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NFPA 52 Compressed Natural Gas (CNG) Vehicular Fuel Systems 1988 Edition

National Fire Protection Association Batterymarch Park, Quincy, MA 02269

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

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

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

Statement on NFPA Procedures

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

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NATIONAL FIRE PROTECTION ASSOCIATION

NFPA 52

Standard for

Compressed Natural Gas (CNG)

Vehicular Fuel Systems

1988 Edition

This edition of NFPA 52, *Standard for Compressed Natural Gas (CNG) Vehicular Fuel Systems*, was prepared by the Technical Committee on Compressed Natural Gas Vehicular Fuel Systems, and acted on by the National Fire Protection Association, Inc. at its Annual Meeting held May 16-18, 1988, in Los Angeles, California. It was issued by the Standards Council on June 8, 1988, with an effective date of June 28, 1988.

The 1988 edition of this standard has been approved by the American National Standards Institute.

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

Origin and Development of NFPA 52

While CNG vehicles have been used extensively in other countries since the late 1940s, it was not until the late 1970s that their use in the United States became extensive enough to warrant preparation of a national consensus standard.

Between 1980 and 1982, a Committee of the American Gas Association developed a draft of a firesafety standard. This was based upon existing worldwide standards and current U.S. practice.

In late 1981, the AGA petitioned the NFPA to establish a technical committee project on this subject. The normal NFPA solicitation of comments revealed sufficient interest from the varied interests necessary and the Committee on Compressed Natural Gas Vehicular Fuel Systems was established by the Standards Council in July 1982.

The first edition of NFPA 52 was issued in 1984.

The major changes in the 1988 edition are the addition of a chapter on residential refueling of CNG vehicles and a gas quality standard to prevent corrosion of CNG containers.

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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.

Contents

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Standard for

Compressed Natural Gas (CNG)

Vehicular Fuel Systems

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NOTICE: Information on referenced publications can be found in Chapter 6 and Appendix B.

Chapter 1 Introduction

1-1 Scope. This standard applies to the design and installation of compressed natural gas (CNG) engine fuel systems on vehicles of all types and to their associated fueling (dispensing) systems.

1-2 Alternate Provisions. It is recognized that advancement in technology and improvements in system design and equipment may result in equipment fabrication methods, component design requirements and installation and operating practices which differ from those specifically called for in this standard. Such deviations or improvements may provide desirable safety and compatible operation meeting the intent of this standard. Such deviations may be accepted when the authority having jurisdiction has seen evidence that a special investigation of all factors has been made and, based on sound experience and engineering judgment, concludes that the proposed deviations meet the intent of this standard.

1-3 Retroactivity. The provisions of this document are considered necessary to provide a reasonable level of protection from loss of life and property from fire and explosion. They reflect situations and the state-of-the-art at the time the standard was issued.

Unless otherwise noted, it is not intended that the provisions of this document be applied to facilities, equipment, structures, or installations that were existing or approved for construction or installation prior to the effective date of the document, except in those cases where it is determined by the authority having jurisdiction that the existing situation involves a distinct hazard to life or adjacent property.

1-4 Metric Practice. Metric units in this standard are based upon ASTM-380, *Standard for Metric Practice*. Where clearance distances are to be determined, the conversion from English to metric units shall be calculated to the nearest ½ meter. Alternate usage of English and metric units on a single project shall not be used to lessen clearance distances.

1-5 Definitions.

ANSI. American National Standards Institute.

Approved. Acceptable to the "authority having jurisdiction."

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

ASME Code. The American Society of Mechanical Engineers' *Boiler and Pressure Vessel Code*; Section 1, Section IV, Section VIII (Division 1), and Section IX.

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."

Bulk Plant. A compressed natural gas installation other than a dispensing unit used for storing a product for further transfer.

Bulk Storage. Storage in pressure vessels other than cylinders.

Capacity. The gross capacity of a container in standard cu ft (cf).

Cascade Storage System. Storage in multiple pressure vessels, cylinders or containers.

CF. Cu ft of gas determined at 14.7 psia and 70°F (101 kPa and 21.1°C).

Code. For new construction, "Code" shall mean the applicable edition of the ASME Code referenced in this edition of NFPA 52. For secondhand pressure vessels and existing installations, the term "Code" shall include those editions of the ASME Code which were current at the time that a pressure vessel was built.

Composite Container. A container fabricated of two or more materials that interact together to facilitate the container design criteria.

Compressed Natural Gas (CNG). Mixtures of

hydrocarbon gases and vapors, consisting principally of methane (CH_4) in gaseous form which has been compressed for use as a vehicular fuel.

Container. A pressure vessel or cylinder used to store CNG.

Container Appurtenances. Devices connected to container openings for safety, control or operating purposes.

Container Valve. A valve operated by hand, connected directly to a container outlet.

Cylinder. A container constructed, inspected, and maintained according to DOT or CTC regulations for the purpose of storing compressed natural gas and having not over 1,000 lb (454 kg) of water capacity (nominal).

Dew Point. The temperature at which water vapor begins to condense.

Dispensing Station. A natural gas installation other than a bulk plant that dispenses CNG from storage containers or a distribution pipeline by means of a compressor or pressure booster into fuel supply containers installed on a vehicle or into portable cylinders.

Filled by Pressure. A method of transferring compressed gas into a container using the pressure differential.

Flexible Metal and Wire Braid Hose. A metal hose made from continuous tubing which is corrugated for flexibility and which, for pressurized applications, shall have an external wire braid.

Fuel Supply Container. A container mounted upon a vehicle to store CNG as the fuel supply to the internal combustion engine of this vehicle.

Hazardous. A substance or circumstance which may cause injury or damage by reason of being explosive, flammable, poisonous, corrosive, oxidizing, or otherwise harmful.

Installation. A system that includes natural gas containers, pressure booster, compressors, and all attached valves, piping, and appurtenances. When filling containers or transferring natural gas directly from distribution lines by means of a compressor, an installation includes the compressor and all piping and piping components beyond the shutoff valve between the distribution system and the compressor.

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.

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

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

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

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.

Manifold. The assembly of piping and fittings used for interconnecting all containers to a common pipeline.

Manual Shutoff Valve. A quick-closing valve located downstream of all CNG fuel supply containers on the vehicle.

Metallic Hose. A hose in which the strength of the hose depends primarily upon the strength of metallic parts; it may have metallic liners and/or covers.

Natural Gas. Mixtures of hydrocarbon gases and vapors consisting principally of methane (CH_4) in gaseous form.

Noncombustible Material. A material (as defined in NFPA 220, *Standard on Types of Building Construction*) which, in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat. Materials reported as noncombustible, when tested in accordance with ASTM E-136, *Standard Method of Test for Behavior of Materials in a Vertical Tube Furnace at 750° C*, shall be considered noncombustible materials.

Point of Transfer. The point where the fueling connection is made.

Pressure Relief Device. A device designed to prevent rupture of a normally charged cylinder when it is placed

in a fire as required by US Department of Transportation (DOT) or Canadian Transport Commission (CTC) regulations. Such devices include rupture disks, fusible plugs, combination rupture disks-fusible plugs, and pressure relief valves. The term "pressure relief device" is synonymous with "safety relief device" as used by the DOT and CTC regulations.

Pressure Relief Device Channels. The passage or passages beyond the operating parts of the pressure relief device through which fluid must pass to reach the atmosphere.

Pressure Vessel. A container or other component designed in accordance with the ASME Code.

Service Valve. A valve operated by hand connected directly to the outlet of a container other than a cylinder not larger than ¾-in. pipe size and having an inlet diameter not exceeding the internal diameter of ½-in., Schedule 80 pipe.

Settled Pressure. The pressure in a container at 70°F (21.1°C) which cannot exceed the marked service or design pressure on the container.

Shall. Indicates a mandatory requirement.

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

Skid Vessel. A pressure vessel equipped with skids or feet used for transporting or storing a product, or a pressure vessel equipped with lugs to which skids shall be attached when used for transporting a product. (This is not intended to include package-type dispensing units.)

Sources of Ignition. Devices or equipment which, because of their modes of use or operation, are capable of providing sufficient thermal energy to ignite flammable compressed natural gas-air mixtures when introduced into such a mixture or when such a mixture comes into contact with them, and which will permit propagation of flame away from them.

Supply Line. The pipe, tubing or hose, including all related fittings, on a vehicle through which natural gas passes.

Transportation Vessel. A container installed on a truck, trailer, or semi-trailer for shipping a product over a highway and governed by DOT regulations.

Working Pressure. The pressure for which the equipment was constructed or, if conditions have changed, the maximum pressure at specified temperatures permitted at the most recent inspection.

Chapter 2 General CNG and Equipment Qualifications

2-1 General.

2-1.1 The provisions of this chapter apply only to pressurized system components handling CNG.

2-2 Gas Quality.

2-2.1 Gas quality in the container shall comply with the following:

H_2S and soluble sulfides partial pressure...0.05 psi max

water vapor .....7.0 lb/MMCF, max

CO_2 partial pressure .....7 psi max

O_2 .....0.5 volume %, max

Exception: When the dew point of the gas entering the cylinder is below the lowest anticipated container temperature at the maximum anticipated container pressure, the above shall not apply.

2-2.2 Natural gas introduced into any system covered by this standard shall have a distinctive odor potent enough for its presence to be detected down to a concentration in air of not over ⅕ of the lower limit of flammability.

2-3 Approval.

2-3.1 Systems and/or system components, as follows, shall be approved:

(a) Containers

(b) Pressure relief devices, including pressure relief valves

(c) Pressure gauges

(d) Pressure regulators

(e) Valves

(f) Hose and hose connections

(g) Vehicle fueling connections

(h) Engine fuel systems

(i) Electrical equipment related to CNG systems.

2-3.2 Devices not otherwise specifically provided for shall be constructed to provide safety equivalent to that required for other parts of a system.

2-4 Design and Construction of Containers.

2-4.1 Containers shall comply with 2-4.2 through 2-4.6 or shall be designed, fabricated, tested and marked using criteria which incorporate an investigation to determine that it is safe and suitable for the proposed service, is recommended for that service by the manufacturer, and is acceptable to the authority having jurisdiction.

2-4.1.1 Containers shall be fabricated of steel, aluminum or composite materials.

The container shall be designed to be suitable for CNG service and permanently marked CNG by the manufacturer.

Containers manufactured prior to the effective date of this standard may be used in CNG service if recommended for CNG service by the container manufacturer or acceptable to the authority having jurisdiction.

2-4.2 Cylinders shall be manufactured, inspected, marked, tested, retested, equipped, and used in accordance with US Department of Transportation (DOT) or Canadian Transport Commission (CTC) regulations, exemptions or special permits specifically for CNG service and shall have a rated service pressure of not less than 2400 psig at 70°F (16.5 MPa at 21.1°C).

NOTE 1: Currently there are no container specifications in DOT or CTC Regulations for CNG. Current documents covering these containers are DOT exemptions or CTC Special Permits. These are single purpose documents issued to a single company for a specific CNG application.

NOTE 2: Four relevant cylinder inspection standards which are useful are Compressed Gas Association, Inc. Pamphlets:

C-6, *Standards for Visual Inspection of Compressed Gas Cylinders.*

C-6.1, *Standards for Visual Inspection of High Pressure Aluminum Compressed Gas Cylinders.*

C-6.2, *Guidelines for Visual Inspection and Requalification of Fiber Reinforced High Pressure Cylinders.*

C-10, *Recommendations for Changes of Service for Compressed Gas Cylinders Including Procedures for Inspection and Contaminant Removal.*

2-4.3 Pressure vessels shall be manufactured, inspected, marked, and tested in accordance with the Rules for the Construction of Unfired Pressure Vessels, Section VIII (Division 1), ASME *Boiler and Pressure Vessel Code.*

2-4.3.1 Adherence to applicable ASME Code Case Interpretations and Addenda shall be considered as compliance with the ASME Code.

2-4.4 The "+" (plus) and "*" (star) markings on DOT and CTC cylinders shall not apply in accordance with DOT and CTC regulations for cylinders for flammable compressed gases. The star marking shall be removed/obliterated. The removal of the marking shall be done by peening and otherwise in accordance with DOT or CTC regulations. Grinding is prohibited.

2-4.5 In addition to the marking required by documents cited in 2-4.2 and 2-4.3, such containers and any used under the provisions of 2-4.1 shall be labeled with the words "CNG ONLY" in letters at least 1 in. (25 mm) high in contrasting color and in a location which will be visible after installation. Decals or stencils are acceptable. (*See 3-10.1.*)

2-4.6 Welding or brazing for the repair or alteration of an ASME pressure vessel shall comply with the documents under which the pressure vessel was fabricated. Other welding or brazing is permitted only on saddle plates, lugs or brackets attached to the pressure vessel by the pressure vessel manufacturer.

The exchange or interchange of pressure vessel appurtenances (*see definition*) intended for the same purpose is not considered a repair or alteration.

2-5 Pressure Relief Devices.

2-5.1 Each fuel supply container complying with 2-4.2 shall be fitted with a pressure relief device in accordance with 2-5.1.1 through 2-5.1.3.

2-5.1.1 Pressure relief devices for cylinders shall be in accordance with Compressed Gas Association (CGA) Pamphlet S-1.1, *Cylinders for Compressed Gases*, U.S. Department of Transportation (DOT) or Canadian Transportation Commission (CTC) regulations, exemptions, or special permits, and be of the Combination Rupture Disk-Fusible Plug CG-5 type in which the fusible plug has a nominal yield temperature of 212°F (100°C).

Cylinders produced under DOT and CTC exemptions or special permits which require fire tests for design qualification shall be equipped with pressure relief devices of the type, temperature rating, pressure rating, number and location used in the fire tests.

2-5.1.2 The pressure relief device shall communicate with the fuel and be vented to the atmosphere by a method that will withstand the maximum pressure which will result.

The discharge flow rate of the pressure relief device shall not be reduced below that required for the capacity of the container upon which the device is installed.

Cylinders shall not be isolated from the pressure relief device in a fashion which will allow fire to act on the cylinder but not on the pressure relief device.

2-5.1.3 The pressure relief device on cylinders shall be permanently marked with the manufacturer's name, initials or trademark, the temperature rating [212°F (100°)] of the fuse plug and the maximum pressure rating of the rupture disk.

2-5.2 Pressure vessels complying with 2-4.3 shall be provided with one or more springloaded pressure relief valves set to open in accordance with the ASME Code.

2-5.2.1 The minimum rate of discharge of pressure relief devices shall be in accordance with CGA Pamphlets S-1.1 (cylinders), S-1.2 (cargo and portable tanks), S-1.3 (storage containers), U.S. Department of Transportation (DOT) or Canadian Transport Commission (CTC) regulations, exemptions, or special permits, or the ASME Code — whichever is applicable.

2-5.2.2 Pressure relief valves for CNG service shall not be fitted with lifting devices. The adjustment, if external, shall be provided with means for sealing the adjustment to prevent tampering by unauthorized persons. If at any time it is necessary to break such seal, the valve shall be removed from service until it has been reset and sealed. Any adjustments necessary shall be made by the manufacturer or other companies having competent personnel and adequate facilities for the repair, adjustment, and testing of such valves. The organization making such adjustment shall attach a permanent tag with the setting, capacity, and date.

2-5.2.3 Each pressure relief valve shall be plainly marked by the manufacturer of the valve, as follows:

(a) With the pressure in pounds per sq in. (psi) at which the valve is set to start to discharge, and

(b) With the discharge capacity in cu ft per minute (cfm).

2-5.3 Containers and pressure vessels complying otherwise with 2-4.1 shall be provided with pressure relief devices approved by the authority having jurisdiction.

2-6 Pressure Gauges.

2-6.1 Pressure gauges shall comply with 2-6.2 through 2-6.4 and are subject to further qualification depending upon their application as noted in Chapters 3 and 4.

2-6.2 Pressure gauges shall be designed for the normal pressure and temperature conditions to which the devices may be subjected with a burst pressure safety factor of at least 4.

2-6.3 Dials shall be graduated to read at least 1.2 times the pressure at which a pressure relief device is set to function.

2-6.4 A gauge shall have an opening not to exceed 0.055 in. (1.4 mm) (No. 54 drill size) at the inlet connection.

2-7 Pressure Regulators.

2-7.1 A pressure regulator inlet and each chamber shall be designed for its maximum working pressure with a pressure safety factor of at least 4.

2-7.2 Low pressure chambers shall provide for overpressure relief or be able to withstand the operating pressure of the upstream pressure chamber.

2-8 Piping.

2-8.1 Pipe, tubing, fittings, gaskets, and packing material shall be compatible with the fuel under the service conditions.

2-8.2 Pipe, tubing, fittings and other piping components between a container and the first shutoff valve shall be capable of withstanding a hydrostatic test of at least four times the rated working pressure without structural failure.

2-8.3 Natural gas piping shall be fabricated and tested in accordance with ANSI/ASME B31.3-1980, *American National Standard Code for Chemical Plant and Petroleum Refinery Piping.*

2-8.4 The following components shall not be used:

(a) Fittings, street ells and other piping components of cast iron or semi-steel other than those complying with ASTM Specifications A-536 (Grade 60-40-18), A-395 and A-47 (Grade 35018),

(b) Plastic pipe, tubing and fittings for high pressure service,

(c) Galvanized pipe and fittings,

(d) Aluminum pipe, tubing and fittings.

Exception No. 1: Refueling connection may be made of nonsparking aluminum alloy suitable for the pressure employed.

Exception No. 2: Aluminum pipe, tubing and fittings may be used downstream of the first stage pressure regulator in an engine fuel system.

(e) Pipe nipples for the initial connection to a container, and

(f) Copper alloy with copper content exceeding 70 percent.

2-8.5 Piping components such as strainers, snubbers and expansion joints shall be permanently marked by the manufacturer to indicate the service ratings.

2-9 Valves.

2-9.1 Valves, valve packing and gaskets shall be suitable for the fuel over the full range of pressures and temperatures to which they may be subjected under normal operating conditions.

2-9.1.1 Shutoff valves shall have a rated working pressure not less than the rated working pressure of the entire system and be capable of withstanding a hydrostatic test of at least four times the rated working pressure without rupture or permanent deformation. Leakage shall not occur at less than 1½ times the rated working pressure using dry air as the test medium.

2-9.2 Valves of cast iron or semi-steel other than those complying with ASTM Specifications A-536 (Grade 60-40-18), A-395 and A-47 (Grade 35018) shall not be used as primary stop valves.

2-9.3 The following valves shall not be used:

(a) Valves of a design that will allow the valve stem to be removed without removal of the complete valve bonnet or disassembly of the valve body, and

(b) Valves with valve stem packing glands which cannot be replaced under pressure.

Exception: Where there is a shutoff valve of acceptable type between them and the container or pressure vessel. (This does not apply to service valves.)

2-9.4 The manufacturer shall stamp or otherwise permanently mark the valve body to indicate the service ratings.

Exception: Container valves incorporating integral pressure relief devices marked in accordance with 2-5.1.3 need no additional marking.

2-10 Hoses and Hose Connections.

2-10.1 Hose and metallic hose shall be of or lined with materials that are resistant to corrosion and the actions of natural gas.

2-10.2 Hose, metallic hose, flexible metal hose, tubing, and their connections shall be suitable for the most severe pressure and temperature conditions expected under normal operating conditions with a burst pressure of at least four times the maximum working pressure.

2-10.3 Hose assemblies shall be tested by the manufacturer or its designated representative prior to use to at least twice the service pressure.

2-10.4 Hose and metallic hose shall be distinctly marked, either by the manufacturer's permanently attached tag or by distinct markings, indicating the manufacturer's name or trademark, natural gas service, and working pressure.

2-11 Compression Equipment.

2-11.1 Compression equipment shall be designed for use with CNG and for the pressure and temperatures to which it may be subjected under normal operating conditions. It shall have pressure relief devices which shall limit each

stage pressure to the maximum allowable working pressure for the cylinder and piping associated with that stage of compression.

2-11.2 When CNG compression equipment is operated unattended, it shall be equipped with a high discharge and low suction pressure automatic shutdown control.

2-11.3 Control devices shall be designed for the pressure, temperature, and service expected under normal operating conditions.

2-12 Vehicle Fueling Connection.

2-12.1 A vehicle fueling connection shall provide for the reliable and secure connection of the fuel system containers to a source of high pressure natural gas.

2-12.2 The fueling connection shall be suitable for the pressure expected under normal conditions and corrosive conditions which might be encountered.

2-12.3 The fueling connection shall prevent escape of gas when the connector is not properly engaged or becomes separated.

2-12.4 The refueling receptable on an engine fuel system shall be firmly supported, and shall:

(a) Receive the fueling connector and accommodate the working pressure of the vehicle fuel system, and

(b) Incorporate a means to prevent the entry of dust, water and other foreign material. If the means used is capable of sealing system pressure it shall be capable of being depressurized before removal, and

(c) Have a different fueling connection for each pressure base vehicle fuel system.

Chapter 3 Engine Fuel Systems

3-1 Application.

3-1.1 This chapter applies to the design, installation, inspection, and testing of CNG fuel supply systems for vehicular internal combustion engines.

3-1.2 Installation of each component of the system shall be made in conformance to the written instructions provided by the manufacturer.

3-2 System Component Qualifications.

3-2.1 System components shall comply with the appropriate provisions in Chapter 2 and with 3-2.2 through 3-2.4.

3-2.2 Components in the engine compartment shall be suitable for service over a range of temperatures from -40 °F to 250 °F (-40 to 121 °C). All other components shall be suitable for service over a range of -40 °F to 180 °F (-40 to 82.2 °C).

3-2.3 Aluminum or copper pipe, tubing or fittings shall not be used between the fuel container and the first stage pressure regulator.

3-2.4 Fuel carrying components shall be labeled or stamped with the following:

(a) The manufacturer's name or symbol,

(b) The model designation,

(c) The design working pressure,

(d) Direction of fuel flow when necessary for correct installation, and

(e) Capacity or electrical rating as applicable.

Exception: Not applicable to container valves, tubing and fittings.

3-3 Installation of Fuel Supply Containers.

3-3.1 Fuel supply containers on vehicles may be located within, below or above the driver or passenger compartment provided all connections to the container(s) are external to, or sealed and vented from, these compartments.

3-3.2 Each fuel supply container shall be mounted in a location to minimize damage from collision. No part of a container or its appurtenances shall protrude beyond the sides or top of the vehicle at the point where it is installed.

3-3.2.1 The fuel system shall be installed with as much road clearance as practical but not less than the minimum road clearance of the vehicle when loaded to its gross vehicle weight rating. This minimum clearance shall be measured from the lowest part of the fuel system.

3-3.2.2 No portion of a fuel supply container or container appurtenance shall be located ahead of the front axle or behind the rear bumper mounting face of a vehicle. Container valves shall be protected from physical damage using the vehicle structure, valve protectors or a suitable metal shield.

3-3.3 Each container rack shall be secured to the vehicle body, bed or frame to prevent damage from road hazards, slippage, loosening or rotation using a method capable of withstanding a static force in the six principal directions (*see Figure 3-3.3*) of eight times the weight of a fully pressurized container(s).

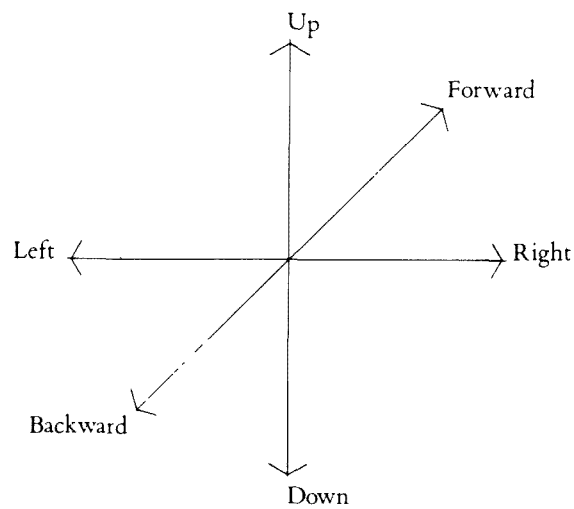

Figure 3-3.3 The Six Principal Directions.

3-3.3.1 Each fuel supply container in the rack shall be secured to its cradle in such a manner that it is capable of withstanding a static force applied in the six principal directions (*see Figure 3-3.3*) of eight times the weight of the fully pressurized container with a maximum displacement of ½ in (12.7 mm).

3-3.4 The container weight shall not be supported by outlet valves, manifolds or other fuel connections.

3-3.5 Fuel supply containers located less than 8 in. (203 mm) from the exhaust system shall be shielded against direct heat.

3-3.6 The mounting system shall minimize fretting corrosion between the container and the mounting system.

3-3.7 Fuel supply containers shall not be installed so as to adversely affect the driving characteristics of the vehicle.

3-4 Installation of Venting Systems.

3-4.1 All pressure relief devices and pressure carrying components installed within a closed compartment (*see 3-3.1*) shall be vented to the outside of the vehicle in a suitable location.

3-4.2 The venting system for the discharge of pressure relief devices (pressure relief devices channels) shall be constructed of metallic tubing with threaded, compression or flare fittings and shall be secured at the outer end.

3-4.3 The vent or vents for the venting system shall not exit into a wheel well.

3-4.4 A vent shall not restrict the operation of a container pressure relief device or pressure relief device channel.

3-5 Installation of Piping.

3-5.1 Manifolds connecting fuel containers shall be fabricated to minimize vibration and shall be installed in a protected location or shielded to prevent damage from unsecured objects.

3-5.2 A pipe thread jointing material impervious to the action of the natural gas used in the system shall be applied to all male pipe threads prior to assembly.

3-5.3 Piping and fittings shall be clear and free from cutting or threading burrs and scales, and the ends of all piping shall be reamed.

3-5.4 Where necessary to prevent abrasion, supply lines passing through a panel shall be protected by grommets or similar devices which shall snugly fit both the supply lines and the holes in the panel.

3-5.5 Supply lines shall have the maximum practical clearance from the engine exhaust system.

3-5.6 Supply lines shall be mounted, braced and supported to minimize vibration and protected against damage, corrosion or breakage due to strain or wear. A supply line shall be supported at least every 24 in. (610 mm).

3-5.7 A bend in piping or tubing is prohibited where such a bend weakens the pipe or tubing.

3-5.8 A joint or connection shall be located in an accessible location.

3-6 Installation of Valves.

3-6.1 A manually operated container valve shall be installed on each fuel container.

3-6.2 In addition to the valve required by 3-6.1, a manual shutoff valve shall be installed in an accessible location which will permit isolation of the container(s) from the remainder of the fuel system.

3-6.2.1 The valve shall be securely mounted and shielded or installed in a protected location to minimize damage from vibration and unsecured objects.

3-6.2.2 The valve location shall be marked with the words "MANUAL SHUTOFF VALVE." Decals or stencils are acceptable.

3-6.3 A valve shall be provided in the system which automatically prevents the flow of gaseous fuel to the engine when the engine is not running even if the ignition is switched on.

3-6.4 When multiple fuel systems are installed on the vehicle, automatic valves shall be provided, as necessary, to shut off the fuel not being used.

3-6.5 The fueling system shall be equipped with a blackflow check valve which will prevent the return flow of gas from the container(s) to the filling connection.

3-7 Installation of Pressure Gauges.

3-7.1 A pressure gauge located within a driver or passenger compartment shall be installed in such a manner that no gas will flow through the gauge in the event of failure.

3-7.2 A pressure gauge installed outside a driver or passenger compartment shall be equipped with a limiting orifice, a shatterproof dial lens and a body relief.

3-7.3 Gauges shall be securely mounted, shielded and installed in a protected location to prevent damage from vibration and unsecured objects.

3-8 Installation of Pressure Regulators.

3-8.1 An automatic pressure reducing regulator(s) shall be installed to reduce the fuel container pressure to a level consistent with the working pressure required by the gas-air mixer.

3-8.2 Means shall be provided to prevent regulator malfunctions due to refrigeration effects.

3-8.3 Regulators shall be installed so that their weight is not placed on, or supported by, the attached gaslines.

3-9 Installation of Fueling Connection.

3-9.1 A fueling connection receptacle complying with Section 2-12 shall be installed in each vehicle.

3-10 Labeling.

3-10.1 A vehicle equipped with a CNG fuel system shall bear a durable label, readily visible and located at the fueling connection receptacle.

3-10.1.1 The label shall include the following:

(a) CNG fueled vehicle,

(b) System working pressure,

(c) Installer's name or company,

(d) Container retest date(s),

(e) Total container water volume in cu in.

3-10.2 Each vehicle shall be identified with a weather-resistant diamond-shaped label located on an exterior vertical or near vertical surface on the lower right rear of the vehicle (on the trunk lid of a vehicle so equipped, but not on the bumper of any vehicle) inboard from any other markings. The label shall be approximately 4¾ in. (120 mm) long by 3¼ in. (83 mm) high. The marking shall consist of a border and the letters "CNG" [1 in. (25 mm) minimum height centered in the diamond] of silver or white reflective luminous material on a blue background.

3-11 System Testing.

3-11.1 The complete assembly shall be leak tested using natural gas or inert gas (carbon dioxide or nitrogen or a mixture of these).

3-11.2 After installation, every connection shall be checked with a nonammonia soap solution or a leak detector instrument after the equipment is connected and pressurized to its working pressure.

3-11.3 If the completed assembly is leak tested with natural gas, the testing shall be done under adequately ventilated conditions.

3-11.4 When a vehicle is involved in an accident or fire causing damage to the CNG container, the CNG container shall be replaced or removed, inspected and retested in accordance with the document under which it was originally manufactured before being returned to service.

3-11.5 When a vehicle is involved in an accident or fire causing damage to any part of the CNG fuel system, the system shall be retested before being returned to service.

3-12 Maintenance and Repair.

3-12.1 Damaged supply lines shall be replaced, not repaired.

3-12.2 The owner or user or both shall maintain all containers, container appurtenances, piping systems, venting systems and other components in a safe condition.

3-12.3 As a precaution to keep pressure relief devices in reliable operating condition, care shall be taken in the handling or storing of compressed natural gas containers to avoid damage. Care shall also be exercised to avoid plugging by paint or other dirt accumulation of pressure relief device channels or other parts which could interfere with the functioning of the device. Only qualified personnel shall be allowed to service pressure relief devices. Only assemblies or original manufacturer's parts shall be used in the repair of pressure relief devices unless the interchange of parts has been proved by suitable tests.

Chapter 4 CNG Compression, Storage and Dispensing Systems

4-1 Application. This chapter applies to the design, construction, installation, and operation of containers, pressure vessels, compression equipment, buildings and structures, and associated equipment used for storage and dispensing of CNG as an engine fuel in fleet and public dispensing operations.

4-2 System Component Qualifications. System components shall comply with the appropriate provisions in Chapter 2 and with Sections 4-5 through 4-13.

4-3 General.

4-3.1 Equipment related to a compression, storage or dispensing installation shall be protected to minimize the possibilities of physical damage and vandalism.

4-3.2 Control devices shall be installed so that internal or external icing or hydrate formation will not cause malfunction.

4-3.3 Vehicles shall not be considered a source of ignition with respect to the provisions in this chapter.

Exception: Vehicles containing fuel-fired equipment, e.g., recreational vehicles and catering trucks, shall be considered a source of ignition unless this equipment is shut off completely before entering an area in which ignition sources are prohibited.

4-4 Siting.

4-4.1 CNG compression, storage and dispensing shall be located and conducted outdoors or indoors in compliance with 4-4.2 and 4-4.3.

4-4.2 Outdoors.

4-4.2.1 CNG storage containers charged with CNG not connected for use shall be located outdoors.

4-4.2.2 A facility in which CNG compression, storage and dispensing equipment is sheltered by an enclosure constructed of noncombustible or limited-combustible materials which has at least one side predominantly open and a roof designed for ventilation and dispersal of escaped gas shall be regarded as outdoors.

4-4.2.3 Compression, storage and dispensing equipment outdoors shall be located aboveground, not beneath electric powerlines or where exposed by their failure, and a minimum of 10 ft (3 m) from the nearest building or line of adjoining property which may be built upon or source of ignition.

Exception: At the discretion of the authority having jurisdiction, such equipment may be located a lesser distance from buildings or walls constructed of concrete or masonry materials, but at least 10 ft (3 m) from any building openings.

4-4.2.4 Compression, storage and dispensing equipment outdoors shall be located not less than 10 ft (3 m) from the nearest public street or sidewalk line, and at least 50 ft (15 m) from the nearest rail of any railroad main track.

4-4.2.5 A clear space of at least 3 ft (1 m) shall be provided for access to all valves and fittings of multiple groups of containers.

4-4.2.6 Readily ignitable material shall not be permitted within 10 ft (3 m) of any stationary container.

4-4.2.7 The minimum separation between containers and aboveground tanks containing flammable or combustible liquids shall be 20 ft (6 m).

4-4.2.8 During outdoor fueling operations, the point of transfer (*see definition*) shall be located at least 10 ft (3 m) from any building, mobile home, public sidewalk, highway, street, or road and at least 3 ft (1 m) from storage containers.

Exception: At the discretion of the authority having jurisdiction, the point of transfer may be located at a lesser distance from buildings or walls constructed of concrete or masonry materials, but at least 10 ft (3 m) from any building openings.

4-4.3 Indoors.

4-4.3.1 Compression, dispensing equipment and storage containers connected for use may be located inside of buildings reserved exclusively for these purposes or in rooms within or attached to buildings used for other purposes in accordance with 4-4.3.

4-4.3.1.1 Storage shall be limited to not more than 10,000 cu ft (283 m^3) of natural gas in each building or room.

4-4.3.2 Buildings reserved exclusively for these purposes shall be constructed of noncombustible or limited-combustible materials. Windows and doors shall be located so as to be readily accessible in case of emergency.

Exception: Window glazing may be plastic.

4-4.3.2.1 Explosion venting shall be provided in exterior walls or roof only. Vents may consist of any one or any combination of the following, designed to relieve at a maximum internal pressure of 25 lb per sq ft (123 kg per m^2) and providing a venting area of not less than 1 sq ft per 30 cu ft (1 m^2 per 9.4 m^3) of room volume:

(a) Walls of light material;

(b) Lightly fastened hatch covers;

(c) Lightly fastened, outward opening doors in exterior walls;

(d) Lightly fastened walls or roof.

Where applicable, snow loads shall be considered.

4-4.3.3 Rooms within or attached to other buildings shall be constructed of noncombustible or limited-combustible materials. Interior walls or partitions shall be continuous from floor to ceiling, shall be securely anchored and shall have a fire resistance rating of at least 2 hours. At least one wall shall be an exterior wall. Windows and doors shall be located so as to be readily accessible in case of emergency.

Exception: Window glazing may be plastic.

4-4.3.3.1 Explosion venting shall be provided in accordance with 4-4.3.2.1.

4-4.3.3.2 Access to the room shall be from outside the primary structure.

Exception: If such access is not possible, access from within the primary structure is permitted provided such access is made through a barrier space having two vapor-sealing, self-closing fire doors suitable for installation in a wall having the fire resistance rating selected.

4-4.3.4 Indoor locations shall be ventilated utilizing air supply inlets and exhaust outlets arranged to provide air movement as uniformly as practical. Inlets shall be uniformly arranged on exterior walls near floor level. Outlets shall be located at the high point of the room in exterior walls or the roof.

4-4.3.4.1 Ventilation shall be by a continuous mechanical ventilation system which shall shut down compression equipment in the event of failure of the ventilation system or by a mechanical ventilation system activated by a continuous monitoring natural gas detection system when a gas concentration of not more than 20 percent of the lower flammable limit is present.

4-4.3.4.2 The ventilation rate shall be at least 1 cu ft/minute per 12 cu ft (1 m^3/min. per 12 m^3) of room volume.

4-4.3.4.3 A ventilation system for a room within or attached to another building shall be separate from any ventilation system for the other building.

4-4.3.5 A gas detection system shall be equipped to sound an alarm when a maximum of 20 percent of the lower flammable limit is reached.

4-4.3.6 Reactivation of compressor function shall be by manual restart conducted by trained personnel.

4-4.3.7 Sources of ignition are prohibited. Electrical equipment and wiring shall comply with Table 4-12.1.

4-4.3.8 Pressure relief devices on storage systems shall have safety relief device channels to convey escaping gas to outdoors and then upward to a safe area so as not to impinge upon buildings, other equipment or areas that could be occupied by the public — e.g., sidewalks.

4-4.3.9 Access doors shall have warning signs with the words "WARNING—NO SMOKING—FLAMMABLE GAS." Such wording shall be in plainly legible bright red

letters on a white background with letters not less than 6 in. (152 mm) high and with the principal strokes thereof not less than ¾ in. (19 mm) in width.

4-5 Installation of Containers and Container Appurtenances (Other than Pressure Relief Devices).

4-5.1 Storage containers shall be installed aboveground on stable, noncombustible foundations. Horizontal containers shall have no more than two points of support longitudinally. Where flooding may occur, they shall be securely anchored to prevent floating.

4-5.2 Containers shall be protected by painting or other equivalent means where necessary to inhibit corrosion. Horizontally installed containers shall not be in direct contact with each other.

Exception: Composite containers shall not be painted without prior permission of the container manufacturer.

4-5.3 Adequate means shall be provided to prevent the flow or accumulation of flammable or combustible liquids under containers, such as by grading, pads or diversion curbs.

4-6 Installation of Pressure Relief Devices.

4-6.1 Pressure relief valves shall be so arranged that they will discharge to a safe area, and so that escaping gas will not impinge upon buildings, other equipment, or areas that could be occupied by the public. (*See 4-4.3.8.*)

4-6.2 Pressure relief valves on pressure vessels shall be installed so that any discharge will be in a vertical position and shall be fitted with suitable raincaps.

4-6.3 A pressure relief device shall be provided in the transfer system to prevent overpressure in the vehicle.

4-7 Installation of Pressure Regulators.

4-7.1 Regulators shall be designed, installed or protected so their operation will not be affected by the elements (freezing rain, sleet, snow) or ice, mud or debris. This protection may be integral with the regulator.

4-8 Installation of Pressure Gauges.

4-8.1 Gauges shall be installed to indicate compression discharge pressure, storage pressure, and fuel supply container fill pressure.

4-9 Installation of Piping and Hoses.

4-9.1 Piping and tubing shall be run as directly as practical with adequate provisions for expansion, contraction, jarring, vibration, and settling. Exterior piping may be either buried or installed aboveground and shall be well supported and protected against mechanical damage. Underground piping shall be buried not less than 18 in. (457 mm) below the surface of the ground unless otherwise protected. Underground piping shall be protected from corrosion in compliance with present recognized practices. Threaded pipe and fittings shall not be used underground.

4-9.2 Natural gas shall not be vented to the atmosphere unless the vent leads to a safe point of discharge. A vent pipe or stack shall have the open end suitably protected to prevent entrance of rain, snow and solid material. Vertical vent pipes and stacks shall have provision for drainage.

4-9.3 The use of hose in an installation is limited to:

(a) A vehicle fueling hose;

(b) An inlet connection to compression equipment;

(c) A section of metallic hose not exceeding 36 in. (0.9 m) in length in a pipeline to provide flexibility where necessary. Each section shall be so installed that it will be protected against mechanical damage and be readily visible for inspection. The manufacturer's identification shall be retained in each section.

4-10 Testing.

4-10.1 Piping, tubing and hoses, and hose assemblies shall be leak tested after assembly to prove free from leaks at a pressure equal to at least the normal operating pressure of that portion of the system.

4-10.2 Pressure relief valves shall be tested at least every five years.

4-11 Installation of Emergency Shutdown Equipment.

4-11.1 Manually operated container valves shall be provided for each container.

4-11.2 A manually operated shutoff valve shall be installed in a manifold as close to a container or group of containers as practical.

4-11.3 Where excess-flow check valves are used, the closing flow shall be less than the flow rating of the piping system which would result from a pipeline rupture between the excess-flow valve and the equipment downstream of the excess-flow check valve.

4-11.4 The fill line on storage containers shall be equipped with a back-flow check valve to prevent discharge of natural gas from the container in case of line, hose, or fittings rupture.

4-11.5 Gas piping to a building shall be provided with shutoff valves located outside the building.

4-11.6 A means for emergency manual shutdown of the compression equipment shall be provided at the dispensing area and also at a location remote from the dispensing area.

4-11.6.1 Emergency shutdown devices shall be distinctly marked for easy recognition with a permanently affixed legible sign.

4-11.7 Breakaway protection shall be provided in a manner such that, in the event of a pullaway, natural gas will cease to flow at any separation.

4-12 Installation of Electrical Equipment.

4-12.1 Electrical equipment shall be installed in accordance with NFPA 70, *National Electrical Code®* , for Class

1, Group D, Division 1 or 2 locations in accordance with Table 4-12.1.

Table 4-12.1

Electrical Installations

Location	Division	Extent of Classified Area*
Containers (other than mounted fuel supply containers)	2	Within 10 ft (3.0 m) of container
Area containing compression, dispensing, and ancillary equipment:		
Outdoors	1	Up to 5 ft (1.5 m) from equipment
Outdoors	2	From 5 to 10 ft (1.5 to 3.0 m) from equipment
Indoors	1	Up to 5 ft (1.5 m) from equipment
Indoors	2	Beyond 5 ft (1.5 m) from equipment
Vicinity of Dispensing Operations:		
Outdoors	1	Up to 5 ft (1.5 m) from point of transfer
Outdoors	2	From 5 to 10 ft (1.5 to 3.0 m) from point of transfer

*The classified area shall not extend beyond an unpierced wall, roof, or solid vaportight partition.

4-13 Stray or Impressed Currents and Bonding.

4-13.1 When stray or impressed currents are used or may be present on dispensing systems (such as cathodic protection), protective measures to prevent ignition shall be taken in accordance with API RP 2003, *Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents.*

4-13.2 Static protection is not required when CNG is loaded or unloaded by conductive or nonconductive hose, flexible metallic tubing, or pipe connections where both halves of the metallic couplings are in contact.

4-14 Operation.

4-14.1 A cylinder shall not be charged in excess of the maximum allowable working pressure at normal temperature for that cylinder. DOT and CTC cylinders shall be charged in accordance with DOT and CTC regulations.

DOT and CTC cylinders shall not be subjected to pressure in excess of 125% of the marked service pressure even if on cooling it settles to the marked service pressure.

4-14.1.1 A fuel supply container shall not have a settled pressure above the working pressure stamped on the container and displayed on a label near the filling connection, corrected for the ambient temperature at time of filling.

4-14.2 CNG dispensing systems shall be equipped to automatically stop fuel flow when a fuel supply container reaches the temperature-corrected fill pressure.

4-14.3 The transfer of CNG into a fuel supply container shall be performed by a person qualified as having performed the transfer operation at least three full cycles under supervision and having competence in initiating emergency procedures. This person shall be responsible for verifying working pressure and container retest date currentness.

4-14.4 When CNG is being transferred to or from a motor vehicle, the engine shall be stopped.

4-14.5 During the transfer of CNG to or from cargo vehicles, the hand or emergency brake of the vehicle shall be set and chock blocks used to prevent rolling of the vehicle.

4-14.6 Bleed connections shall be provided in transfer systems to permit depressurizing before disconnecting the line. These bleed connections shall lead to a safe point of discharge.

4-14.7 CNG shall not be used to operate any device or equipment which has not been designed or properly modified for CNG service.

4-14.8 Sources of ignition shall not be permitted within 10 ft (3 m) of any filling connection during a transfer operation. (*See 4-4.3.*)

4-14.9 Warning signs with the words "STOP MOTOR," "NO SMOKING," "NO OPEN FLAMES PERMITTED" — FLAMMABLE GAS" shall be posted at dispensing station and compressor areas. The location of signs shall be determined by local conditions but shall be visible from each point of transfer.

4-15 Fire Protection.

4-15.1 A portable fire extinguisher having a rating of not less than 20-B:C shall be provided at the dispensing area.

4-16 Maintenance.

4-16.1 Containers and their appurtenances, piping systems, compression equipment, controls, and devices shall be maintained in proper operating condition.

4-16.2 After the original installation, vehicle fueling hoses shall be examined visually at such intervals as are necessary to assure that they are safe for use. Hose shall be tested for leaks with soap suds or equivalent leak detection equipment at least annually and any unsafe leakage shall be reason for rejection.

4-16.3 While in transit, fueling hose and flexible metal hose on a cargo vehicle to be used in a transfer operation, including their connections, shall be depressurized and protected from wear and injury.

4-16.4 Pressure relief valves shall be maintained in proper operating condition.

4-16.4.1 As a precaution to keep pressure relief devices in reliable operating condition, care shall be taken in the

handling or storing of compressed natural gas containers to avoid damage. Care shall also be exercised to avoid plugging by paint or other dirt accumulation of pressure relief device channels or other parts which could interfere with the functioning of the device. Only qualified personnel shall be allowed to service pressure relief devices. Only assemblies or original manufacturer's parts shall be used in the repair of pressure relief devices unless the interchange of parts has been proved by suitable tests.

Chapter 5 Residential Fueling Facility

5-1 Scope.

5-1.1 A residential fueling facility (RFF) is an assembly used for the compression and delivery of natural gas into vehicles with its associated equipment and piping. The capacity of a RFF shall not exceed 5 SCFM of natural gas. Storage of CNG, except in the vehicle fuel supply container, is prohibited.

5-1.2 This chapter applies to the design, construction, installation, and operation of a RFF as defined in 5-1.1.

5-1.3 The provisions of this chapter shall apply to all residential refueling installations except where prohibited by local laws.

5-2 System Component Qualifications.

5-2.1 System components shall comply with the appropriate provisions in Chapter 2.

5-3 General.

5-3.1 All equipment releated to a RFF installation shall be suitably packaged and located to protect from physical damage and vandalism. This requirement may be met by enclosing the compressor package in an enclosure, similar to a central air conditioner.

5-3.2 All equipment related to a RFF installation shall be designed for the pressure, temperature, and service expected.

5-3.3 Vehicles shall be considered as unclassified electrically with respect to Article 500 of NFPA 70, *National Electrical Code*.

5-3.4 Natural gas shall not be vented to the atmosphere under normal operation.

5-4 Installation.

5-4.1.1 Approval of residential refueling installations shall be obtained from the authority having jurisdiction and the natural gas distribution company.

5-4.1.2 The primary concern for the location of the refueling system shall be based solely upon its safety, whether it be indoors or outdoors. CNG compression and dispensing should be located and conducted outdoors wherever practicable. However, when not practicable, e.g., inclement weather is common, compression and dispensing can be located indoors.

5-4.1.3 All RFF equipment shall be installed in accordance with the equipment manufacturer's instructions.

5-4.1.4 The RFF shall have a nameplate marked with minimum and maximum gas inlet pressure and flow rate, gas outlet maximum pressure and electrical requirements.

5-4.2 Indoor Installations.

5-4.2.1 Where it is necessary to install the compression equipment and refueling connection indoors, the compression unit shall be mounted to or otherwise located adjacent to an outside wall to facilitate the rapid venting of released gases. The room or garage shall be considered for an acceptable site when the compressor enclosure is vented to the outside.

5-4.2.2 When the RFF or the vehicle being fueled is located indoors, a gas detector set to operate at one fifth the lower limit of flammability of natural gas shall be installed in the room. The detector shall be located within 6 inches of the ceiling or highest point in the room. The detector shall stop the compressor and operate an audible or visual alarm.

5-4.3 Outdoor Installations.

5-4.3.1 The RFF shall be installed on a firm noncombustible support to prevent undue stress on piping and conduit.

5-5 Installation of Pressure Relief Valves.

5-5.1 Pressure relief valves shall have pressure valve channels to convey escaping gas to outdoors and then upwards to a safe area so as not to impinge on buildings, other equipment, or areas that could be occupied by the public, e.g., sidewalks.

5-6 Installation of Pressure Gauges.

5-6.1 For measurement and test purposes, pressure gauges may be installed but are not required.

5-7 Pressure Regulation.

5-7.1 A RFF shall be equipped to automatically stop fuel flow when container(s) reach temperature corrected fill pressure.

5-8 Piping and Hose.

5-8.1 All piping and hose from the outlet of the compressor shall be supplied as part of the RFF.

5-8.2 All gas piping to the RFF shall be installed in accordance with NFPA 54, *National Fuel Gas Code*.

5-8.3 The use of hose in an installation is limited to:

(a) A vehicle refueling hose; the maximum length fueling hose is 12 ft (3.7 m) and shall be supported above the floor.

(b) An inlet connection to compression equipment not exceeding 36 in. (0.9 m). This connector, if used, shall be supplied as part of the RFF.

(c) A section of metallic hose not exceeding 36 inches in length in a pipeline to provide flexibility where necessary. Each section shall be so installed that it will be protected against mechanical damage and be readily visible for inspection. The manufacturer's identification shall be retained in each section.

(d) Hose used for pressure relief device channels may exceed 36 in. (0.9 m).

5-8.4 The number of connections shall be minimized in order to minimize the possibility of leakage in the RFF.

5-8.5 Bleed connections shall be provided in transfer systems to permit depressurizing the line before disconnection. These bleed connections shall lead to a safe point of discharge.

5-9 Testing.

5-9.1 All piping and tubing shall be tested after assembly to prove free from leaks at a pressure equal to the maximum working pressure of that portion of the system.

5-10 Installation of Emergency Shutdown Equipment.

5-10.1 A RFF shall be equipped with emergency manual shutdown of the gas supply and electric power. The emergency electrical switch shall be at least 5 ft (1.5 m) from the RFF and in view of the RFF.

5-10.2 Break-away protection shall be provided in a manner such that, in the event of a pull-away, natural gas will cease to flow at any separation.

5-11 Operation.

5-11.1 A RFF shall be operated in accordance with the manufacturer's instructions.

5-11.2 A fuel supply container shall not be charged in excess of its maximum allowable working pressure at normal temperature. DOT and CTC containers shall be charged in accordance with DOT and CTC regulations.

5-11.3 When CNG is being transferred to a motor vehicle, the engine shall be stopped.

5-12 Maintenance and Inspection.

5-12.1 All RFF equipment shall be inspected and maintained in accordance with the manufacturer's instructions.

5-12.2 After installation, all hoses shall be examined visually as part of this inspection. Hoses that are kinked or worn shall be replaced.

5-12.3 All safety relief valves shall be maintained in proper operating condition, in accordance with manufacturer's/supplier's recommendation.

Chapter 6 Referenced Publications

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

6-1.1 NFPA Publications. National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

NFPA 54-1988, *National Fuel Gas Code.*

NFPA 70-1987, *National Electrical Code.*

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

NFPA 259-1987, *Standard Test Method for Potential Heat of Building Materials.*

6-1.2 Other Publications.

6-1.2.1 The following publications are available from the American Society of Mechanical Engineers, 345 East 47th St., New York, NY 10017.

ANSI/ASME B31.3 (1987), *American National Standard Code for Chemical Plant and Petroleum Refinery Piping.*

Boiler and Pressure Vessel Code Section VIII (1986).

6-1.2.2 The following publications are available from the American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103.

A-47-1984, *Specification for Malleable Iron Castings.*

A-395-1986, *Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures.*

A-536-1984, *Specification for Ductile Iron Castings.*

E-136-1982, *Standard Method of Test for Behavior of Materials in a Vertical Tube Furnace at 750° C.*

6-1.2.3 The following publications are available from the Compressed Gas Association, Inc., 1235 Jefferson Davis Highway, Arlington, VA 22202.

Pressure Relief Device Standards:

S-1.1, *Cylinders for Compressed Gases* (1979).

S-1.2, *Cargo and Portable Tanks for Compressed Gases* (1980).

S-1.3, *Compressed Gas Storage Containers* (1980).

6-1.2.4 US DOT and CTC container data is available from the US Department of Transportation, 400 7th St., SW, Washington, DC 20590 and the Canadian Transport Commission, Transport Canada Building, Place de Ville, Ottawa, Ontario, K1A ON 5.

6-1.2.5 The following publication is available from the American Petroleum Institute, 2101 L St., NW, Washington, DC 20037.

RP 2003, Protection Against Ignitions Arising Out of Static, Lightning and Stray Currents, Fourth Edition, 1982.

Appendix A Explanatory Material

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

A-1 Properties of CNG.

A-1-1 Natural gas is a flammable gas. It is colorless, tasteless and nontoxic. It is a light gas, weighing about two-thirds as much as air. As used in the systems covered by this standard, it tends to rise and diffuses rapidly in air when it escapes from the system.

A-1-2 Natural gas burns in air with a luminous flame. At atmospheric pressure, the ignition temperature of natural gas-air mixtures has been reported to be as low as 900°F (482°C). The flammable limits of natural gas-air mixtures at atmospheric pressure are about 5 percent to 15 percent by volume natural gas.

A-1-3 Natural gas is nontoxic but can cause anoxia (asphyxiation) when it displaces the normal 21 percent oxygen in air in a confined area without adequate ventilation.

A-1-4 Natural gas is not a unique, specific substance with a common composition at all times and in all places. While, as noted in the definition of Compressed Natural Gas in Section 1-5, natural gas consists principally of methane, it also contains ethane, small amounts of propane, butane and higher hydrocarbons and may contain small amounts of nitrogen, carbon dioxide, hydrogen sulfide and helium. The quantity of nitrogen, carbon dioxide, hydrogen sulfide and helium will vary from zero to a few percent depending upon the source, seasonal effects, etc.

A-1-4.1 As distributed in the extensive gas transmission and distribution piping network in the United States and Canada, natural gas also contains water vapor. This "pipeline quality" gas can contain up to 7 lb or more of water per million cu ft of gas.

A-1-4.2 Some constituents of natural gas, especially carbon dioxide and hydrogen sulfide in the presence of liquid water, can be corrosive to carbon steel and the corrosive effect is increased by pressure. The pressures used in CNG systems covered by NFPA 52 are substantial and well above those used in transmission and distribution piping and in other natural gas consuming equipment. As excessive corrosion can lead to sudden explosive rupture of a container, this hazard must be controlled.

As a result of such a failure in a cylinder comprising one of several such in a tube trailer in 1978, the US Department of Transportation has specified CNG composition for CNG being transported in interstate commerce. The limits for carbon dioxide, hydrogen sulfide and water are very low, e.g., the limit for water is 0.5 lb per million cu ft.

A-1-4.3 There is a substantial body of opinion on the Committee that the DOT stipulated composition is intentionally conservative and would require expensive, sophisticated gas conditioning equipment to be used. This view is supported by experience of up to 15 years' duration with no failure of either storage or fuel supply containers in CNG vehicle applications. This experience has largely been with carbon steel cylinders fabricated to DOT 3A or 3AA specification and, therefore, relatively subject to internal corrosion if the conditions are present.

A-1-4.4 Corrosion protection can also be addressed by the use of materials which are corrosion resistant. A number of exemptions and special permits have been issued by DOT and CTC for cylinders made of materials other than carbon steel. However, the impetus for these materials has come from other considerations, principally lighter weight.

A-1-4.5 The Committee encouraged the conduct of a research program to explore this gas quality/material matter and the research work was performed by Southwest Research Institute in San Antonio, Texas. Funding was provided by the New York State Energy Research and Development Authority (NYSERDA), the New York Gas Group (NYGAS), and the U.S. Department of Energy (DOE). The Committee gratefully acknowledges both the financial support of NYSERDA, NYGAS and DOE, and the cooperation and contributions of management, engineering, and operating personnel of the gas transmission companies, gas distribution companies, and CNG container manufacturers who supplied technical data, used gas cylinders, test materials, and test gases for this research program.

A-1-4.6 The principal objective of the research program was to define natural gas contaminant concentration limits necessary to insure that internal corrosion of CNG containers does not constitute a hazard over the lifetimes of the containers. A secondary objective included definition of the effects of materials variables, container fabrication procedures, and other CNG system parameters on internal corrosion of CNG containers and container materials. Accomplishment of the research program objectives permitted the Committee to define the limiting concentrations of corrosive contaminants in CNG necessary to prevent corrosion or corrosion-related damage to vehicle fuel and storage containers.

A-1-4.7 Paragraph 2-2.1 as a control of the amount of hydrogen sulfide and sulfides, water, carbon dioxide and oxygen reflects a Committee consensus that if the water content is limited the other potentially corrosive constituents should not be a major concern.

A-2 Vehicle Fuel Systems.

A-2-1 A typical vehicle fuel system consists of one or more (if more than one, the containers are manifolded together) fuel supply containers holding CNG at high pressure and fitted with pressure relief devices and manual shutoff valves, a filling connection with a check valve to prevent flow back out of the connection, a manual valve downstream from the container valve or valves, a valve which will automatically close if the engine stops for any reason, a pressure regulator to reduce fuel supply container pressure to a low engine operating pressure, a gas-air mixer to produce a flammable mixture and a pressure gauge to show fuel supply container pressure.

A-2-2 Systems are designed to operate at fuel supply container pressures of 2400, 3000 or 3600 psi (16.5 MPa, 20.6

MPa or 25 MPa). Fueling connections are designed to accommodate compatible filling nozzles suitable only for the proper pressure.

A-2-3 Fuel supply containers are installed on either the outside of the vehicle or inside the vehicle. If inside, all connections to the containers are either external to a driver or passenger compartment or inside a compartment that is gastight with respect to a driver or passenger compartment. The compartment is vented to outside the vehicle.

A-3 Fueling Systems.

A-3-1 A typical fueling system consists of one or more compressors taking suction from a natural gas transmission or distribution pipeline or a building piping system connected to a transmission or distribution pipeline with the compressor discharging into either one or more storage containers or to a dispensing system, and a dispensing system consisting of a hose and nozzle and sometimes a meter. Where a storage container is present, it discharges to a dispensing system.

A-3-2 Where storage containers are used, the system is known as a "fast-fill" system with a vehicle filling time of about 3-5 minutes. Where storage containers are not used, the system is known as a "slow-fill" system and filling times can be several hours.

A-3-3 The suction pressure for compressors ranges from about 2-500 psig (13.7 kPa-3.4 MPa) with most being under 60 psig (40 kPa). The delivery pressure is more than the vehicle system pressure but less than 5000 psi (35 MPa), with most around 3600 psi (25 MPa).

A-3-4 CNG is stored in two types of storage systems — bulk storage and cascade storage. They differ in the manner in which the CNG is withdrawn from them.

A-3-4.1 Bulk storage of CNG can be accomplished with one large container or a number of smaller containers manifolded together. As vehicles draw CNG from bulk storage, all containers draw down (reduce in pressure) at the same rate.

Bulk storage provides less "available" CNG storage than the cascade system.

A-3-4.2 Storage containers arranged in a cascade can provide more "available" CNG storage than a bulk system for the same size containers. A brief description of the operation of a typical cascade system is as follows:

A cascade is usually arranged in at least three banks of containers with the containers in any one bank manifolded together so that each bank acts as one large container. The banks are separated by automatic switching valves. The valve sequencing is controlled automatically by a sequencing control panel.

The cascade banks are initially filled with CNG in sequence by the compressor to the normal operating pressure of the system. The highest pressure bank is refilled first ("Bank 1"), followed by successively lower pressure banks ("Bank 2," "Bank 3," etc.). This sequence is called "priority fill."

Vehicles can then be fueled from the cascade, beginning with Bank 3 (for a three-bank cascade).

If there is insufficient CNG in Bank 3 to pressurize the vehicle fuel supply container(s), Bank 3 will be valved off and Bank 2 will "top up" the vehicle container(s). Successive vehicles will draw from Banks 3 and 2 as above, until Bank 1 is required to "top up" the vehicle container(s). When Bank 1 pressure is reduced to a preset value, the compressor will bypass the cascade and fill the vehicle directly. At the completion of the last vehicle fill, the compressor will continue running, and refill the cascade by priority fill.

Cascade valving can be arranged to provide more available storage than the system described.

A-4 Container Capacity.

A-4-1 Containers are described by their liquid capacity, and the design and allowable working pressures. The liquid capacity (cu ft of water) is the volume of liquid that would be required to fill the container. The allowable working pressure is the maximum pressure at which the container should be operating. From the liquid capacity and allowable working pressure, the gas storage capacity can be calculated.

A-4-2 The amount of gas being stored in a cylinder can be calculated by applying the "ideal gas law" taking account of the "compressibility factor" (or "supercompressibility") of the specific gas being stored.

A-4-2.1 The ideal gas law states that, if the absolute pressure of a certain volume of gas is doubled, the volume will decrease to half (at a constant temperature). However, natural gas does not follow the ideal gas law exactly. The term "supercompressibility," as it relates to natural gas, simply indicates that more natural gas can be stored in a given volume !below about 5,000 psig (35 MPa)[6] than would be indicated by the ideal gas law.

Appendix B Referenced Publications

B-1 The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 The following publications are available from the Compressed Gas Association, 1235 Jefferson Davis Highway, Arlington, VA 22202.

C-1 *Methods for Hydrostatic Testing of Compressed Gas Cylinders* (1975).

C-2 *Recommendations for the Disposition of Unserviceable Compressed Gas Cylinders* (1987).

C-5 *Cylinder Service Life-Seamless, High-Pressure Cylinder Specifications* DOT-3, DOT-3A, DOT-3AA (1981).

C-6 *Standards for Visual Inspection of Compressed Gas Cylinders* (1984).

C-6.1 *Standards for Visual Inspection of High Pressure Aluminum Compressed Gas Cylinders* (1984).

C-6.2 *Guidelines for Visual Inspection and Requalification of Fiber Reinforced High Pressure Cylinders* (1982).

C-10 *Recommendations for Changes of Service for Compressed Gas Cylinders Including Procedures for Inspection and Contaminant Removal* (1985).

C-14 *Procedures for Fire Testing of DOT Cylinder Safety Relief Device Systems* (1979).

P-1 *Safe Handling of Compressed Gases in Containers* (1984).

P-11 *Metric Practice Guide for the Compressed Gas Industry* (1980).

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SUBMITTING PROPOSALS ON NFPA TECHNICAL COMMITTEE DOCUMENTS

Contact NFPA Standards Administration for final date for receipt of proposals on a specific document.

INSTRUCTIONS

Please use the forms which follow for submitting proposed amendments. Use a separate form for each proposal.

1. For each document on which you are proposing amendment indicate:
   (a) The number and title of the document
   (b) The specific section or paragraph.

2. Check the box indicating whether or not this proposal recommends new text, revised text, or to delete text.

3. In the space identified as "Proposal" include the wording you propose as new or revised text, or indicate if you wish to delete text.

4. In the space titled "Statement of Problem and Substantiation for Proposal" state the problem which will be resolved by your recommendation and give the specific reason for your proposal including copies of tests, research papers, fire experience, etc. If a statement is more than 200 words in length, the technical committee is authorized to abstract it for the Technical Committee Report.

5. Check the box indicating whether or not this proposal is original material, and if it is not, indicate source.

6. If supplementary material (photographs, diagrams, reports, etc.) is included, you may be required to submit sufficient copies for all members and alternates of the technical committee.

NOTE: The NFPA Regulations Governing Committee Projects in Paragraph 10-10 state: Each proposal shall be submitted to the Council Secretary and shall include:

(a) identification of the submitter and his affiliation (Committee, organization, company) where appropriate, and

(b) identification of the document, paragraph of the document to which the proposal is directed, and

(c) a statement of the problem and substantiation for the proposal, and

(d) proposed text of proposal, including the wording to be added, revised (and how revised), or deleted.