined. If there are exposures, and such protection for exposures does not exist, the distances in column 4 shall be doubled.

4-8.1.4 When total quantity stored does not exceed 50 percent of maximum per pile, the distances in columns 4 and 5 may be reduced 50 percent, but to not less than 3 ft (0.90 m).

4-8.2 A maximum of 1100 gal (4163 L) of liquids in closed containers and portable tanks may be stored adjacent to a building under the same management provided that:

(a) The adjacent building wall has an exterior fire resistance rating of 2 hours,

(b) There are no openings to areas at grade or above grade that are within 10 ft (3 m) horizontally of the storage,

(c) There are no openings directly above the storage, and

(d) There are no openings to areas below grade within 50 ft (15 m) horizontally of the storage.

Exception: The above provisions are not necessary if the building in question is limited to one story, is of fire-resistive or noncombustible construction, is devoted principally to the storage of liquids, and is acceptable to the authority having jurisdiction.

4-8.2.1 The quantity of liquids stored adjacent to a building protected in accordance with 4-8.2 may exceed that permitted in 4-8.2, provided the maximum quantity per pile does not exceed 1100 gal (4163 L) and each pile is separated by a 10-ft (3-m) minimum clear space along the common wall.

4-8.2.2 Where the quantity stored exceeds the 1100 gal (4163 L) permitted adjacent to the building given in 4-8.2, or the provisions of 4-8.2 cannot otherwise be met, a minimum distance in accordance with column 4 of Table 4-8 shall be maintained between buildings and the nearest container or portable tank.

4-8.3 The storage area shall be graded in a manner to divert possible spills away from buildings or other exposures or shall be surrounded by a curb at least 6 in. (15 cm) high. When curbs are used, provisions shall be made for draining of accumulations of ground or rain water or spills of liquids. Drains shall terminate at a safe location and shall be accessible to operation under fire conditions.

4-8.4 The storage area shall be protected against tampering or trespassers where necessary and shall be kept free of weeds, debris, and other combustible materials not necessary to the storage.

4-9 Hazardous Materials Storage Lockers Located Outside.

4-9.1* This section shall apply to the outside storage of flammable and combustible liquids in containers, in hazardous material storage lockers (hereinafter referred to as lockers).

4-9.2 The design and construction of a locker shall meet all applicable local, state, and federal regulations and requirements and shall be subject to the approval of the authority having jurisdiction. Movable prefabricated structures that have been examined, listed, or labeled by an organization acceptable to the authority having jurisdiction for use as a hazardous materials storage facility may be acceptable.

4-9.2.1 Lockers governed by this standard shall not exceed 1500 sq ft gross floor area. Vertical stacking of lockers shall not be permitted.

4-9.2.2 When electrical wiring and equipment is required, it shall comply with 4-4.1.5 of this code.

4-9.2.3 When dispensing or filling is permitted inside a locker, operations shall comply with the provisions of Chapter 5.

4-9.2.4 Ventilation shall be provided in accordance with 4-4.1.6.

4-9.2.5 Spill or Leakage Control. Lockers shall include a spill containment system to prevent the flow of liquids from the structure under emergency conditions. The containment system shall have sufficient capacity to contain 10 percent of the volume of containers allowed or the volume of the largest container, whichever is greater.

4-9.3 Designated sites shall be provided for the location and use of lockers and shall be subject to the approval of the authority having jurisdiction. The designated sites shall be arranged to provide at least the minimum separation distance between individual lockers, distance from locker to property line that is or can be built upon, and distance from locker to nearest side of public ways or to important buildings on the same property, as given in Table 4-9.3 and explanatory notes 1, 2, 3, and 4 as applicable.

4-9.3.1 Once the designated site is approved, it shall not be changed without the approval of the authority having jurisdiction.

4-9.3.2 More than one locker shall be as permitted on a designated site, provided that separation distance individual lockers is maintained in accordance with Table 4-9.3.

4-9.3.3 The approved designated storage site shall be protected from tampering or trespassing when the area is accessible to the general public.

4-9.3.4 Storage Practices.

4-9.3.4.1 Containers of liquid in their original shipping packages shall be permitted to be stored either palletized or solid piled. Unpackaged containers shall be permitted to be stored on shelves or directly on the floor of the locker. Containers over 30 gal (113.5 L) capacity storing Class I or

Class II liquids shall not be stored more than two containers high. In all cases, the storage arrangement shall provide unrestricted access to and egress from the locker.

4-9.3.4.2 No other flammable or combustible material storage shall be permitted within the designated site approved for lockers.

4-9.3.4.3 Placarding or warning signs for lockers shall be in accordance with applicable local, state, and federal regulations or with NFPA 704.

Table 4-9.3 Designated Sites

Area of Designated Site (1) (sq ft)	Distance between Individual Lockers (ft)	Distance from Locker to Property Line that Is or Can Be Built Upon (2) (ft)	Distance from Locker to Nearest Side of Public Ways or to Important Buildings on Same Property (2) (3) (ft)
≤100	5	10	5
>100≤500	5	20	10
>500≤1500(4)	5	30	20

NOTES:

(1) Site area limits are intended to differentiate the relative size and thus the number of lockers that may be located in one designated site.

(2) Distances apply to properties that have protection for exposures, as defined. If there are exposures and such protection for exposures does not exist, the distances shall be doubled.

(3) When the exposed building has an exterior wall, facing the designated site, that has a fire resistance rating of at least 2 hr and has no openings to above grade areas within 10 ft horizontally and no openings to below grade areas within 50 ft horizontally of the designated area, the distances can be reduced to half of those shown in the table, except they shall never be less than 5 ft.

(4) When a single locker has a gross single story floor area that will require a site area limit of greater than 1500 sq ft or when multiple units exceed the area limit of 1500 sq ft, the authority having jurisdiction shall be consulted for approval of distances.

Chapter 5 Operations

5-1 Scope.

5-1.1 This chapter applies to operations involving the use or handling of liquids either as a principal or incidental activity, except as covered elsewhere in this code or in other NFPA standards.

5-1.2 The provisions of this chapter relate to the control of hazards of fire involving liquids. These provisions may not provide adequate protection for operations involving hazardous materials or chemical reactions nor do they consider health hazards resulting from exposure to such materials.

5-1.3 Provisions of this chapter shall not prohibit the use of movable tanks in conjunction with the dispensing of flammable or combustible liquids into fuel tanks of motorized equipment outside on premises not accessible to the public. Such uses shall only be made with the approval of the authority having jurisdiction.

5-2 General. Liquid processing operations shall be located and operated so that they do not constitute a significant fire or explosion hazard to life, to property of others, or to important buildings or facilities within the same plant. Specific requirements are dependent on the inherent risk in the operations themselves, including the liquids being processed, operating temperatures and pressures, and the capability to control any liquid or vapor releases or fire incidents that might occur. The interrelationship of the many factors involved must be based on good engineering and management practices to establish suitable physical and operating requirements. (*See 5-5.1.3.*)

5-3 Facility Design.

5-3.1 Location.

5-3.1.1 The minimum distance of a processing vessel to adjoining property or to the nearest important building on the same property shall be based on the stability of the liquid and vessel capacity and shall be in accordance with Table 5-3.1.1, except as modified in 5-3.1.2.

Table 5-3.1.1 Location of Processing Vessels from Property Lines and Nearest Important Building on the Same Property Where Protection for Exposures Is Provided

Vessel Maximum Operating Liquid Capacity (gal)	Minimum Distance from Property Line that Is or Can Be Built Upon, Including Opposite Side of Public Way (ft)				Minimum Distance from Nearest Side of Any Public Way or from Nearest Important Building on Same Property that Is Not an Integral Part of the Process (ft)			
	Stable Liquid Emergency Relief		*Unstable Liquid Emergency Relief*		*Stable Liquid Emergency Relief*		*Unstable Liquid Emergency Relief*	
	Not Over 2.5 psig	Over 2.5 psig	Not Over 2.5 psig	Over 2.5 psig	Not Over 2.5 psig	Over 2.5 psig	Not Over 2.5 psig	Over 2.5 psig
275 or less	5	10	15	20	5	10	15	20
276 to 750	10	15	25	40	5	10	15	20
751 to 12,000	15	25	40	60	5	10	15	20
12,001 to 30,000	20	30	50	80	5	10	15	20
30,001 to 50,000	30	45	75	120	10	15	25	40
50,001 to 100,000	50	75	125	200	15	25	40	60
Over 100,000	80	120	200	300	25	40	65	100

NOTE: Double all of above distances where protection for exposures is not provided.

5-3.1.2 Where process vessels are located in a building and the exterior wall facing the exposure (line of adjoining property that can be built upon or nearest important building on the same property) is greater than 25 ft (7.6 m) from the exposure and is a blank wall having a fire resistance rating of not less than 2 hr, any greater distances required in Table 5-3.1.1 may be waived. Where a blank wall having a fire resistance rating of not less than 4 hr is provided, distance requirements may be waived. In addition, when Class IA or unstable liquids are handled, the wall shall have explosion resistance in accordance with good engineering practice. (*See 5-3.2.7 relative to explosion relief of other walls of this building.*)

5-3.1.3 Other liquid processing equipment, such as pumps, heaters, filters, exchangers, etc., shall not be located closer than 25 ft (7.6 m) to property lines where the adjoining property is or can be built upon or to the nearest important building on the same property that is not an integral part of the process. This spacing requirement may be waived where exposures are protected as outlined in 5-3.1.2.

NOTE: Equipment operated at pressures over 1000 psig (7000 kPa) may require greater spacing.

5-3.1.4 Processing equipment in which unstable liquids are handled shall be separated from unrelated plant facilities that use or handle liquids by either 25-ft (7.6-m) clear spacing or a wall having a fire resistance rating of not less than 2 hr. The wall shall also have explosion resistance in accordance with good engineering practice.

5-3.1.5 Each process unit or building containing liquid-processing equipment shall be accessible from at least one side for fire fighting and fire control.

5-3.2 Construction.

5-3.2.1 Processing buildings or structures shall be of fire resistive or noncombustible construction, except that combustible construction may be used when automatic sprinklers or equivalent protection is provided, subject to approval of the authority having jurisdiction. (*See NFPA 220, Standard on Types of Building Construction.*)

5-3.2.2 Where walls are required for separation of processing operations from other occupancies or property lines, they shall have a fire resistance rating of at least 2 hr. In addition, when Class IA or unstable liquids are being stored or processed, the separating wall shall have explosion resistance in accordance with good engineering practice. (*See 5-3.2.7 relative to explosion relief of other walls of this building or area.*)

5-3.2.3 Class I liquids shall not be handled or used in basements. Where Class I liquids are handled or used above grade within buildings with basements or closed pits into which flammable vapors may travel, such below grade areas shall be provided with mechanical ventilation designed to prevent the accumulation of flammable vapors. Means shall be provided to prevent liquid spills from running into basements.

5-3.2.4 Provision for smoke and heat venting may be desirable to assist access for fire fighting. (NFPA 204M, *Guide for Smoke and Heat Venting*, provides information on this subject.)

5-3.2.5 Areas shall have exit facilities arranged to prevent occupants from being trapped in the event of fire. NFPA *101, Life Safety Code*, provides information on the design of exit facilities. Exits shall not be exposed by the drainage facilities described in 5-3.4.

5-3.2.6 Adequate aisles shall be maintained for unobstructed movement of personnel and fire protection equipment.

5-3.2.7 Areas where Class IA or unstable liquids are processed shall have explosion venting through one or more of the following methods: (a) open air construction; (b) lightweight walls and/or roof; (c) lightweight wall pan-

els and roof hatches; (d) windows of explosion-venting type. (NFPA 68, *Guide for Venting of Deflagrations*, provides information on this subject.)

5-3.3 Ventilation.

5-3.3.1 Enclosed processing areas handling or using Class I liquids or Class II or Class III liquids at temperatures above their flash points shall be ventilated at a rate sufficient to maintain the concentration of vapors within the area at or below 25 percent of the lower flammable limit. This shall be confirmed by one of the following:

(a) Calculations based on the anticipated fugitive emissions (*see Appendix F for calculation method*), or

(b) Sampling of the actual vapor concentration under normal operating conditions.

The sampling shall be conducted at a 5-ft (1.5-m) radius from each potential vapor source extending to or toward the bottom and the top of the enclosed processing area. The vapor concentration used to determine the required ventilation rate shall be the highest measured concentration during the sampling procedure.

NOTE: Equipment in enclosed processing areas may deteriorate over time, and periodic sampling should be conducted to ensure that leakage rates have not increased or that the ventilation rate is adequate for any increase in leakage rates.

An acceptable alternate is to provide ventilation at a rate of not less than 1 cu ft per minute per sq ft of solid floor area (0.3 m^3 per min per m^2). Ventilation shall be accomplished by natural or mechanical ventilation, with discharge or exhaust to a safe location outside the building, without recirculation of the exhaust air.

Exception: Recirculation is permitted where it is monitored continuously using a fail-safe system that is designed to automatically sound an alarm, stop recirculation, and provide full exhaust to the outside in the event that vapor-air mixtures in concentration over one-fourth of the lower flammable limit are detected.

Provision shall be made for introduction of make-up air in such a manner as to avoid short-circuiting the ventilation. Ventilation shall be arranged to include all floor areas or pits where flammable vapors may collect. Where natural ventilation is inadequate, mechanical ventilation shall be provided and shall be kept in operation while flammable liquids are being handled. Local or spot ventilation may be needed for the control of special fire or health hazards. Such ventilation, if provided, can be utilized for up to 75 percent of the required ventilation. (NFPA 91, *Standard for the Installation of Blower and Exhaust Systems for Dust, Stock, and Vapor Removal or Conveying*, and NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, provide information on this subject.)

5-3.3.2 Equipment used in a building and the ventilation of the building shall be designed to limit flammable vapor-air mixtures under normal operating conditions to the interior of equipment and to not more than 5 ft (1.5 m) from equipment that exposes Class I liquids to the air. Examples of such equipment are dispensing stations, open centrifuges, plate and frame filters, open vacuum filters, and surfaces of open equipment.

5-3.4 Drainage.

5-3.4.1 Emergency drainage systems shall be provided to direct flammable or combustible liquid leakage and fire protection water to a safe location. This may require curbs, scuppers, or special drainage systems to control the spread of fire (*see 2-3.3*). (Appendix A of NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, provides information on this subject.)

5-3.4.2 Emergency drainage systems, if connected to public sewers or discharged into public waterways, shall be equipped with traps or separators.

5-3.4.3 A facility shall be designed and operated to prevent the normal discharge of flammable or combustible liquids to public waterways, public sewers, or adjoining property.

5-3.5 Electrical Equipment.

5-3.5.1 This section shall apply to areas where Class I liquids are stored or handled and to areas where Class II or Class III liquids are stored or handled at a temperature above their flash points (*see 1-1.3*).

5-3.5.2 All electrical equipment and wiring shall be of a type specified by, and installed in accordance with, NFPA 70, *National Electrical Code*.

5-3.5.3 So far as it applies, Table 5-3.5.3 shall be used to delineate and classify areas for the purpose of installation of electrical equipment under normal conditions. In the application of classified areas, a classified area shall not extend beyond a floor, wall, roof, or other solid partition that has no communicating openings. The designation of classes and divisions is defined in Chapter 5, Article 500, of NFPA 70, *National Electrical Code*. [*See NFPA 497A, Recommended Practice for Classification of Class I Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas, and NFPA 497M, Manual for Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous (Classified) Locations, for guidance.*]

5-3.5.4 The area classifications listed in Table 5-3.5.3 are based on the premise that the installation meets the applicable requirements of this code in all respects. Should this not be the case, the authority having jurisdiction shall have the authority to classify the extent of the area.

5-3.5.5 Where the provisions of 5-3.5.1, 5-3.5.2, 5-3.5.3, and 5-3.5.4 require the installation of electrical equipment suitable for Class I, Division 1 or Division 2 locations, ordinary electrical equipment including switchgear may be used if installed in a room or enclosure that is maintained under positive pressure with respect to the classified area. Ventilation make-up air shall not be contaminated. (NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*, provides details for these types of installations.)

5-3.5.6 For marine terminals handling flammable liquids, Figure 5-3.5.6 shall be used as a minimum basis to delineate and classify areas for the purpose of installation of electrical equipment.

Table 5-3.5.3 Electrical Area Classifications

Location	NEC Class I Division	Extent of Classified Area
Indoor equipment installed in accordance with 5-3.3.2 where flammable vapor-air mixtures may exist under normal operation	1	Area within 5 ft of any edge of such equipment, extending in all directions.
	2	Area between 5 ft and 8 ft of any edge of such equipment, extending in all directions. Also, area up to 3 ft above floor or grade level within 5 ft to 25 ft horizontally from any edge of such equipment.*
Outdoor equipment of the type covered in 5-3.3.2 where flammable vapor-air mixtures may exist under normal operation	1	Area within 3 ft of any edge of such equipment, extending in all directions.
	2	Area between 3 ft and 8 ft of any edge of such equipment, extending in all directions. Also area up to 3 ft above floor or grade level within 3 ft to 10 ft horizontally from any edge of such equipment.
Tank—Aboveground	1	Area inside dike where dike height is greater than the distance from the tank to the dike for more than 50 percent of the tank circumference.
Shell, Ends, or Roof and Dike Area	2	Within 10 ft from shell, ends, or roof of tank. Area inside dikes to level of top of dike.
Vent	1	Within 5 ft of open end of vent, extending in all directions.
	2	Area between 5 ft and 10 ft from open end of vent, extending in all directions.
Floating Roof	1	Area above the roof and within the shell.
Underground Tank Fill Opening	1	Any pit, box, or space below grade level, if any part is within a Division 1 or 2 classified area.
	2	Up to 18 in. above grade level, within a horizontal radius of 10 ft from a loose fill connection and within a horizontal radius of 5 ft from a tight fill connection.
Vent—Discharging Upward	1	Within 3 ft of open end of vent, extending in all directions.
	2	Area between 3 ft and 5 ft of open end of vent, extending in all directions.
Drum and Container Filling Outdoors, or Indoors with Adequate Ventilation	1	Within 3 ft of vent and fill openings, extending in all directions.
	2	Area between 3 ft and 5 ft from vent or fill opening, extending in all directions. Also, up to 18 in. above floor or grade level within a horizontal radius of 10 ft from vent or fill openings.
Pumps, Bleeders, Withdrawal Fittings, Meters and Similar Devices		
Indoors	2	Within 5 ft of any edge of such devices, extending in all directions. Also up to 3 ft above floor or grade level within 25 ft horizontally from any edge of such devices.
Outdoors	2	Within 3 ft of any edge of such devices, extending in all directions. Also up to 18 in. above grade level within 10 ft horizontally from any edge of such devices.
Pits		
Without Mechanical Ventilation	1	Entire area within pit if any part is within a Division 1 or 2 classified area.
With Adequate Mechanical Ventilation	2	Entire area within pit if any part is within a Division 1 or 2 classified area.
Containing Valves, Fittings, or Piping, and not within a Division 1 or 2 Classified Area	2	Entire pit.
Drainage Ditches, Seperators, Impouding Basins		
Outdoor	2	Area up to 18 inches above ditch, seperator, or basin. Also up to 18 inches above grade within 15 ft horizontally from any edge.
Indoor		Same as pits.

*The release of Class I liquids may generate vapors to the extent that the entire building, and possibly a zone surrounding it, should be considered a Class I, Division 2 location.

(continued)

Table 5-3.5.3, cont.

Location	NEC Class I Division	Extent of Classified Area
Tank Vehicle and Tank Car* Loading through Open Dome	1	Within 3 ft of edge of dome, extending in all directions.
	2	Area between 3 ft and 15 ft from edge of dome, extending in all directions.
Loading through Bottom Connections with Atmospheric Venting	1	Within 3 ft of point of venting to atmosphere, extending in all directions.
	2	Area between 3 ft and 15 ft from point of venting to atmosphere, extending in all directions. Also up to 18 in. above grade within a horizontal radius of 10 ft from point of loading connection.
Office and Rest Rooms	Ordinary	If there is any opening to these rooms within the extent of an indoor classified area, the room shall be classified the same as if the wall, curb, or partition did not exist.
Loading through Closed Dome with Atmospheric Venting	1	Within 3 ft of open end of vent, extending in all directions.
	2	Area between 3 ft and 15 ft of open end of vent, extending in all directions. Also within 3 ft of edge of dome, extending in all directions.
Loading through Closed Dome with Vapor Control	2	Within 3 ft of point of connection of both fill and vapor lines, extending in all directions.
Bottom Loading with Vapor Control Any Bottom Unloading	2	Within 3 ft of point of connections, extending in all directions. Also up to 18 in. above grade within a horizontal radius of 10 ft from point of connections.
Storage and Repair Garage for Tank Vehicles	1	All pits or spaces below floor level.
	2	Area up to 18 in. above floor or grade level for entire storage or repair garage.
Garages for Other than Tank Vehicles	Ordinary	If there is any opening to these rooms within the extent of an outdoor classified area, the entire room shall be classified the same as the area classification at the point of the opening.
Outdoor Drum Storage	Ordinary	
Indoor Warehousing Where There Is No Flammable Liquid Transfer	Ordinary	If there is any opening to these rooms within the extent of an indoor classified area, the room shall be classified the same as if the wall, curb, or partition did not exist.
Piers and Wharves		See Figure 5-3.5.6.

*When classifying extent of area, consideration shall be given to the fact that tank cars or tank vehicles may be spotted at varying points. Therefore, the extremities of the loading or unloading positions shall be used.

5-4 Liquid Handling, Transfer, and Use.

5-4.1 General.

5-4.1.1 Class I liquids shall be kept in closed tanks or containers when not actually in use. Class II and Class III liquids shall be kept in closed tanks or containers when ambient or process temperature is at or above their flash point.

5-4.1.2 Where liquids are used or handled, provisions shall be made to promptly and safely dispose of leakage or spills.

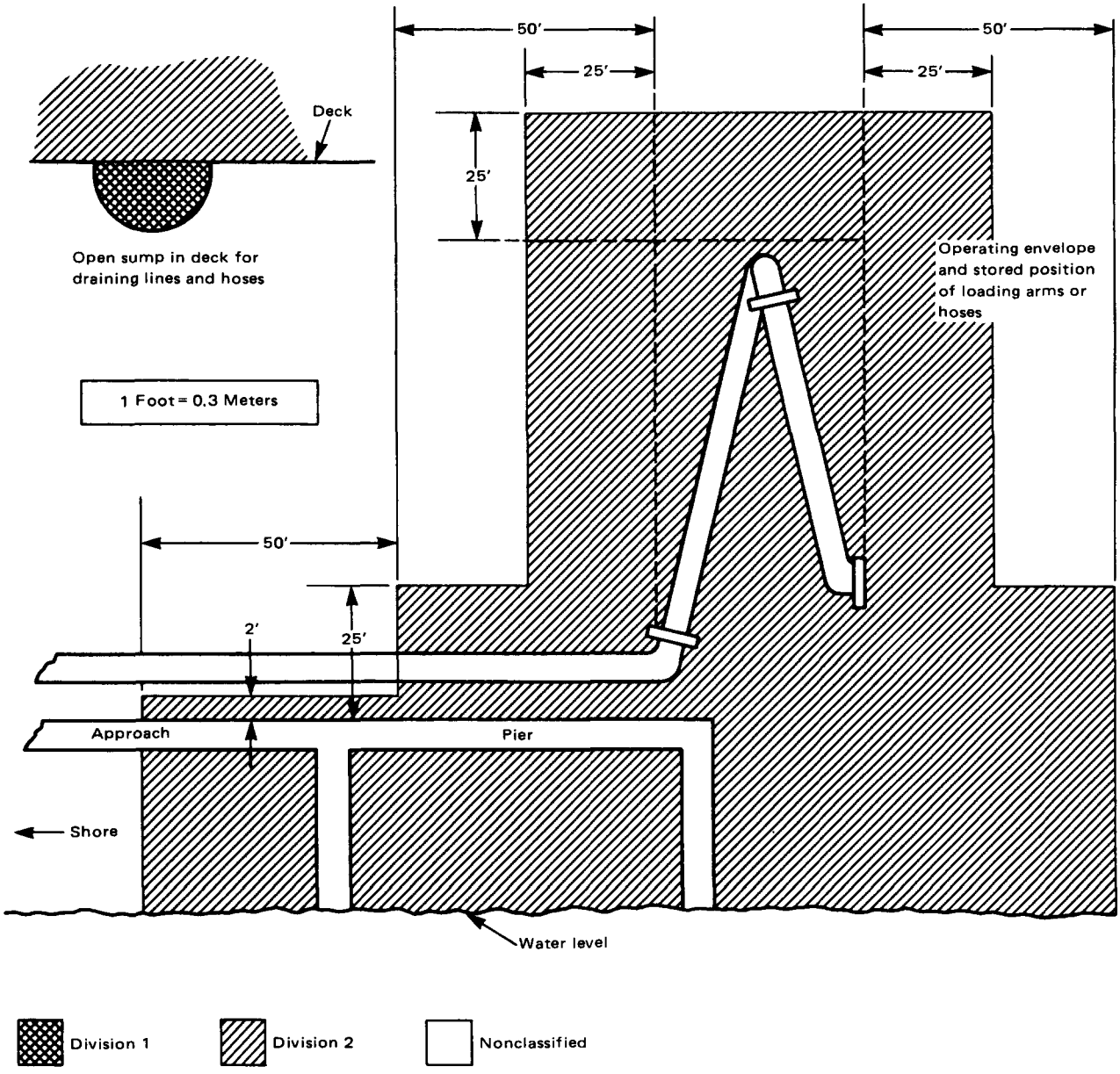
5-4.1.3 Class I liquids shall not be used outside closed systems where there are open flames or other ignition sources within the classified areas as set forth in Table 5-3.5.3.

5-4.1.4 Transferring liquids by means of pressurizing the container with air is prohibited. Transferring liquids by pressure of inert gas is permitted only if controls, including pressure-relief devices, are provided to limit the pressure so it cannot exceed the design pressure of the vessel, tank, container, and piping system.

5-4.1.5 Positive displacement pumps shall be provided with pressure relief discharging back to the tank, pump suction, or other suitable location or shall be provided with interlocks to prevent overpressure.

5-4.1.6 Piping, valves, and fittings shall be in accordance with Chapter 3, "Piping Systems."

5-4.1.7 Listed flexible connectors may be used where vibration exists. Approved hose may be used at transfer stations.



NOTES:

(1) The "source of vapor" shall be the operating envelope and stored position of the outboard flange connection of the loading arm (or hose).
(2) The berth area adjacent to tanker and barge cargo tanks is to be Division 2 to the following extent:
  a. 25 ft (7.6 m) horizontally in all directions on the pier side from that portion of the hull containing cargo tanks.
  b. From the water level to 25 ft (7.6 m) above the cargo tanks at their highest position.
(3) Additional locations may have to be classified as required by the presence of other sources of flammable liquids on the berth, or by Coast Guard or other regulations.

Figure 5-3.5.6 Marine terminal handling flammable liquids.

5-4.2* Equipment. Equipment shall be designed and arranged to prevent the unintentional escape of liquids and vapors and to minimize the quantity escaping in the event of accidental release.

5-4.3 Incidental Use of Liquids.

5-4.3.1 This section shall be applicable where the use and handling of liquids is only incidental to the principal business, such as automobile assembly, construction of electronic equipment, furniture manufacturing, or other similar activities.

5-4.3.2 Class I and Class II liquids shall be drawn from or transferred into vessels, containers, or portable tanks in the following manner only.

(a) From original shipping containers with a capacity of 5 gal (19 L) or less,

(b) From safety cans,

(c) Through a closed piping system,

(d) From portable tanks or containers by means of a device drawing through an opening in the top of the tank or container,

(e) By gravity through a listed self-closing valve or self-closing faucet, or

(f) If hose is used in the transfer operation, it shall be equipped with a self-closing valve without a hold-open latch in addition to the outlet valve. Only listed or approved hose shall be used.

5-4.3.3 Except as provided in 5-4.3.4 and 5-4.3.5, all storage shall comply with Chapter 4, "Container and Portable Tank Storage."

5-4.3.4 The quantity of liquid that may be located outside of storage cabinets, inside storage rooms, cut-off rooms and attached buildings, general purpose warehouses, liquid warehouses, or other specific processing areas that are cut off by at least a 2-hr fire-rated separation from the general plant area shall not exceed the greater of the quantity in either (a) or the sum of (b), (c), (d), and (e) below:

(a) A supply for one day, or

(b) 25 gal (95 L) of Class IA liquids in containers,

(c) 120 gal (454 L) of Class IB, IC, II, or III liquids in containers,

(d) Two portable tanks each not exceeding 660 gal (2498 L) of Class IB, IC, Class II, or Class IIIA liquids, and

(e) 20 portable tanks each not exceeding 660 gal (2498 L) of Class IIIB liquids.

5-4.3.5 Where quantities of liquids in excess of the limits in 5-4.3.4 are necessary, storage shall be in tanks, which shall comply with the applicable requirements of Chapter 2, "Tank Storage," Section 5-3, and 5-4.1 and 5-4.2.

5-4.3.6 Areas in which liquids are transferred from one tank or container to another container shall be separated from other operations that might represent an ignition source by distance or by fire resistant construction. Drainage or other means shall be provided to control spills. Natural or mechanical ventilation shall be provided in accordance with 5-3.3, "Ventilation." (NFPA 91, *Standard for the Installation of Blower and Exhaust Systems for Dust, Stock, and Vapor Removal or Conveying*, provides information on the design and installation of mechanical ventilation.)

5-4.4 Loading and Unloading Operations.

5-4.4.1 Tank Vehicles and Tank Cars.

5-4.4.1.1 Tank vehicle and tank car loading or unloading facilities shall be separated from aboveground tanks, warehouses, other plant buildings, or the nearest line of adjoining property that can be built upon by a distance of at least 25 ft (7.6 m) for Class I liquids and at least 15 ft (4.6 m) for Class II and Class III liquids, measured from the nearest fill spout or (liquid or vapor) transfer connection. These distances may be reduced by utilizing fixed fire protection systems, dikes, fire-rated barriers, or combinations of any of these. Buildings for pumps or shelters for personnel may be a part of the facility.

5-4.4.1.2 Static Protection. Bonding facilities for protection against static sparks during the loading of tank vehicles through open domes shall be provided (a) where Class I liquids are loaded, or (b) where Class II or Class III liquids are loaded into vehicles that may contain vapors from previous cargoes of Class I liquids.

5-4.4.1.3 Protection as required in 5-4.4.1.2 shall consist of a metallic bond wire permanently electrically connected to the fill stem or to some part of the rack structure in electrical contact with the fill stem. The free end of such wire shall be provided with a clamp or equivalent device for convenient attachment to some metallic part in electrical contact with the cargo tank of the tank vehicle.

5-4.4.1.4 Such bonding connection shall be made to the vehicle or tank before dome covers are raised and shall remain in place until filling is completed and all dome covers have been closed and secured.

5-4.4.1.5 Bonding, as specified in 5-4.4.1.2, 5-4.4.1.3, and 5-4.4.1.4, is not required:

(a) Where vehicles are loaded exclusively with products not having a static accumulating tendency, such as asphalts (including cutback asphalts), most crude oils, residual oils, and water-soluble liquids

(b) Where no Class I liquids are handled at the loading facility and the tank vehicles loaded are used exclusively for Class II and Class III liquids

(c) Where vehicles are loaded or unloaded through closed-bottom or -top connections whether the hose or pipe is conductive or nonconductive.

5-4.4.1.6 Filling through open domes into the tanks of tank vehicles or tank cars that contain vapor-air mixtures within the flammable range, or where the liquid being filled can form such a mixture, shall be by means of a downspout that extends near the bottom of the tank. This precaution is not required when loading liquids that are

nonaccumulators of static charges. (NFPA 77, *Recommended Practice on Static Electricity*, provides additional information on static electricity protection.)

5-4.4.1.7 Stray Currents. To protect against stray currents, tank car facilities where flammable and combustible liquids are loaded or unloaded through open domes shall be protected by permanently bonding the fill pipe to at least one rail and to the rack structure, if of metal. Multiple pipes entering the rack area shall be permanently bonded together. In addition, in areas where excessive stray currents are known to exist, all pipes entering the rack area shall be provided with insulating sections to electrically isolate the rack piping from the pipelines. These precautions are not necessary where Class II or Class III liquids are handled exclusively and there is no probability that tank cars will contain vapors from previous cargoes of Class I liquids.

5-4.4.1.8 Equipment such as piping, pumps, and meters used for the transfer of Class I liquids between storage tanks and the fill stem of the loading rack shall not be used for the transfer of Class II or Class III liquids.

Exception No. 1: This provision shall not apply to water-miscible liquids when the class is determined by the concentration of liquid in water.

Exception No. 2: This provision shall not apply where the equipment is cleaned between transfers.

5-4.4.1.9 Remote pumps located in underground tanks shall have a listed leak-detection device installed on the pump discharge side that will indicate if the piping system is not essentially liquidtight. This device shall be checked and tested at least annually according to the manufacturer's specifications to ensure proper installation and operation.

5-4.4.1.10 When top loading a tank vehicle with Class I or Class II liquids without a vapor control system, valves used for the final control of flow shall be of the self-closing type and shall be manually held open except where automatic means are provided for shutting off the flow when the vehicle is full. Automatic shutoff systems shall be provided with a manual shutoff valve located at a safe distance from the loading nozzle to stop the flow if the automatic system fails. When top loading a tank vehicle with vapor control, flow control shall be in accordance with 5-4.4.1.11 and 5-4.4.1.12.

5-4.4.1.11 When bottom loading a tank vehicle with or without vapor control, a positive means shall be provided for loading a predetermined quantity of liquid, together with a secondary automatic shutoff control to prevent overfill. The connecting components between the loading rack and the tank vehicle required to operate the secondary control shall be functionally compatible. The connection between the liquid loading hose or pipe and the truck piping shall be by means of a dry disconnect coupling.

5-4.4.1.12 When bottom loading a tank vehicle that is equipped for vapor control, but when vapor control is not used, the tank shall be vented to the atmosphere, at a height not lower than the top of the cargo tank of the vehicle, to prevent pressurization of the tank. Connections to the plant vapor control system shall be designed to prevent the escape of vapor to the atmosphere when not connected to a tank vehicle.

5-4.4.2 Wharves.

5-4.4.2.1 This section shall apply to all wharves, except marine service stations as covered in NFPA 30A, *Automotive and Marine Service Station Code*. If liquids are handled in bulk quantities across general purpose piers or wharves, NFPA 307, *Standard for the Construction and Fire Protection of Marine Terminals, Piers, and Wharves*, shall be followed.

5-4.4.2.2 Handling packaged cargo of liquids, including full and empty drums, bulk fuel, and stores, over a wharf during cargo transfer shall be subject to the approval of the wharf supervisor and the senior deck officer on duty.

5-4.4.2.3 Wharves at which liquid cargoes are to be transferred in bulk quantities to or from tank vessels shall be at least 100 ft (30 m) from any bridge over a navigable waterway or from an entrance to or superstructure of any vehicular or railroad tunnel under a waterway. The termination of the wharf loading or unloading fixed piping shall be at least 200 ft (60 m) from a bridge or from an entrance to or superstructure of a tunnel.

5-4.4.2.4 Substructure and deck shall be substantially designed for the use intended. Deck may employ any material that will afford the desired combination of flexibility, resistance to shock, durability, strength, and fire resistance. Heavy timber construction is acceptable.

5-4.4.2.5 Tanks used exclusively for ballast water or Class II or Class III liquids may be installed on suitably designed wharves.

5-4.4.2.6 Loading pumps capable of building up pressures in excess of the safe working pressure of cargo hose or loading arms shall be provided with bypasses, relief valves, or other arrangements to protect the loading facilities against excessive pressure. Relief devices shall be tested at least annually to determine that they function satisfactorily at their set pressure.

5-4.4.2.7 All pressure hoses and couplings shall be inspected at intervals appropriate to the service. With the hose extended, the hose and couplings shall be tested using the in-service maximum operating pressure. Any hose showing material deterioration, signs of leakage, or weakness in its carcass or at the couplings shall be withdrawn from service and repaired or discarded.

5-4.4.2.8 Piping, valves, and fittings shall be in accordance with Chapter 3, with the following exceptions and additions.

(a) Flexibility of piping shall be assured by appropriate layout and arrangement of piping supports so that motion of the wharf structure resulting from wave action, currents, tides, or the mooring of vessels will not subject the pipe to excessive strain.

(b) Pipe joints that depend on the friction characteristics of combustible materials or on the grooving of pipe ends for mechanical continuity of piping shall not be permitted.

(c) Swivel joints may be used in piping to which hoses are connected, and for articulated swivel-joint transfer systems, provided the design is such that the mechanical strength of the joint will not be impaired if the packing materials should fail, as by exposure to fire.

(d) Each line conveying Class I or Class II liquids leading to a wharf shall be provided with a readily accessible block valve located on shore near the approach to the wharf and outside of any diked area. Where more than one line is involved, the valves shall be grouped in one location.

(e) Means shall be provided for easy access to cargo line valves located below the wharf deck.

5-4.4.2.9 Pipelines on wharves shall be adequately bonded and grounded if Class I or Class II liquids are handled. If excessive stray currents are encountered, insulating joints shall be installed. Bonding and grounding connections on all pipelines shall be located on the wharf side of hose riser insulating flanges, if used, and shall be accessible for inspection.

5-4.4.2.10 Hose or articulated swivel-joint pipe connections used for cargo transfer shall be capable of accommodating the combined effects of change in draft and maximum tidal range, and mooring lines shall be kept adjusted to prevent surge of the vessel from placing stress on the cargo transfer system. Hose shall be supported to avoid kinking and damage from chafing.

5-4.4.2.11 Material shall not be placed on wharves in such a manner as to obstruct access to fire fighting equipment or important pipeline control valves. Where the wharf is accessible to vehicle traffic, an unobstructed roadway to the shore end of the wharf shall be maintained for access of fire fighting apparatus.

5-4.4.2.12 Loading or unloading shall not commence until the wharf supervisor and the person in charge of the tank vessel agree that the tank vessel is properly moored and all connections are properly made.

5-4.4.2.13 Mechanical work shall not be performed on the wharf during cargo transfer, except under special authorization based on a review of the area involved, methods to be employed, and precautions necessary.

5-5 Fire Prevention and Control.

5-5.1 General.

5-5.1.1 This section covers the commonly recognized management control systems and methods used to prevent or minimize the loss from fire or explosion in liquid processing facilities.

NOTE: Other recognized factors of fire prevention and control, involving construction, location, separation, etc., are covered elsewhere in this chapter.

5-5.1.2 The wide range in size, design, and location of liquid processing facilities precludes the inclusion of detailed fire prevention and control systems and methods applicable to all such facilities. The authority having jurisdiction may be consulted on specific cases, where applicable; otherwise, qualified engineering judgment shall be exercised per 5-5.1.3.

5-5.1.3 The extent of fire prevention and control provided for the liquid processing facility shall be determined by an engineering evaluation of the operation, followed by the application of sound fire protection and process engineering principles. The evaluation shall include, but not be limited to:

(a) Analysis of fire and explosion hazards of the liquid operations

(b) Analysis of hazardous materials, hazardous chemicals, or hazardous reactions in the operations and the safeguards taken to control such materials, chemicals, or reactions

(c) Analysis of facility design requirements in Section 5-3 of this chapter

(d) Analysis of the liquid handling, transfer, and use requirements in Section 5-4 of this chapter

(e) Analysis of local conditions, such as exposure to and from adjacent properties, flood potential, or earthquake potential

(f) Consideration of fire department or mutual aid response.

5-5.2 Control of Ignition Sources.

5-5.2.1 Precautions shall be taken to prevent the ignition of flammable vapors. Sources of ignition include, but are not limited to:

(a) Open flames
(b) Lightning
(c) Hot surfaces
(d) Radiant heat
(e) Smoking
(f) Cutting and welding
(g) Spontaneous ignition
(h) Frictional heat or sparks
(i) Static electricity
(j) Electrical sparks
(k) Stray currents
(l) Ovens, furnaces, and heating equipment.

5-5.2.2 Smoking shall be permitted only in designated and properly identified areas.

5-5.2.3 Welding, cutting, and similar spark-producing operations shall not be permitted in areas containing flammable liquids until a written permit authorizing such work has been issued. The permit shall be issued by a person in authority following his/her inspection of the area to assure that proper precautions have been taken and will be followed until the job is completed. (*See NFPA 51B, Standard for Fire Prevention in Use of Cutting and Welding Processes.*)

5-5.2.4 Static Electricity. All equipment, such as tanks, machinery, and piping, where an ignitable mixture may be present shall be bonded or connected to a ground. The bond or ground or both shall be physically applied or shall be inherently present by the nature of the installation. Electrically isolated sections of metallic piping or equipment shall be bonded to the other portions of the system or individually grounded to prevent hazardous accumulations of static electricity. (NFPA 77, *Recommended Practice on Static Electricity*, provides information on this subject.)

5-5.3 Inspection and Maintenance.

5-5.3.1 All fire protection equipment shall be properly maintained, and periodic inspections and tests shall be done in accordance with both standard practice and equipment manufacturer's recommendations.

5-5.3.2 Maintenance and operating practices shall control leakage and prevent spillage of flammable liquids.

5-5.3.3 Combustible waste material and residues in operating areas shall be kept to a minimum, stored in covered metal containers, and disposed of daily.

5-5.3.4 Ground areas around facilities where liquids are stored, handled, or used shall be kept free of weeds, trash, or other unnecessary combustible materials.

5-5.3.5 Aisles established for movement of personnel shall be maintained clear of obstructions to permit orderly evacuation and ready access for manual firefighting activities.

5-5.4 Emergency Planning and Training.

5-5.4.1 An emergency action plan, consistent with the available equipment and personnel, shall be established to respond to fire or other emergencies. This plan shall include the following.

(a) Procedures to be used in case of fire, such as sounding the alarm, notifying the fire department, evacuating personnel, and controlling and extinguishing the fire

(b) Appointment and training of persons to carry out firesafety duties

(c) Maintenance of fire protection equipment

(d) Holding fire drills

(e) Shutdown or isolation of equipment to reduce the escape of liquid

(f) Alternate measures for the safety of occupants while any fire protection equipment is shut down.

5-5.4.2 Personnel responsible for the use and operation of fire protection equipment shall be trained in the use of that equipment. Refresher training shall be conducted at least annually.

5-5.4.3 Planning of effective fire control measures shall be coordinated with local emergency response agencies.

5-5.4.4 Procedures shall be established to provide for safe shutdown of operations under emergency conditions. Provisions shall be made for periodic training, inspection, and testing of associated alarms, interlocks, and controls.

5-5.4.5 The emergency procedure shall be kept readily available in an operating area and updated regularly.

5-5.4.6 Where premises are likely to be unattended for considerable periods of time, a summary of the emergency plan shall be posted or located in a strategic and accessible location.

5-5.5 Detection and Alarm.

5-5.5.1 An approved means for prompt notification of fire or emergency to those within the plant and to the available public or mutual aid fire department shall be provided.

5-5.5.2 Those areas, including buildings, where a potential exists for a flammable liquid spill shall be monitored as appropriate. Some methods may include:

(a) Personnel observation or patrol

(b) Process monitoring equipment that would indicate a spill or leak may have occurred

(c) Provision of gas detectors to continuously monitor the area where facilities are unattended.

5-5.6 Portable Fire-Control Equipment.

5-5.6.1 Listed portable fire extinguishers shall be provided for facilities in such quantities, sizes, and types as may be needed for the special hazards of operation and storage as determined per 5-5.1.3. (NFPA 10, *Standard for Portable Fire Extinguishers*, provides information on the suitability of various types of extinguishers.)

5-5.6.2 When the need is indicated per 5-5.1.3, water may be utilized through standpipe and hose systems (*see NFPA 14, Standard for the Installation of Standpipe and Hose Systems*) or through hose connections from sprinkler systems using combination spray and straight stream nozzles to permit effective fire control (*see NFPA 13, Standard for the Installation of Sprinkler Systems*).

5-5.6.3 When the need is indicated per 5-5.1.3, mobile foam apparatus shall be provided. NFPA 11C, *Standard for Mobile Foam Apparatus*, provides information on the subject.

5-5.6.4 Automotive and trailer-mounted fire apparatus, where determined necessary, shall not be used for any purpose other than fire fighting.

5-5.7 Fixed Fire Control Equipment.

5-5.7.1 A reliable water supply or other suitable fire control agent shall be available in pressure and quantity to meet the fire demands indicated by the special hazards of operation, storage, or exposure as may be determined by 5-5.1.3.

5-5.7.2 Hydrants, with or without fixed monitor nozzles, shall be provided in accordance with accepted practice. The number and placement will depend on the hazard of the liquid-processing facility, storage, or exposure as may be determined by 5-5.1.3. (*See NFPA 24, Standard for the Installation of Private Fire Service Mains and Their Appurtenances, for information on this subject.*)

5-5.7.3 Where the need is indicated by the hazards of liquid processing, storage, or exposure as determined by 5-5.1.3, fixed protection may be required utilizing approved sprinkler systems, water spray systems, deluge systems, fire resistive materials, or a combination of these. (*See NFPA 13, Standard for the Installation of Sprinkler Systems, and NFPA 15, Standard for Water Spray Fixed Systems for Fire Protection, for information on these subjects.*)

5-5.7.4 The following fire control systems may be appropriate for the protection of specific hazards as determined per 5-5.1.3. If provided, such systems shall be designed, installed, and maintained in accordance with the following NFPA standards:

(a) NFPA 11, *Standard for Low Expansion Foam and Combined Agent Systems*,

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

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

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

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

(f) NFPA 16, *Standard on Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*,

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

Chapter 6 Referenced Publications

6-1 The following documents or portions thereof are referenced within this code and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

6-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 11-1988, *Standard for Low Expansion Foam and Combined Agent Systems*

NFPA 11A-1988, *Standard for Medium and High Expansion Foam Systems*

NFPA 12-1989, *Standard on Carbon Dioxide Extinguishing Systems*

NFPA 12A-1989, *Standard on Halon 1301 Fire Extinguishing Systems*

NFPA 12B-1990, *Standard on Halon 1211 Fire Extinguishing Systems*

NFPA 13-1989, *Standard for the Installation of Sprinkler Systems*

NFPA 14-1990, *Standard for the Installation of Standpipe and Hose Systems*

NFPA 15-1990, *Standard for Water Spray Fixed Systems for Fire Protection*

NFPA 16-1986, *Standard on Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*

NFPA 17-1990, *Standard for Dry Chemical Extinguishing Systems*

NFPA 30A-1990, *Automotive and Marine Service Station Code*

NFPA 31-1987, *Standard for the Installation of Oil Burning Equipment*

NFPA 32-1990, *Standard for Drycleaning Plants*

NFPA 33-1989, *Standard for Spray Application Using Flammable and Combustible Materials*

NFPA 34-1989, *Standard for Dipping and Coating Processes Using Flammable or Combustible Liquids*

NFPA 35-1987, *Standard for the Manufacture of Organic Coatings*

NFPA 36-1988, *Standard for Solvent Extraction Plants*

NFPA 37-1990, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*

NFPA 45-1986, *Standard on Fire Protection for Laboratories Using Chemicals*

NFPA 51B-1989, *Standard for Fire Prevention in Use of Cutting and Welding Processes*

NFPA 69-1986, *Standard on Explosion Prevention Systems*

NFPA 70-1990, *National Electrical Code*

NFPA 80-1990, *Standard for Fire Doors and Windows*

NFPA 90A-1989, *Standard for the Installation of Air Conditioning and Ventilating Systems*

NFPA 91-1990, *Standard for the Installation of Blower and Exhaust Systems for Dust, Stock, and Vapor Removal or Conveying*

NFPA 99-1990, *Standard for Health Care Facilities*

NFPA *101*-1988, *Life Safety Code*

NFPA 220-1985, *Standard on Types of Building Construction*

NFPA 231-1990, *Standard for General Storage*

NFPA 231C-1986, *Standard for Rack Storage of Materials*

NFPA 251-1990, *Standard Methods of Fire Tests of Building Construction and Materials*

NFPA 307-1990, *Standard for the Construction and Fire Protection of Marine Terminals, Piers, and Wharves*

NFPA 385-1990, *Standard for Tank Vehicles for Flammable and Combustible Liquids*

NFPA 386-1990, *Standard for Portable Shipping Tanks for Flammable and Combustible Liquids*

NFPA 395-1988, *Standard for the Storage of Flammable and Combustible Liquids on Farms and Isolated Construction Projects*

NFPA 505-1987, *Firesafety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation*

NFPA 704-1990, *Standard System for the Identification of the Fire Hazards of Materials.*

6-1.2 Other Publications.

6-1.2.1 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM A 395-88, *Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures*

ASTM D 56-87, *Standard Method of Test for Flash Point by the Tag Closed Cup Tester*

ASTM D 93-85, *Standard Method of Test for Flash Point by the Pensky-Martens Closed Tester*

ASTM D 3278-82, *Standard Method of Tests for Flash Point of Liquids by Setaflash Closed Tester*

ASTM D 3828-87, *Standard Test Methods for Flash Point by Setaflash Closed Tester*

ASTM D 5-86, *Test for Penetration for Bituminous Materials*

ASTM D 323-89, *Standard Method of Test for Vapor Pressure of Petroleum Products (Reid Method)*

ASTM D 92-85, *Cleveland Open Cup Test Method*

ASTM/ANSI D 3435-80, *Plastic Containers (Jerry Cans) for Petroleum Products*

ASTM D 4021-86, *Standard Specification for Glass-Fiber Reinforced Polyester Underground Petroleum Storage Tanks*

ASTM F 852-86, *Standard for Portable Gasoline Containers for Consumer Use*

ASTM F 976-86, *Standard for Portable Kerosine Containers for Consumer Use.*

6-1.2.2 ANSI Publications. American National Standards Institute, Inc., 1430 Boradway, New York, NY 10018.

ANSI B31, *American National Standard Code for Pressure Piping*

ANSI/UL 1313-83, *Nonmetallic Safety Cans for Petroleum Products.*

6-1.2.3 ASME Publication. American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ASME, *Boiler and Pressure Vessel Code.*

6-1.2.4 API Publications. American Petroleum Institute, 1220 L Street, N.W., Washington, DC 20005.

API 650, *Welded Steel Tanks for Oil Storage,* Sixth Edition, 1988

API Specifications 12B, *Bolted Tanks for Storage of Production Liquids,* Twelfth Edition, January, 1977

API 12D, *Field Welded Tanks for Storage of Production Liquids,* Eighth Edition, January, 1982

API 12F, *Shop Welded Tanks for Storage of Production Liquids,* Seventh Edition, January, 1988

API 2000, *Venting Atmospheric and Low Pressure Storage Tanks,* 1982.

6-1.2.5 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 142-1987, *Standard for Steel Aboveground Tanks for Flammable and Combustible Liquids*

UL 80-1980, *Standard for Steel Inside Tanks for Oil Burner Fuel*

UL 842-1980, *Standard for Valves for Flammable Fluids*

UL 58-1986, *Standard for Steel Underground Tanks for Flammable and Combustible Liquids*

UL 1316-1983, *Standard for Glass-Fiber Reinforced Plastic Underground Storage Tanks for Petroleum Products.*

6-1.7.6 STI Publication. Steel Tank Institute, 728 Anthony Trail, Northbrook, IL 60062.

sti-P_3-1987, *sti-P_3 Specification and Manual for External Corrosion Protection of Underground Steel Storage Tanks.*

Appendix A Additional Explanatory Material

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

A-3-6 Buried steel piping should be coated with a suitable material and should be cathodically protected. Galvanized steel pipe, by itself and without other corrosion protection methods, is not acceptable for underground piping. Steel swing joints and stainless steel flexible connectors should also be made corrosion resistant when in contact with the soil. Thus, such fittings should also be coated and cathodically protected when installed between nonmetallic, compatible tanks and piping, such as fiberglass reinforced plastic.

A-3-9 Where loading and unloading risers for Class II or Class IIIA liquids are located in the same immediate area as loading and unloading risers for Class I liquids, consideration should be given to providing positive means, such as different pipe sizes, connection devices, special locks, or other methods designed to prevent the erroneous transfer of Class I liquids into or from any container or tank used for Class II or Class IIIA liquids.

Exception No. 1: This provision need not apply to water-miscible liquids when the class is determined by the concentration of liquid in water.

Exception No. 2: This provision need not apply where the equipment is cleaned between transfers.

A-4-3.2 Venting of storage cabinets has not been demonstrated to be necessary for fire protection purposes. Additionally, venting a cabinet could compromise the ability of the cabinet to adequately protect its contents from involvement in a fire since cabinets are not generally tested with any venting. Therefore, venting of storage cabinets is not recommended.

However, it is recognized that some jurisdictions may require storage cabinets to be vented and that venting may also be desirable for other reasons, such as health and safety. In such cases, the venting system should be installed so as to not affect substantially the desired performance of the cabinet during a fire. Means of accomplishing this may include thermally actuated dampers on the vent openings or sufficiently insulating the vent piping system to prevent the internal temperature of the cabinet from rising above that specified. Any make-up air to the cabinet should also be arranged in a similar manner.

If vented, the cabinet should be vented from the bottom with make-up air supplied to the top. Also, mechanical exhaust ventilation is preferred and should comply with NFPA 91, *Standard for the Installation of Blower and Exhaust Systems for Dust, Stock, and Vapor Removal or Conveying*. Manifolding the vents of multiple storage cabinets should be avoided.

A-4-5.5.1 The following table can be consulted for guidance in determining amounts of storage permitted in mercantile establishments.

Table A-4-5.5.1 Allowable Storage Amounts, Gallons per Sq Ft

	IA	IB	IC	II	IIIA
Protected					
Basement	0	2	2	2	2
Ground Floor	1	2	2	2	2
Other Floors	1	2	2	2	2
Unprotected					
Basement	0	1	1	1	1
Ground Floor	1	2	2	2	2
Other Floors	0	1	1	1	1

Maximum total quantities permitted should be limited to the sum of proportional amounts that each class of liquid present bears to the maximum total permitted for its respective class. The sum of proportional amounts should not exceed 100 percent.

A-4-5.6.4 Exception No. 2 Based on work done by the Factory Mutual Research Corp., it was determined that flammable liquids in plastic containers could cause uncontrollable fires under certain conditions of storage in general purpose warehouses. A research project on flammable liquids container storage carried out by Underwriters Laboratories Inc., under the auspices of the National Fire Protection Research Foundation, has suggested a test protocol that can judge the capability of packaging systems to withstand a small ignition source or to minimize the rate at which the lading is released from the containers, so that the fire can be controlled by automatic sprinklers.

There is currently (as of December, 1989) no nationally recognized consensus standard for conducting such tests.

A-4-9.1 Environmental concerns have dictated special handling of hazardous materials, chemicals, and wastes. Some of these have flammable and combustible liquid characteristics, in addition to their environmental and health problems, thus causing some questions as to how they should be stored and handled.

Several manufacturers have met this problem by designing and manufacturing movable, modular prefabricated storage lockers — working diligently with various building officials and authorities having jurisdiction. This results in a product that is intended to meet government standards and regulations for hazardous materials storage. Several municipalities have passed model ordinances covering the design, construction, and location of hazardous materials storage lockers. Design features include but are not limited to the following:

(1) Secondary spill containment sumps

(2) Deflagration venting

(3) Ventilation requirements, including mechanical ventilation when dispensing operations are expected

(4) Electrical equipment for hazardous locations in accordance with the NFPA 70, *National Electrical Code*

(5) Static electricity control

(6) Fire suppression systems (dry chemical or sprinklers)

(7) Heavy structural design for:

(a) Security provisions

(b) Doors that lock and permit pallet loading

(c) Wind load, snow load, and storage load conditions

(d) Anchorage provisions

(e) Skid design, permitting relocation using lift trucks

(8) Fire rated exterior walls, if required

(9) Interior partitions to segregate incompatible materials

(10) Size limits to limit quantities that may be stored within preassembled or ready-to-assemble designs

(11) Non sparking floors

(12) Shelving, if required

(13) Heating or cooling units, if needed

(14) Corrosion protection as required

(15) Employee safety provisions (eye/face wash)

(16) NFPA 704 Hazard Identification.

Features provided are determined by specific storage requirements and needs of the owner, keeping in mind applicable regulations and ordinances that apply and the approval requirements of the authority having jurisdiction.

Several testing laboratories have developed internal procedures for the examination, testing, and listing on labeling of hazardous material storage lockers submitted by manufacturers.

A-5-4.2 Where the vapor space of equipment is usually within the flammable range, the probability of explosion damage to the equipment can be limited by inerting, by providing an explosion suppression system, or by designing the equipment to contain the peak explosion pressure that can be modified by explosion relief. Where the special hazards of operation, sources of ignition, or exposures indicate a need, consideration should be given to providing protection by one or more of the above means.

See NFPA 68, *Guide for Venting of Deflagrations*, and NFPA 69, *Standard on Explosion Prevention Systems*, for additional information on various methods of mitigating losses from explosions.

Appendix B Emergency Relief Venting for Fire Exposure for Aboveground Tanks

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

The requirements for emergency venting given in Table 2-8 and the modification factors in 2-2.5.7 are derived from a consideration of:

1. Probable maximum rate of heat transfer per unit area

2. Size of tank and the percentage of total area likely to be exposed

3. Time required to bring tank contents to boil

4. Time required to heat unwet portions of the tank shell or roof to a temperature where the metal will lose strength

5. Effect of drainage, insulation, and the application of water in reducing fire exposure and heat transfer.

Table 2-8 is based on a composite curve that is considered to be composed of three straight lines when plotted on log-log paper. The curve may be defined in the following manner:

The first straight line is drawn on log-log paper between the point 400,000 Btu/hr, at 20 sq ft (1.858 m^2) exposed surface area and the point 4,000,000 Btu/hr, at 200 sq ft (18.58 m^2) exposed surface area. The equation for this portion of the curve is $Q = 20{,}000A$.

The second straight line is drawn on log-log graph paper between the points 4,000,000 Btu/hr, at 200 sq ft (18.58 m^2) exposed surface area and 9,950,000 Btu/hr, at 1000 sq ft (92.9 m^2) exposed surface area. The equation for this portion of the curve is $Q = 199{,}300A^{0.566}$.

The third straight line is plotted on log-log graph paper between the points 9,950,000 Btu/hr, at 1000 sq ft (92.9 m^2) exposed surface area and 14,090,000 Btu/hr, at 2800 sq ft (260.12 m^2) exposed surface area. The equation for this portion of the curve is $Q = 963{,}400A^{0.338}$.

$Q = 20{,}000A$		$Q = 199{,}300A^{0.566}$		$Q = 963{,}400A^{0.338}$	
A	Q	A	Q	A	Q
20	400,000	200	4,000,000	1,000	10,000,000
30	600,000	250	4,539,000	1,200	10,593,000
40	800,000	300	5,032,000	1,400	11,122,000
50	1,000,000	350	5,491,000	1,600	11,601,000
60	1,200,000	400	5,922,000	1,800	12,040,000
70	1,400,000	500	6,719,000	2,000	12,449,000
80	1,600,000	600	7,450,000	2,400	13,188,000
90	1,800,000	700	8,129,000	2,800	14,000,000
100	2,000,000	800	8,768,000	and over	
120	2,400,000	900	9,372,000		
140	2,800,000	1,000	10,000,000		
160	3,200,000				
180	3,600,000				
200	4,000,000				

For areas exceeding 2800 sq ft (260.12 m^2) it has been concluded that complete fire involvement is unlikely, and loss of metal strength from overheating will cause failure in the vapor space before development of maximum possible vapor evolution rate. Therefore, additional venting capacity beyond the vapor equivalent of 14,090,000 Btu/hr will not be effective or required.

For tanks and storage vessels designed for pressures over 1 psig, additional venting for exposed surfaces beyond 2800 sq ft (260.12 m^2) is believed to be desirable because, under these storage conditions, liquids are stored close to their boiling points. Therefore, the time to bring the container contents to boiling conditions may not be significant. For these situations a heat input value should be determined on the basis of

$$Q = 21{,}000A^{0.82}$$

The flow capacities are based on the assumption that the stored liquid will have the characteristics of hexane, and the vapor liberated has been transposed to equivalent free air at 60°F (15.6°C) and 14.7 psia (101.3 kPa) by using appropriate factors in:

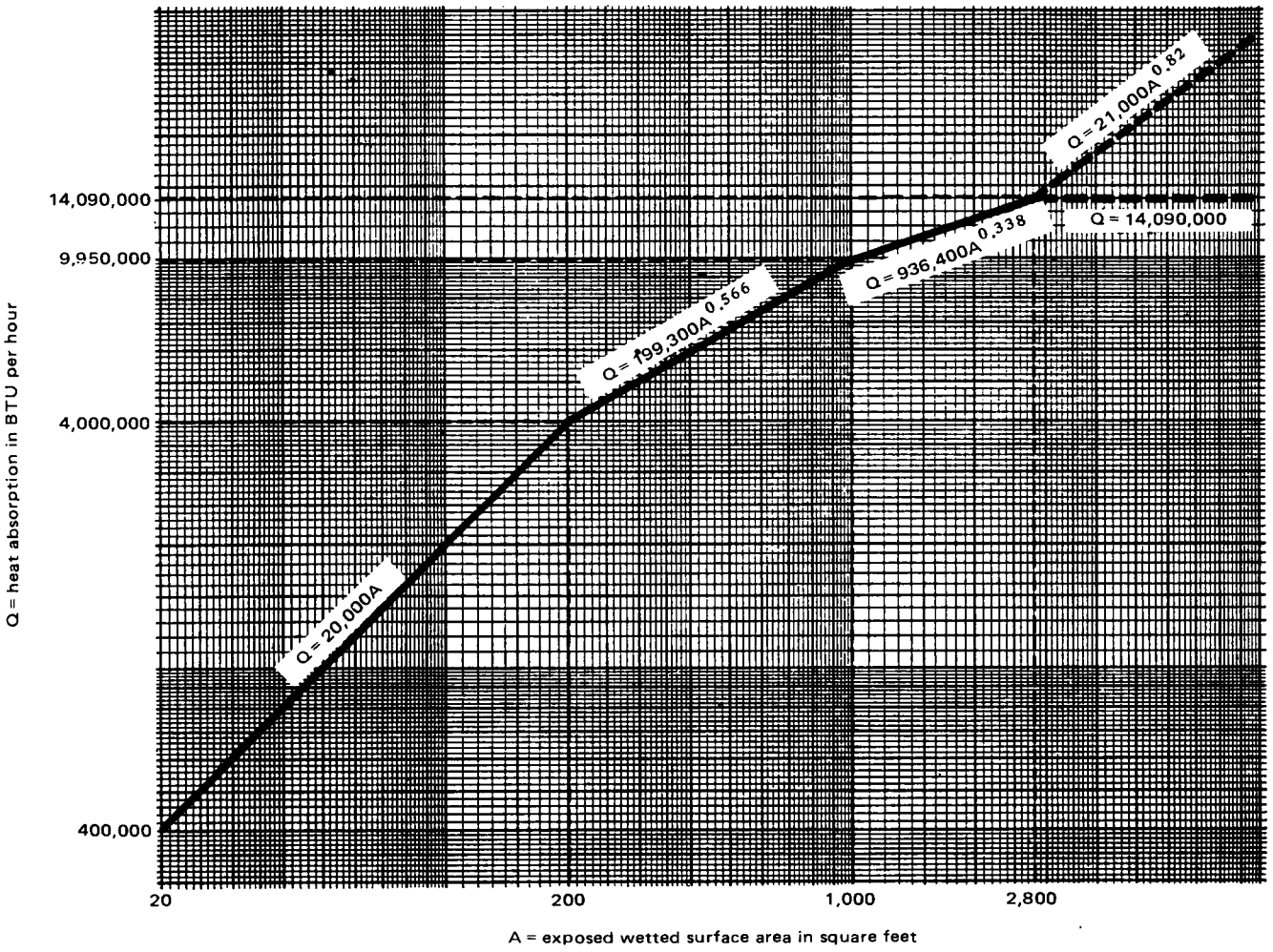
$$CFH = \frac{70.5Q}{L\sqrt{M}}$$

where 70.5 is the factor for converting pounds of gas to cubic feet of air; Q = the total heat input per hour expressed in Btu; L = latent heat of vaporization; and M = molecular weight.

No consideration has been given to possible expansion from the heating of the vapor above the boiling point of the liquid, its specific heat, or the difference in density between the discharge temperature and 60°F (15.6°C), since some of these changes are compensating.

Since tank vent valves are ordinarily rated in CFH standard air, the figures derived from Table 2-8 may be used with the appropriate tank pressure as a basis for valve selection.

Table B-2 gives for a variety of chemicals the constants that can be used to compute the vapor generated and equivalent free air for liquids other than hexane, where greater exactness is desired. Inspections of the table will show that the use of hexane in deriving Table 2-8 provides results that are within an acceptable degree of accuracy for the listed liquids.



NOTE: See Table B-1 for approximate wetted area for horizontal tanks.

Figure B-1 Curve for determining requirements for emergency venting during fire exposure.

Table B-1 Approximate Wetted Areas for Horizontal Tanks (Wetted Area Equals 75 Percent Total Area)

Tank Diameter, Feet	3	4	5	6	7	8	9	10	11	12
Tank Length, Feet	Approximate Wetted Area of Tanks with Flat Heads									
3	32									
4	39	55								
5	46	65	88							
6	53	74	100	128						
7	60	84	112	142	173					
8	67	93	124	156	190	226				
9	74	102	136	170	206	245	286			
10	81	112	147	184	223	264	308	353		
11	88	121	159	198	239	283	329	377	428	
12	95	131	171	213	256	301	350	400	454	509
13	102	140	183	227	272	320	371	424	480	537
14	109	150	194	241	289	339	393	447	506	565
15	116	159	206	255	305	358	414	471	532	594
16	123	169	218	269	322	377	435	495	558	622
17	130	178	230	283	338	395	456	518	584	650
18	137	188	242	298	355	414	477	542	610	678
19		197	253	312	371	433	499	565	636	707
20		206	265	326	388	452	520	589	662	735
21		216	277	340	404	471	541	612	688	763
22		225	289	354	421	490	562	636	714	792
23		235	300	368	437	508	584	659	740	820
24		244	312	383	454	527	605	683	765	848
25			324	397	470	546	626	706	791	876
26			336	411	487	565	647	730	817	905
27			347	425	503	584	668	754	843	933
28			359	440	520	603	690	777	869	961
29			371	454	536	621	711	801	895	989
30			383	468	553	640	732	824	921	1018
31			395	482	569	659	753	848	947	1046
32				496	586	678	775	871	973	1074
33				510	602	697	796	895	999	1103
34				524	619	715	817	918	1025	1131
35				539	635	734	838	942	1051	1159
36				553	652	753	860	966	1077	1187
37				567	668	772	881	989	1103	1216

Tank Diameter, Feet	3	4	5	6	7	8	9	10	11	12
Tank Length, Feet	Approximate Wetted Area of Tanks with Flat Heads									
38					685	791	902	1013	1129	1244
39					701	810	923	1036	1155	1272
40					718	828	944	1060	1181	1301
41					734	847	966	1083	1207	1329
42					751	866	987	1107	1233	1357
43					767	885	1008	1130	1259	1385
44						904	1029	1154	1284	1414
45						923	1051	1178	1310	1442
46						941	1072	1201	1336	1470
47						960	1093	1225	1362	1498
48						979	1114	1248	1388	1527
49						998	1135	1272	1414	1555
50							1157	1295	1440	1583
51							1178	1319	1466	1612
52							1199	1342	1492	1640
53							1220	1366	1518	1668
54							1246	1389	1544	1696
55							1263	1413	1570	1725
56								1437	1593	1753
57								1460	1622	1781
58								1484	1648	1809
59								1507	1674	1839
60								1531	1700	1866
61									1726	1894
62									1752	1923
63									1778	1951
64									1803	1979
65									1829	2007
66									1855	2036
67										2064
68										2092
69										2120
70										2149
71										2177
72										2205

SI Units: 1 ft = 0.30 m; 1 sq ft = 0.09 m^2.

Table B-2 Values of L $\sqrt{M}$ for Various Flammable Liquids

Chemical	L$\sqrt{M}$	Molecular Weight	Heat of Vaporization Btu per lb at Boiling Point
Acetaldehyde	1673	44.05	252
Acetic acid	1350	60.05	174
Acetic anhydride	1792	102.09	177
Acetone	1708	58.08	224
Acetonitrile	2000	41.05	312
Acrylonitrile	1930	53.06	265
n-Amyl alcohol	2025	88.15	216
iso-Amyl alcohol	1990	88.15	212
Aniline	1795	93.12	186
Benzene	1493	78.11	169
n-Butyl acetate	1432	116.16	133
n-Butyl alcohol	2185	74.12	254
iso-Butyl alcohol	2135	74.12	248
Carbon disulfide	1310	76.14	150
Chlorobenzene	1422	112.56	134
Cyclohexane	1414	84.16	154
Cyclohexanol	1953	100.16	195
Cyclohexanone	1625	98.14	164
o-Dichlorobenzene	1455	147.01	120
cis-Dichloroethylene	1350	96.95	137
Diethylamine	1403	73.14	164
Dimethylacetamide	1997	87.12	214
Dimethylamine	1676	45.08	250
Dimethylformamide	2120	73.09	248
Dioxane (diethylene ether)	1665	88.10	177
Ethyl acetate	1477	88.10	157
Ethyl alcohol	2500	46.07	368
Ethyl chloride	1340	64.52	167
Ethylene dichloride	1363	98.96	137
Ethyl ether	1310	74.12	152
Furan	1362	68.07	165
Furfural	1962	96.08	200
Gasoline	1370-1470	96.0	140-150
n-Heptane	1383	100.20	138
n-Hexane	1337	86.17	144
Hydrogen cyanide	2290	27.03	430
Methyl alcohol	2680	32.04	474
Methyl ethyl ketone	1623	72.10	191
Methyl methacrylate	1432	100.14	143
n-Octane	1412	114.22	132
n-Pentane	1300	72.15	153
n-Propyl acetate	1468	102.13	145
n-Propyl alcohol	2295	60.09	296
iso-Propyl alcohol	2225	60.09	287
Tetrahydrofuran	1428	72.10	168
Toluene	1500	92.13	156
Vinyl acetate	1532	86.09	165
o-Xylene	1538	106.16	149

NOTE: For data on other chemicals refer to available handbooks on properties of chemicals.

Appendix C Abandonment or Removal of Underground Tanks

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

C-1 Introduction.

C-1-1 Care is required not only in the handling and use of flammable or combustible liquids, but also in abandoning tanks that have held flammable or combustible liquids. This is particularly true of underground service station tanks that are most frequently used for the storage of motor fuel and occasionally for the storage of other flammable or combustible liquids, such as crankcase drainings (which may contain some gasoline). Through carelessness, explosions have occurred because flammable or combustible liquid tanks had not been properly conditioned before being abandoned.

C-1-2 In order to prevent accidents caused by improper conditioning, it is recommended that the procedures outlined below be followed when underground tanks are removed, abandoned, or temporarily taken out of service.

C-1-3 Underground tanks taken out of service may be safeguarded or disposed of by any one of the three following means:

(a) Placed in a temporarily out of service condition. Tanks should be rendered temporarily out of service only when it is planned that they will be returned to active service within a reasonable period or pending removal or abandonment within 90 days.

(b) Abandoned in place, with proper safeguarding.

(c) Removed.

C-1-4 In cases where tanks are either rendered temporarily out of service or permanently abandoned, records should be kept of tank size, location, date of abandonment, and method used for placing the abandoned tank in a safe condition.

C-1-5 Procedures for carrying out each of the above methods of disposing of underground tanks are described in the following sections. No cutting torch or other flame- or spark-producing equipment shall be used until the tank has been completely purged or otherwise rendered safe. In each case, the numbered steps given shall be carried out successively.

C-2 Rendering Tanks "Temporarily Out of Service."

C-2-1 Cap or plug all lines such as fill line, gage opening, pump suction, and vapor return. Secure against tampering.

C-2-2 Disconnect piping at all tank openings.

C-3 Abandoning Underground Tanks in Place.

C-3-1 Remove all flammable or combustible liquid from the tank and from all connecting lines.

C-3-2 Disconnect the suction, inlet, gage, and vent lines.

C-3-3 Fill the tank completely with an inert solid material. Cap remaining underground piping.

C-4 Removal of Underground Tanks.

C-4-1 Remove all flammable or combustible liquids from tank and from connecting lines.

C-4-2 Disconnect piping at all tank openings. Remove sections of connecting lines that are not to be used further and cap or plug all tank openings. After removal, the tank may be gas freed on the premises if it can be done safely at that location or may be transported to an area not accessible to the public and the gas freeing completed at that location.

C-5 Disposal of Tanks.

C-5-1 If a tank is to be disposed of as junk, it should be retested for flammable vapors and, if necessary, rendered gas-free. After junking and before releasing to junk dealer, a sufficient number of holes or openings should be made in it to render it unfit for further use. NFPA 327, *Standard Procedures for Cleaning or Safeguarding Small Tanks and Containers*, provides information on safe procedures for such operations.

Appendix D

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

The following contains additional information and recommendations relating to the requirements in Chapter 4. The individual items bear the same number as the text of Chapter 4 to which they apply.

D-4-4 The preferred method of storage of liquids in buildings is in cutoff rooms or in attached buildings rather than in inside rooms because of fire department accessibility and the advantages of providing explosion venting where needed.

D-4-6.2

(a) Sprinkler system densities and areas of application presented in this appendix are based upon limited test data and fire experience. Design criteria in this appendix do not apply to storage in plastic drums. (*See Appendix E for additional information on this subject.*)

(b) For design criteria for specific installations, insurance engineers, fire protection consultants, and other knowledgeable persons should be consulted.

(c) **Palletized and Solid Pile Storage.** For protected storage of liquids, as specified in Table 4-6.1(a), automatic sprinkler protection should be provided in accordance with Table D-4-6.2(a).

(d) **Rack Storage.** In protected storage of liquids arranged, as specified in Table 4-6.1(b), automatic sprinkler protection should be provided in accordance with Tables D-4-6.2(b) and D-4-6.2(c), as applicable, except that racks with solid shelves should be provided with in-rack sprinklers at every tier or level.

D-4-6.2.1

(a) Automatic aqueous film-forming foam (AFFF)-water sprinkler systems for container storage of liquids has been shown to be an acceptable method for providing fixed protection. (*See Appendix E for additional information on this subject.*)

(b) For design criteria for specific installations, insurance engineers, fire protection consultants, and other knowledgeable persons should be consulted.

(c) Rack storage of liquids in containers [drums of 55 gal (208 L) capacity] stored on-end on wood pallets on conventional double-row racks to a maximum height of storage of 25 ft (7.6 m) should be provided protection in accordance with Table D-4-6.2.1.

Tables D-4-6.2(a) Automatic Sprinkler Protection for Solid Pile and Palletized Storage of Liquids in Containers and Portable Tanks[1]

Storage Conditions		Ceiling Sprinkler Design and Demand					
			Area (sq ft)[3]				
Class Liquid	Container Size and Arrangement	Density gpm/ sq ft	High Temp.	Ord. Temp.	Maximum Spacing	Minimum Hose Stream Demand (gpm)	Minimum Duration Sprinklers & Hose Streams[2]
IA	5 gal or less, with/without cartons, palletized or solid pile	0.30	3000	5000	100 sq ft	750	2 hr
	containers greater than 5 gal, on end or side, palletized or solid pile	0.60	5000	8000	80 sq ft	750	
IB,* IC,* & II*	5 gal or less, with/without cartons, palletized or solid pile	0.30	3000	5000	100 sq ft	500	2 hr
	containers greater than 5 gal, on pallets or solid pile, one high	0.25	5000	8000	100 sq ft		
II	containers greater than 5 gal, on pallets or solid pile, more than one high on end or side	0.60	5000	8000	80 sq ft	750	2 hr
IB,* IC,* II*	portable tanks, one high	0.30	3000	5000	100 sq ft	500	2 hr
II	portable tanks, two high	0.60	5000	8000	80 sq ft	750	2 hr
III	5 gal or less, with/without cartons, palletized or solid pile	0.25	3000	5000	120 sq ft	500	1 hr
	containers greater than 5 gal, on pallets or solid pile, on end or sides, up to three high	0.25	3000	5000	120 sq ft	500	1 hr
	containers greater than 5 gal, on pallets or solid pile, on end or sides, up to 18 ft high	0.35	3000	5000	100 sq ft	750	2 hr
	portable tanks, one high	0.25	3000	5000	120 sq ft	500	1 hr
	portable tanks, two high	0.50	3000	5000	80 sq ft	750	2 hr

* See Appendix E, introductory paragraphs.

NOTES: (1) See Table 4-6.1(a) and Section 4-6 for additional information pertaining to protected palletized or solid piling of liquids.
(2) Minimum hose stream demand includes small hand hose (1½ in.) required in 4-7.1.3.
(3) The design area contemplates the use of wet pipe systems. Where dry pipe systems are required, it introduces a possible delay that needs to be compensated for by increased area of application (plus 30 percent).

SI Units: 1 gal = 3.8 L; 1 sq ft = 0.30 m.

Table D-4-6.2(b) Automatic Sprinkler Protection Requirements for Rack Storage of Liquids in Containers of Five Gallon Capacity or Less, in Cartons on Conventional Wood Pallets or without Cartons but strapped to Pallets[1]

	Ceiling Sprinkler Design & Demand				In-Rack Sprinkler Arrangement and Demand[2],[3],[4]					
		Area (sq ft)[6]							Minimum Hose Stream Demand (gpm)	Minimum Duration Sprinkler & Hose Stream[5]
Class Liquid	Density gpm/ sq ft	High Temp.	Ord. Temp.	Max. Spacing	Racks up to 9 ft (2.7 m) deep	Racks over to 9 ft (2.7 m) to 12 ft (3.7 m) deep	Minim. Nozzle Pressure	Number of Sprinklers Operating		
I (max. 25 ft height)	0.40	3000	5000	80 sq ft/hd	a) ord. temp. sprinklers 8 ft apart horizontally b) one line sprinklers above each level of storage c) locate in longitudinal flue space, staggered vertically d) shields req'd. where multilevel	a) ord. temp. sprinklers 8 ft apart horizontally b) two lines sprinklers above each level of storage c) locate in transverse flue spaces, staggered vertically and within 20 in. of aisle d) shields req'd. where multilevel	30 psi	a) 8 sprinklers if only one level b) 6 sprinklers ea. on two levels, if only two levels c) 6 sprinklers ea. on top 3 levels, if three or more levels d) hydraulically most remote	750	2 hr
II (max. 25 ft height)	0.30	3000	5000	100 sq ft/hd	a) ord. temp. sprinklers 8 ft apart horizontally b) one line sprinklers betw. levels at nearest 10 ft vertical intervals c) locate in longitudinal flue space, staggered vertically d) shields required where multilevel	a) ord. temp. sprinklers 8 ft apart horizontally b) two lines betw. levels at nearest 10 ft vertical intervals c) locate in transverse flue spaces, staggered vertically and within 20 in. of aisle d) shields required where multilevel	30 psi	a) hydraulically most remote — 6 sprinklers at each level, up to max. of three levels	750	2 hr
III (max. 40 ft height)	0.25	3000	5000	120 sq ft/hd	Same as Class II	Same as Class II	30 psi	Same as Class II	500	2 hr

NOTES:
(1) See Table 4-6.1(b) and Section 4-6 for additional information pertaining to protected rack storage.
(2) Additional in-rack protection required for solid shelves, as indicated in D-4-6.2(d).
(3) See 4-6.3 for types of racks permitted.
(4) See 4-6.5 for additional informationpertaining to in-rack sprinklers.
(5) Minimum hose streams demand includes small hand hose (1 1/2 in.) required in 4-7.1.3.
(6) The design area conteplates the use of wet pipe systems. Where dry pipe systems are required, it introduces a possible delay that needs to be compensated for by increased areas of application (plus 30 percent).

SI Units: 1 gal = 3.8 L; 1 sq ft = 0.09 m^2; 1 ft = 0.30 m; 1 in. = 2.5 cm.

Table D-4-6.2(c) Automatic Sprinkler Protection for Rack Storage of Liquids in Containers Greater than five Gallon Capacity[1]

Class Liquid	Ceiling Sprinkler Design & Demand				In-Rack Sprinkler Arrangement and Demand[2],[3],[4]				Minimum Hose Stream Demand (gpm)	Minimum Duration Sprinkler & Hose Stream[5]
	Density gpm/ sq ft	Area (sq ft)[6] High Temp.	Area (sq ft)[6] Ord. Temp.	Max. Spacing	On-Side Storage Racks up to 9 ft	On-End Storage (on pallets) up to 9 ft deep racks	Minim Nozzle Pressure	Number of Sprinklers Operating		
IA (max. 25 ft height)	0.60	3000	5000	80 sq ft/hd	a) ord. temp. sprinklers 8 ft apart horizontally b) one line sprinklers above each tier of storage c) locate in longitudinal flue space, staggered vertically d) shields required where multilevel	a) ord. temp. sprinklers 8 ft apart horizontally b) one line sprinklers above each tier of storage c) locate in longitudinal flue space, staggered vertically d) shields required where multilevel	30 psi	a) hydraulically most remote—6 sprinklers at each level	1000	2 hr
IB, IC & II (max. 25 ft height)	0.60[7]	3000	5000	100 sq ft/hd	a) see a) above b) one line sprinklers every three tiers of storage c) see c) above d) see d) above	a) see a) above b) see b) above c) see c) above d) see d) above	30 psi	a) see a) above	750	2 hr
III (max. 40 ft height)	0.25	3000	5000	120 sq ft/hd	a) see a) above b) one line sprinklers every sixth level (maximum) c) see c) above d) see d) above	a) see a) above b) one line sprinklers every third level (maximum) c) see c) above d) see d) above	15 psi	a) see a) above	500	1 hr

NOTES:
(1) See Table 4-6.1(b) and D-4-6.2(b) for additional information pertaining to protected rack storage.
(2) Additional in-rack protection required for solid shelves, as indicated in D-4-6.2(d).
(3) See 4-6.3 for types of racks permitted.
(4) See 4-6.5 for additional information pertaining to in-rack sprinklers.
(5) Minimum hose stream demand includes small hand hose ($1\frac{1}{2}$ in.) required in 4-7.1.3.
(6) The design area contemplates the use of wet pipe systems. Where dry pipe systems are required, it introduces a possible delay that needs to be compensated for by increased areas of application (plus 30 percent).
(7) Where there is only one tier of drums above the highest line of in-rack sprinklers, the ceiling water demand density may be reduced to 0.25 gpm/sq ft over 5000 sq ft.

SI Units: 1 gal = 3.8 L; 1 sq ft = 0.09 m^2; 1 ft = 0.30 m; 1 in. = 2.5 cm.

Table D-4-6.2.1 Automatic AFFF-Water Protection[1] Requirements for Rack Storage of Liquids in Containers

Class Liquid[4]	Ceiling Sprinkler Design & Demand: Density gpm/sq ft	Area (sq ft): High Temp.	Area (sq ft): Ord. Temp.	In-Rack Sprinkler Arrangement and Demand[2]: On-End Storage, of drums (on pallets) up to 25 ft	Minimum Nozzle Pressure	Number of Sprinklers Operating	Hose Stream Demand[3]	Duration AFFF Supply	Duration Water Supply
IA, IB, IC, II	0.30	1500	2550	a) ord. temp. sprinklers up to 10 ft apart horizontally b) one line sprinklers above each level of storage c) locate in longitudinal flue space, staggered vertically d) shields required for multilevel	30 psi	3 sprinklers per level	500	15 min	2 hr

NOTES: (1) System shall be a closed head wet system with approved devices for proportioning AFFF.
(2) Except as modified herein, in-rack sprinklers should be installed in accordance with NFPA 231C, *Standard for Rack Storage of Materials*.
(3) Hose stream demand includes inside hand hose (1½ in.) required in 4-7.1.3.
(4) Maximum height of storage should be limited to 25 ft.

SI Units: 1 gal = 3.8 L; 1 sq ft = 0.09 m^2; 1 ft = 0.30 m; 1 in. = 2.5 cm.

Appendix E

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

SI Units: 1 gal = 3.8 L; 1 ft = 0.30 m; 1 sq ft = 0.09 m^2.

This appendix explains fire test data and loss experience that were used to help promulgate protection tables that are presented in Appendix D. While these data are limited, they do illustrate the seriousness of a potential drum rupture in a fire and the primary failure mode of built-up internal pressure in combination with the weakening of the rim joint, due to localized overheating. The possibility of a BLEVE (Boiling Liquid Expanding Vapor Explosion) is also demonstrated. Due to the many unknowns, conservative practice would be to limit all Class I liquids stored in drums to not over one drum high, since protection tables were developed with this philosophy.

Very limited fire tests and fire experience, relative to flammable aerosols, indicate the serious problem they present to the fire protection engineer. Exploding pressurized aerosol cans are to be expected, together with the flaming fireball and rocketing action, spreading fire to a potentially larger area. The protection philosophy expressed is primarily to limit storage heights and to contemplate a larger area of application. Use of pressure-relieving can designs would be expected to affect favorably the design considerations for fixed protection.

E-4-6(a) Fire Tests — Drum Storage:

(1) 1949 Fire Tests. A series of fire tests were made in 1949 at the Factory Mutual test center in Norwood, Massachusetts. The tests were conducted in the 15-ft high section of the fire test building used at that time. The tests used ICC Specification 5 drums, which were 14 gage compared with the 16 gage Specification 17C drums and 18 gage Specification 17E drums used more commonly today.

The tests involved storage horizontally on metal racks up to four drums high, and palletized upright, three drums high. Test drums contained either water, gasoline, or benzene, located in the first or second tier and equipped with pressure- and temperature-sensing connections. The gasoline and benzene drums were piped to manual vents so that pressure could be relieved before the drums ruptured. Other drums in the array contained water or were empty.

Sprinkler protection consisted of open, old-type sprinklers, which could be manually turned on, either at the start of the fire (short preburn) or at a time simulating the first sprinkler operation (long preburn). Sprinklers were spaced either at 100 sq ft/head with a flow rate of 0.22 or 0.28 gpm/sq ft or spaced at 50 sq ft/head with a flow rate of 0.44 or 0.56 gpm/sq ft.

Gasoline was pumped through piping to designated discharge points in or near the pile at flow rates from 1 to 15 gpm. In some tests, 5 or 10 gal of fuel were poured on the floor below the drums and ignited. Duration of flows were the length of time required to empty a single drum at the rate of flow used.

When sprinkler discharge was turned on immediately, the pressure that developed in the test drums was due almost entirely to the vapor pressure as the body of liquid increased in temperature. When sprinkler discharge was started, simulating normal sprinkler operation, there was a rapid pressure increase due to heating of the vapor space. This usually dropped when cooling by sprinkler discharge started.

Early tests showed that 100 sq ft spacing of sprinklers and densities of 0.22 and 0.28 gpm/sq ft would not prevent excessive temperature and pressure increases in drums. Spacing of 50 sq ft per sprinkler was used in subsequent tests. Test measurement and visual observation indicated

that 0.56 gpm/sq ft provided considerably better cooling and flushing away of fuel than the 0.44 gpm/sq ft sprinkler density.

When fuel was discharged on the floor, only the bottom tier of storage was severely exposed. When fuel was discharged at a higher level, simulating a leaking drum, those drums in the immediate vicinity in upper tiers were severely exposed.

The rate of fuel flow had very little effect on the heating of any particular drum. The lower rates, 1 to 2 gpm, had a much longer duration and resulting exposure was greater before the 55-gal duration supply was used up.

With on-side drum storage in racks, the rate of temperature rise in the test drum on the lowest tier was 3 to 5 times as high with storage more than one drum high than it was with one-high storage. Tests with on-end palletized storage were only conducted three-high.

When 5 or 10 gal of gasoline were spilled on the floor and then ignited, the 5-gal spill gave a more severe exposure to drums because of the longer time before sprinklers would have operated. The 10-gal spill exposed more drums, but the exposure to any one drum was no more severe.

A very small leak from a drum filled with gasoline gave a very severe exposure, because of the localized exposure to the leaking drum and insufficient heat at the ceiling to operate the sprinklers.

Drums containing benzene heated much more rapidly than drums containing water because of the lower specific heat of benzene. Early pressure build-up in the vapor space is more pronounced with water, possibly because of more film vaporization on the early stages of the fire.

(2) 1967 Fire Tests. A series of fire tests were made to compare the effects of severe fire exposure to water- and heptane-filled drums. The tests were carried out in the Factory Mutual explosion tunnel, using new ICC-17E (18 gage) 55-gal drums.

A single drum was encircled with a ring of oil burners. Temperatures were measured at various points in the drum. The fuel rate to the oil burners was about 1 gpm. There was no cooling applied to the drum.

Using heptane, the drum ruptured at about 17 psig, at a drum rim temperature of 1190°F (643.4°C). The cover seam unrolled and a BLEVE resulted, after a fire exposure of 3 to 4 minutes.

On similar tests using water, failure occurred at 40 psig after 10 minutes.

The tests indicated that the heptane-filled drum will rupture much sooner and at a much lower internal pressure than a water-filled drum. This is attributed to the fact that drums were found to leak around the joint of the rim before the rupture. The small leakage of heptane vapor through the rim joint causes a localized flame at this already weakened location on the rim, whereas steam issuing from a similar leak in a water-filled drum tends to cool the metal at this point.

(3) 1974 Fire Tests. A series of fire tests were made to evaluate protection of on-end drum storage with AFFF foam discharging from a standard sprinkler system. The tests were conducted in the 30-foot high area of the Factory Mutual test center in Rhode Island.

Based on the 1967 tests, a standard for success was that no drum should exceed 15 psig pressure.

Tests were made with water-filled drums, palletized, 2, 3, and 4 pallets high, and on racks, 5 tiers high.

Fuel was heptane, piped to the base of the top tier of storage, with a 10-gal floor spill in each case. Sprinklers were automatic, 286°F (141.1°C) heads.

Test 1: In this test, storage was 4 pallet-loads high. Fuel discharge rate was 2 gpm. Sprinkler discharge density was 0.30 gpm/sq ft. The first sprinkler opened at 34 sec. Only 4 sprinklers operated, but the three-dimensional fire in the pile continued strong. Several drums bulged, 2 ruptured, and 6 exceeded 15 psig pressure.

Test 2: In this test, storage was 3 tiers high, sprinkler density was 0.60 gpm/sq ft. Other conditions were the same as Test 1.

Two sprinklers opened at about 1 minute 20 sec. A considerable number of drums were deformed. Four of the 8 monitored drums exceeded 15 psig pressure.

Test 3: This test was rack storage with 160°F (71.1°C) automatic sprinklers in each tier except the bottom. Fuel rate was 2 gpm. Ceiling protection was 0.30 gpm/sq ft.

Five in-rack sprinklers and one ceiling sprinkler opened. One drum in the first tier, which had no in-rack sprinklers, reached a pressure of 16 psig. Two drums fell from the fifth tier, due to burning away of a pallet.

Test 4: Test 4 was a repeat of Test 3, except the fuel flow rate was 15 gpm.

Eight ceiling sprinklers and 5 in-rack sprinklers operated. Ceiling temperatures reached 1665°F (909.5°C). One monitored drum in the first tier reached 20 psig. Several drums were bulged.

Test 5: Test 5 was a repeat of Test 2, except storage was 2 tiers high.

The fuel was a greater distance from the ceiling so sprinklers did not operate until 3½ to 4 minutes after ignition. Damage to drums was severe, with many rupturing and all eight monitored drums going over 15 psig.

Generally, results were good in rack storage, where in-rack sprinklers were provided at each tier. For palletized storage, the AFFF protection controlled the floor fire, although pallets hindered spread of foam. Ceiling sprinklers only did not adequately protect palletized storage where an elevated spill resulted in a three-dimensional fire within the pile.

Most of the ruptured drums failed at the top chime, but one drum developed a slow leak at a bottom chime. In Test 5, several drums were heated by a localized fire that did

not open sprinklers at the roof. This slow overpressurization can lead to superheated liquid release and a resulting severe BLEVE when the drum eventually ruptures.

E-4-6(b) Fire Tests — Small Containers.

(1) 1957 Fire Test (Nonpressurized Smaller Containers). A fire test was made on 10½-ft high storage of paint in 1-gal cans in cartons. The storage was palletized, but the pallets were fire-stopped, so it was equivalent to solid piled storage. The paint varied in flash point from 105 to 170°F (40.5 to 76.7°C) (Class II and IIIA). Sprinkler protection was 160°F (71.1°C) heads, 10 × 10 ft, with a density of 0.23 gpm/sq ft. Ceiling height was 15 ft.

Six sprinklers operated and controlled the fire. Temperatures over the fire reached a maximum of 1100°F (593.3°C) and dropped below 500°F (260°C) after 10 minutes. Five hundred and three cans had their covers blown off and 20 cans had burst seams. The paint released from the cans was slight, but it would be much more significant if a pile had toppled over or if cans had not all been stored cover-side up.

(2) 1970 Fire Test (Pressurized Containers). A fire test was made in the 30-ft high section of the Factory Mutual Rhode Island test facility. The storage was 13 and 16-oz cans of lacquer in shipping cartons stored 2 pallet by 2 pallet by 2 pallet high on racks. Storage height was 9 ft 9 in. Protection was by twelve 160°F (71.1°C) sprinklers spaced 10 × 10 ft providing a discharge density of 0.30 gpm/sq ft.

Fifty seconds after ignition, containers began to burst. At 62 sec, 3 sprinklers operated. The fire became more and more intense and with all 12 sprinklers operating, there was no suppressing effect. The discharge was increased to 0.50 gpm/sq ft without effect. After about 5 minutes, the fuel was nearly exhausted. Containers were thrown to every corner of the test building.

Temperatures over the fire were over 1000°F (537.8°C) for 3½ minutes and over 1700°F (926.6°C) for 2 minutes.

E-4-6(c) Fire experience examples involving flammable and combustible liquids in containers stored in buildings.

(1) 1951 Fire. Drums of petroleum naphtha were stored temporarily in a general purpose warehouse used mainly for storing can ends in wood boxes. Storage was 1 drum high on pallets.

Two drums had small punctures and leaks near the bottom, caused either maliciously or by moving equipment. The leak was ignited, and one drum ruptured at the bottom seam. A drum rupture resulted that opened 272 sprinklers. The fire department was called promptly and they and sprinklers were able to contain the fire, helped by the low combustible concentration in the warehouse and by failure of any other drums to rupture.

Forty-two million can ends were wet down, but fire damage was limited. No explosion damage was reported. (The intensity of the BLEVE may have been limited by much of the liquid leaking from the drum before it ruptured.) Total damage was about $200,000.

(2) 1965 Fire. Pressurized containers of paint were stored 15 ft high on racks. A fire started in the top tier from a gas-fired radiant heater. Bursting containers spread burning paint over a large area, opening one hundred eighty-eight 165°F (73.9°C) sprinklers. The fire spread 25 ft along a rack but was slowed by aisles and inert material. A portion of the roof over the fire area collapsed.

(3) 1966 Fire. Pressurized containers of alcohol-base hair spray and deodorant were stored palletized, 17 ft high. The fire was contained within a 1,200 sq ft pile by 107 operating sprinklers. Damage exceeded $400,000.

(4) 1971 Distribution Warehouse Fire. A sprinklered 67,000 sq ft, one-story, noncombustible warehouse for automotive equipment and supplies was destroyed by fire from undetermined cause. Storage consisted of various metal, plastic and rubber parts in cardboard cartons, plus flammable and combustible liquids in containers ranging from 1 pt aerosol cans up to, and including, 55-gal metal drums. Method of storage was mostly on wooden pallets on open metal racks, double row, with 3 and 4 tiers to a total storage height of 15 to 17 ft. A considerable portion of the racks was used for storage of flammable and combustible liquids in 5-gal and 55-gal metal containers on wooden pallets, 4 tiers high. Both flammable and nonflammable aerosols in pint cans in cartons were palletized and stored in portions of the racks. Ceiling sprinkler design was wet pipe, extra-hazardous schedule, using 17/32 orifice, 165°F (73.9°C) heads, supplied from a fairly strong city water supply (52 psi static, 38 psi residual, with 1,580 gpm flowing). A review of the hydraulics indicates system was capable of supplying a density of 0.20 gpm/sq ft for the most remote 2,000 sq ft area.

Despite immediate fire department response to a central station water flow alarm and use of a fire department siamese connection, the fire spread beyond the capability of the sprinkler system and the system was soon overtaxed, resulting in early roof collapse and breaking of sprinkler piping, and thus requiring closing of the main control valve. Numerous "fireball" explosions of aerosol cans and ruptures of 55-gal drums were reported, several affecting manual fire fighting operations, requiring about 5 hrs for control.

(5) 1975 Fire. About one hundred 55-gal drums of Class IB and IC liquids were stored palletized, 3 drums high, in a corner of a general-purpose warehouse, together with ordinary combustible commodities up to 11 ft high in racks. The roof was Class II steel deck, 15 ft high.

Sprinklers were on an ordinary hazard system, 160°F (71.1°C) heads.

Employees discovered a large fire in progress in the drum storage area. Shortly after the public fire department arrived, drums started to rupture, creating large fireballs. One drum failed at the bottom and rocketed through the roof, landing 750 ft from the building. The roof partially collapsed and one system was then shut off. Most of the building and contents were severely damaged.

The fire probably started in an open waste pail near the drum storage. Total loss was about $3,300,000.

Appendix F Fugitive Emissions Calculations

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

F-1 Introduction.

An alternative method of providing adequate ventilation for an enclosed area is by making a reasonable estimate of fugitive emissions from hydrocarbon-handling equipment within the enclosed area and providing sufficient diluent ventilation. Application of this method requires certain calculations, and one technique is described below.

In calculating the ventilation rate required, the anticipated hydrocarbon leakage rate (under normal conditions) must be determined. Then, sufficient dilution air must be added to the space in question to ensure that the concentration of flammable vapor/gas is maintained below 25 percent of the lower flammable limit (LFL) for all but periods of process upset, abnormal operation or equipment, rupture, or breakdown.

Fugitive emission factors for specific hydrocarbon handling equipment can be obtained from emission testing at specific facilities or from existing publications. A few existing publications are: API's *Fugitive Hydrocarbon Emissions from Petroleum Production Operations*, Volume I and II, 1980, and *EPA/Radian Study* conducted in 1979, and EPA's *Protocols for Generating Unit-Specific Emission Estimates for Equipment Leaks of VOC and HAP*, 1987 (Document No. 87-222-124-10-02). All emission data used should be reviewed to assure emission rates are representative of actual conditions during normal operations.

F-2 Calculation Technique.

In the example below, the required ventilation rate will be determined for an enclosed area (60 ft W × 120 ft L × 40 ft H) on a cold-weather, offshore platform containing production equipment.

1. List the total applicable hydrocarbon-handling components and their anticipated total hydrocarbon fugitive emissions. The fugitive emissions equipment component leak rates can be obtained from emission measurements at the facility in question, from one of the existing publications listed above, or from other studies that are representative of the equipment involved.

2. The total number of specific components handling hydrocarbons should be obtained by an actual field count for existing equipment or from the design drawings for proposed equipment. Note that components handling gas should be listed separately from those handling liquid hydrocarbons.

3. Determine the total anticipated gas emission (pounds/day) for each component by multiplying the number of components by the applicable prediction factor. This product is the total gas emission anticipated for that specific type component.

4. Subtotal the total anticipated gas emissions (pounds/day) for all components to obtain the total gas service emission rate.

5. Repeat Steps 2 through 4 to determine the hydrocarbon liquids total anticipated emissions.

6. Add the subtotals from Steps 4 and 5 to determine the total anticipated emissions.

7. Convert the total hydrocarbon emission from pounds/day to pounds/hour. For the example chosen, assume that the total anticipated hydrocarbon emissions is 297.26 lb/day. Dividing by 24, the conversion yields 12.39 lb/hour.

8. Calculate the average mole weight of the hydrocarbon emissions. An example follows:

83%	methane	(Molecular Wt = 16)
13%	ethane	(Molecular Wt = 30)
4%	butane	(Molecular Wt = 58)
100%		

0.83 × 16	= 13.28
0.13 × 30	= 3.90
0.04 × 58	= 2.32
Total	= 19.50

To simplify further calculations, the 19.5 is rounded to 20, and 20 is used as the average mole weight of the hydrocarbon emissions mixture.

9. Calculate the cubic feet/pound-mole at the estimated ambient temperature of the area. This calculation is made utilizing the fact that the volume of one pound-mole of an ideal gas is 359 cu ft at 32°F and 14.7 psia.

From the Gas Law ($PV = nRT$) and Charles' Gas Law ($V_1T_2 = V_2T_1$), and from the fact that volume at constant pressure varies proportionately to the ratio of temperatures when the temperature is expressed in degrees Rankine (°F + 460), calculate the actual volume. Assuming an ambient temperature of 88°F, an example follows:

At 88°F and 14.7 psia, 359 cu ft of ideal gas would occupy:

(359) (460 + 88)/(460 + 32), or 400 cu ft

10. Determine the total hydrocarbon leak rate in cubic feet per minute (cfm) using the equation:

$$G = \frac{(E)\,(V)}{60\,(mw)}$$

Where G = Leak rate, cfm
E = Emissions rate, lb/hr
V = Volume, ft^3/lb-mole
mw = Average mole weight
60 = minutes/hour

In our example, E = 12.39 lb/hr and the average mole weight is 20,

G = (12.39 lb/hr) (400 ft^3/lb-mole) / (60 min/hr) (20)

G = 4.13 cfm

11. As per NFPA 69, *Standard on Explosion Prevention Systems*, the hydrocarbon concentration may be expressed by the following equation:

$$C = (G/Q)\ (1 - e^{-kn}),$$

Where C = Concentration of hydrocarbon in air, % expressed as a decimal
G = Leak rate, cfm
Q = Fresh air introduction rate, cfm
n = Number of air changes
k = Mixing efficiency factor = 0.2 to 0.9

The factor $(1 - e^{-kn})$ can be considered equal to 1 because as the number of air changes (n) approaches steady state (i.e., approximately 3 air changes), this factor approaches unity.

As an example, if the leakage rate is assumed to be 4.13 cfm, 100 percent LFL methane is assumed (5 percent concentration), and it is desired to maintain a 25% LFL mixture, the required fresh air introduction rate may be determined as follows:

$$Q = 4.13 \text{ cfm}/(0.25 \times 0.05)$$

$$Q = 330 \text{ cfm}$$

12. Due to the variations in emission factors for processing equipment, the calculated rate should be multiplied by a safety factor of four (4). The required ventilation rate is determined as follows:

$$Q = 330 \text{ cfm} \times 4$$

$$Q = 1320 \text{ cfm, the minimum ventilation rate}$$

Thus, minimum ventilation to achieve adequate ventilation for an enclosed area of the size given above that contains the fugitive emissions sources assumed is 1320 cfm.

13. Depending on the size of the enclosed area and the equipment configuration, supplemental internal recirculation may be advisable to avoid areas of stagnation. With higher local concentrations where recirculation is justified, it should be designed with adequate air movement and direction to minimize "dead" areas where vapor may collect. If other criteria is lacking, a recirculation rate of 1 cfm/ft^2 of floor area can be used.

14. If conditions exist where there is a substantial risk of a large flammable vapor release in a confined space and the calculated rate of diluent ventilation is not sufficient to dilute and disperse the released vapor to below the LFL within four hours, then supplemental emergency ventilation should be produced. This can be by natural ventilation through panels or louvers, or by switching recirculation fans to full fresh air make-up, or exhaust. Consideration shall be given to the travel direction of ventilated vapor to avoid it reaching an ignition source outside the enclosed space being ventilated.

15. The above procedure is adapted from "Module Ventilation Rates Quantified," Oil and Gas Journal, W. E. Gale, December 23, 1985, p. 41.

Appendix G Referenced Publications

G-1 The following documents or portions thereof are referenced within this code for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

G-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10-1990, *Standard for Portable Fire Extinguishers*

NFPA 13-1989, *Standard for the Installation of Sprinkler Systems*

NFPA 14-1990, *Standard for the Installation of Standpipe and Hose Systems*

NFPA 15-1990, *Standard for Water Spray Fixed Systems for Fire Protection*

NFPA 24-1987, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*

NFPA 30A-1990, *Automotive and Marine Service Station Code*

NFPA 30B-1990, *Code for the Manufacture and Storage of Aerosol Products*

NFPA 49-1975, *Hazardous Chemicals Data*

NFPA 51B-1989, *Standard for Fire Prevention in Use of Cutting and Welding Processes*

NFPA 68-1987, *Guide for Venting of Deflagrations*

NFPA 69-1986, *Standard on Explosion Prevention Systems*

NFPA 70-1990, *National Electrical Code*

NFPA 77-1988, Recommended Practice on Static Electricity

NFPA 78-1989, *Lightning Protection Code*

NFPA 90A-1989, *Standard for the Installation of Air Conditioning and Ventilating Systems*

NFPA 91-1990, *Standard for the Installation of Blower and Exhaust Systems for Dust, Stock, and Vapor Removal or Conveying*

NFPA 204M-1985, *Guide for Smoke and Heat Venting*

NFPA 220-1985, *Standard on Types of Building Construction*

NFPA 321-1987, *Standard on Basic Classification of Flammable and Combustible Liquids*

NFPA 325M-1984, *Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*

NFPA 327-1987, *Standard Procedures for Cleaning or Safeguarding Small Tanks and Containers*

NFPA 329-1987, *Recommended Practice for Handling Underground Leakage of Flammable and Combustible Liquids*

NFPA 386-1990, *Standard for Portable Shipping Tanks for Flammable and Combustible Liquids*

NFPA 496-1989, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*

NFPA 497A-1986, *Recommended Practice for Classification of Class I Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*

NFPA 497M-1986, *Manual for Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous (Classified) Locations*

NFPA 704-1990, *Standard System for the Identification of the Fire Hazards of Materials.*

G-1.2 Other Publications.

G-1.2.1 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D 86-82, *Standard Method of Test for Distillation of Petroleum Products*

ASTM D 4021-86, *Standard Specification for Glass-Fiber Reinforced Polyester Underground Petroleum Storage Tanks.*

G-1.2.2 API Publications. American Petroleum Institute, 1220 L Street, N.W., Washington, DC 20005.

API 2015-1985, *Cleaning Petroleum Storage Tanks*

API 2015A-1982, *A Guide for Controlling the Lead Hazard Associated with Tank Entry and Cleaning*

API 2015B-1981, *Cleaning Open Top and Covered Floating Roof Tanks*

API 620-1982, *Recommended Rules for the Design and Construction of Large, Welded, Low-Pressure Storage Tanks*

API 1632-1983, *Cathodic Protection of Underground Petroleum Storage Tanks and Piping Systems*

API 650-1988, *Welded Steel Tanks for Oil Storage*

API 1615-1979, *Installation of Underground Petroleum Storage Systems.*

G-1.2.3 PEI Publication. Petroleum Equipment Institute, 6514 East 6th Street, Tulsa, OK 74133-1719.

PEI RP-100-80, *Recommended Practice for the Installation of Underground Liquid Storage Systems.*

G-1.2.4 UL Publication. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 142-1987, *Standard for Steel Aboveground Tanks for Flammable and Combustible Liquids.*

G-1.2.5 ULC Publication. Underwriters Laboratories of Canada, 7 Crouse Road, Scarborough, Ontario, Canada.

ULC-S603.1 M 1982, *Standard for Galvanic Corrosion Protection Systems for Steel Underground Tanks for Flammable and Combustible Liquids.*

G-1.2.6 STI Publication. Steel Tank Institute, 728 Anthony Trail, Northbrook, IL 60062.

sti-P_3-1987, *sti-P_3 Specification and Manual for External Corrosion Protection of Underground Steel Storage Tanks.*

G-1.2.7 NACE Publications. National Association of Corrosion Engineers, P.O. Box 218340, Houston, TX 77218.

NACE Standard RP-01-69 (1983 Rev.), Recommended Practice, *Control of External Corrosion of Underground or Submerged Metallic Piping Systems*

NACE Standard RP-02-85, Recommended Practice, *Control of External Corrosion on Metallic Buried, Partially Buried, or Submerged Liquid Storage Systems.*

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