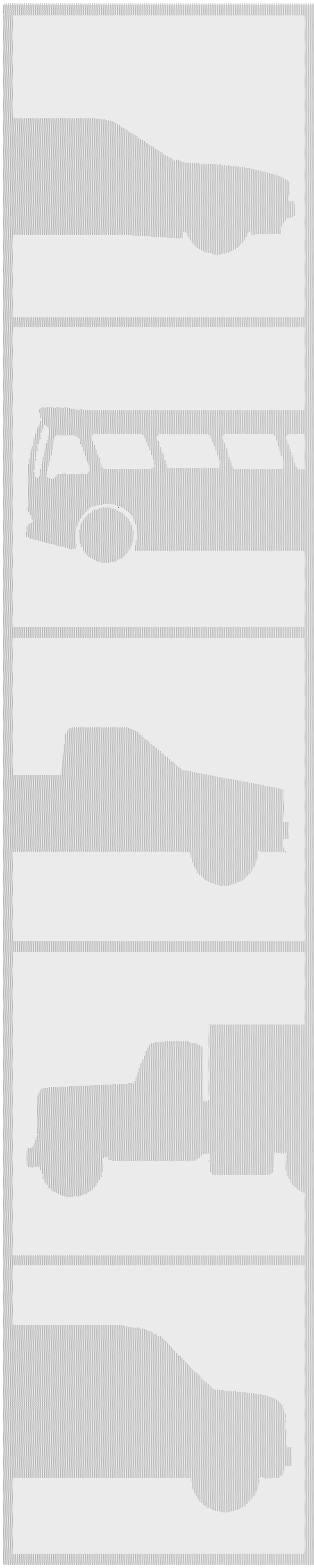

Approved American National Standard

ANSI/CSA
NGV2-2000

AMERICAN NATIONAL STANDARD

FOR

BASIC REQUIREMENTS FOR COMPRESSED NATURAL GAS VEHICLE (NGV) FUEL CONTAINERS

A project of the Natural Gas Vehicle Coalition

THE NATURAL GAS VEHICLE COALITION

Secretariat

CSA INTERNATIONAL
8501 East Pleasant Valley Rd.
Cleveland, Ohio 44131

AMERICAN NATIONAL STANDARD
ANSI/CSA NGV2-2000

Third Edition - 2000

BASIC REQUIREMENTS FOR COMPRESSED NATURAL GAS VEHICLE (NGV) FUEL CONTAINERS

Approved
March 3, 2000

Prepared by

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On behalf of
the Natural Gas Vehicle Coalition

Published - October 2000

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PREFACE

This publication represents a standard for safe operation, substantial and durable construction and performance testing of containers for the on-board storage of compressed natural gas for vehicle operation, within limitations given below and in the scope of this standard.

This standard is based on engineering principles, research and the combined expertise of gas utilities, manufacturers, users, and others having specialized experience.

Nothing in this standard is to be considered in any way as indicating a measure of quality beyond compliance with the provisions it contains. It is designed to allow compliance of products which may exceed that specified in the provisions herein. In its preparation, full recognition has been given to possibilities of improvement through ingenuity of design. This standard is subject to revision as further experience and investigation may show it is necessary and desirable.

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EFFECTIVE DATE: An organization using this standard for product evaluation as a part of its certification program will normally establish the date by which all products certified by that organization should comply with this standard.

HISTORY OF DEVELOPMENT OF ANSI/CSA NGV2

(This history is informative and is not part of the standard.)

In 1988 a group of U.S. gas utility companies formed the Natural Gas Vehicle (NGV) Coalition (the Coalition) to promote widespread use of natural gas as a vehicle fuel. The Coalition organized committees to address technical, marketing and legislative issues which would affect future expansion.

The Coalition recognized that an important consideration in the successful commercialization of natural gas as a vehicle fuel was the issue of codes and standards (or the lack of codes and standards, or harmonized codes and standards) pertaining to both fuel stations and vehicle fuel systems. The Coalition's Technology Committee undertook the goal of establishing a program for the development of an organized family of coordinated codes, standards and regulations addressing natural gas vehicles and fueling stations.

One of the major technical obstacles to the above goal concerned the on-board fuel container. It was acknowledged that lack of a design standard and certification program for light-weight composite vehicle fuel supply containers was a major obstacle to wider use of compressed natural gas as a vehicle fuel. U.S. Department of Transportation (DOT) regulations and exemptions do not address the use of cylinders as vehicle fuel containers. Such government regulations only cover cylinders which are approved for use in interstate transport.

The Standards and Standardization Subcommittee's On-Board Fuel Containers Working Group established a task group to prepare a draft standard addressing NGV on-board fuel containers.

The Fuel Cylinder Task Group initiated a proposed draft standard for NGV on-board fuel containers, which was (1) based on existing standards, (2) had no limitation on materials or method of construction, (3) considered the internal and external container environment, and (4) incorporated a certification process for design, manufacturing and quality control. The draft standard was initially based on the format of U.S. DOT cylinder regulations and exemptions (e.g., *DOT FRP-1 for Fiber Reinforced, Full Composite Cylinders Using a Seamless Aluminum Liner*).

The draft NGV fuel container standard was processed as an American National Standard under the canvass method in accordance with procedures of the American National Standards Institute (ANSI).

On June 30 1997, the Canadian Standards Association (CSA) acquired International Approval Services (IAS) which was until then a joint venture of the American Gas Association (A.G.A.) and the Canadian Gas Association (CGA). Under this agreement CSA acquired the complete range of IAS standards administration, certification and registration products and services for appliances and accessories fueled by natural and liquefied petroleum gases.

The revisions contained in the third edition of NGV2-2000 were originally proposed to be published as an "a" addenda to the 1998 edition. In response to industry requests these revisions were incorporated in the base document and are being released as a new edition of NGV2. This, the third edition of the NGV fuel containers standard was approved by the American National Standards Institute, Inc. on March 3, 2000.

Previous editions of this standard, and addenda thereto, approved by the American National Standards Institute are as follows:

NGV2-1992
NGV2-1998

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AMERICAN NATIONAL STANDARD/CSA STANDARD FOR BASIC REQUIREMENTS FOR COMPRESSED NATURAL GAS VEHICLE (NGV) FUEL CONTAINERS

1. SCOPE

1.1 General.

This standard contains requirements for the material, design, manufacture and testing of serially produced, refillable Type NGV2 containers intended only for the storage of compressed natural gas for vehicle operation. These containers are to be permanently attached to the vehicle. Type NGV2 containers shall not be over 1,000 liters (35.4 cu ft) water capacity.

Where the word "shall" is used in this code, it indicates a requirement unless approved otherwise by the authority having jurisdiction.

1.2 Container Type.

Type NGV2 containers are designated as follows:

NGV2-1. Metal.

NGV2-2. Resin impregnated continuous filament with metal liner with a minimum burst pressure of 125% of service pressure. The container may be either hoop-wrapped or full-wrapped.

NGV2-3. Resin impregnated continuous filament with metal liner. The container may be either hoop-wrapped or full-wrapped.

NGV2-4. Resin impregnated continuous filament with a non-metallic liner.

2. REFERENCED PUBLICATIONS

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Box 753, Waldorf, MD, U.S.A. 20601.

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AMERICAN SOCIETY OF MECHANICAL ENGINEERS (www.asme.org),
345 East 47th Street, New York, New York, U.S.A. 10017.

BPVC-1998, Boilers and Pressure Vessels

AMERICAN SOCIETY FOR TESTING AND MATERIALS (www.astm.org)
100 Barr Harbor Drive, West Conshohochen, Pennsylvania, U.S.A. 19428-2959.

ASTM D638-1999, Standard Test Method for Tensile Properties of Plastics

ASTM D1186-1993, Standard Test Methods for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base

ASTM D1400-1994, Standard Test Method for Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Nonferrous Metal Base

ASTM D2344-2000, Standard Test Method for Short Beam Strength of Polymer Matrix Composite Materials and Their Laminates

ASTM D3359-1997 - Standard Test Methods for Measuring Adhesion by Tape Test

ASTM D4138-1994 (R1999), Standard Test Methods for Measurement of Dry Film Thickness of Protective Coating Systems, by Destructive Means

ASTM D4814-2000, Standard Specification for Automotive Spark-Ignition Engine Fuel

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ASTM E23-2000, Standard Test Methods for Notched Bar Impact Testing of Metallic Materials

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AMERICAN SOCIETY FOR QUALITY (www.asq.org),
611 East Wisconsin Ave., Milwaukee, Wisconsin, U.S.A. 53201-3005.

ANSI/ISO/ASQC Q9000 Series-1994, Quality Management and Quality Assurance Standards

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Dept. 77839, P.O. Box 77000, Detroit, MI, U.S.A. 48277-0839.

QS-9000-1998, Quality System Requirements

BRITISH STANDARDS INSTITUTE (www.bsi.org.uk),
389 Chiswick High Road, London, England W4 4AL.

BS PD6493-1991, Guidance on Methods for Assessing the Acceptability of Flaws in Fusion Welded Structures

BS 7512-1989, General Requirements for Bodies Operating Assessment and Certification Registration of Quality Systems

BS 7910-1999, Guide on Methods for Assessing the Acceptability of Flaws in Fusion Welded Structures

CANADIAN GENERAL STANDARDS BOARD (www.pwgsc.gc.ca/cgsb),
Phase III, 6B1, 11 Laurier St., Hull, PQ, Canada K1A 1G6.

CGSB-3.513 - 1992, Natural Gas For Vehicles

CSA INTERNATIONAL (www.csa.ca),
178 Rexdale Boulevard, Toronto, Ontario, Canada M9W 1R3.

CAN/CGA-B149.4-M91 (R1998), Natural Gas For Vehicles Installation Code

CSA INTERNATIONAL (www.csa.ca),
8501 E. Pleasant Valley Rd., Cleveland, OH, U.S.A. 44131.

ANSI/IAS PRD 1-1998, and Addenda ANSI/IAS PRD 1a-1999, Basic Requirements for Pressure Relief Devices for Natural Gas Vehicle (NGV) Fuel Containers

COMPRESSED GAS ASSOCIATION, INC. (www.cganet.com),
1725 Jefferson Davis Hwy, Suite 1004, Arlington, Virginia, U.S.A. 22202-4102.

CGA C-1-1996, Methods for Hydrostatic Testing of Compressed Gas Cylinders

CGA C-6.4-1998, Methods for External Visual Inspection of Natural Gas Vehicle Fuel Containers and Their Installations

DEPARTMENT OF TRANSPORTATION (www.nhtsa.dot.gov),
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
400 Seventh Street, S.W., Washington, DC, U.S.A. 20590.

FMVSS No. 303, (49CFR571.303) Fuel System Integrity of Compressed Natural Gas Vehicles

FMVSS No. 304, (49CFR571.304) Compressed Natural Gas Fuel Container Integrity

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (www.iso.ch),
1, Rue de Varembé, Case postale 56, CH-1211 Genéve 20, Switzerland.

ISO 148 – 1993, Steel-Charpy Impact Test (V-Notch)

ISO 306 –1994, Plastics - Thermoplastic Materials - Determination of Vicat Softening Temperature

ISO 7866-1999 – Gas Cylinders Refillable Seamless Aluminum Alloy Gas Cylinders—Design, Construction and Testing

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ISO 9809-1-1999, Gas Cylinders - Refillable Seamless Steel Gas Cylinders - Design, Construction and Testing — Part 1, Quenched and Tempered Steel Cylinders with Tensile Strength Less than 1100 MPa.

ISO 12737 – 1996, Metallic Materials—Determination of Plane-Strain Fracture Toughness

NATIONAL ASSOCIATION OF CORROSION ENGINEERS (www.nace.org),
P.O. Box 218340, Houston, TX, U.S.A. 77218.

NACE TM0177 – 96, Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking and Stress Corrosion Cracking in H_2S Environments

NATIONAL FIRE PROTECTION ASSOCIATION (www.nfpa.org),
One Batterymarch Park, P.O. Box 9101, Quincy, Massachusetts, U.S.A. 02269-9101.

ANSI/NFPA 52-1998, Compressed Natural Gas (CNG) Vehicular Fuel Systems Code

SOCIETY OF AUTOMOTIVE ENGINEERS (www.sae.org),
400 Commonwealth Drive, Warrendale, PA, U.S.A. 15096-0001.

SAE J1616-1994, Recommended Practice for Compressed Natural Gas Vehicle Fuel

TRANSPORT CANADA, ROAD & MOTOR VEHICLE TRAFFIC SAFETY (www.tc.gc.ca),
Place de Ville, 330 Sparks Street, Ottawa, Ontario, Canada K1A 0N5.

Motor Vehicle Safety Regulations, Section 301.2 of Schedule IV, January 1995, "CNG Fuel System Integrity"

3. DEFINITIONS

Accredited Registrar. A qualified organization accredited by a national or international body (e.g., the Registrar Accreditation Board in the U.S. [RAB]) as operating a certification system (e.g. in accordance with *BS 7512, General Criteria for Certification Bodies Operating Quality Systems Certification-Criteria for Technical and Management Competence*) that provides third-party assessment, certification, and registration of suppliers' quality systems to applicable standards (i.e., the *ANSI/ASQC Q9000 Series, Quality Management and Quality Assurance Standards*). The registrar's scope of accreditation is described by the accrediting body for particular industry sectors (e.g. Standard Industrial Classification [SIC]). The registrar is thereby authorized to issue accredited certificates of registration to suppliers in the recognized industry.

Autofrettage. A pressure application procedure, used in manufacturing composite cylinders with metal liners, which strains the liner past its yield point sufficiently to cause permanent plastic deformation which results in the liner having compressive stresses and the fibers having tensile stresses at zero internal pressure.

Composite. A filament and resin system.

Destroyed. Physically made permanently unusable.

Hoop Wrapped. Reinforcement by a composite material applied in a substantially circumferential pattern over the cylindrical portion of the liner so that the filament does not transmit any significant stresses in a direction parallel to the container longitudinal axis.

Leakage. Release of contents through a defect or crack (see "Rupture"). For purposes of this standard, leakage is anything in excess of 0.25cc/hour per liter of water capacity.

Liner. Inner gas tight container or gas container to which the overwrap is applied.

Maximum Service Temperature. The maximum temperature to which the container will be subjected in normal service.

Full Wrapped. The reinforcement by a composite material applied over the entire liner including the domes.

Fold. The place where two metal flows meet in such a manner as to create a sharp, visual groove. The groove of the fold will always be along the length of the container and usually in the dome area.

Pre-stressing. The process which puts the liner in compression. This can be done either by autofrettage or by winding a composite material under significant controlled tension.

Pressure Relief Device. A pressure and/or temperature activated device used to vent the container contents, and thereby prevent rupture of an NGV fuel container when subjected to a standard fire test.

PRESSURES.

Autofrettage Pressure. The pressure to which a container is taken with the intent of yielding the liner or inner surface of the container. The autofrettage operation is considered to be part of the manufacturing operation and is conducted prior to proof testing.

Burst Pressure. The highest pressure reached in a container during a burst test.

Fill Pressure. The pressure attained at the actual time of filling. Fill pressure varies according to the gas temperature in the container, which is dependent on the filling parameters and the ambient conditions. The maximum fill pressure shall not exceed 125 percent of service pressure.

Hydrostatic Pressure. The pressure to which a container is taken during acceptance testing. Measurement of permanent volumetric expansion and total volumetric expansion are taken during this testing. (See Compressed Gas Association *CGA C-1, Methods for Hydrostatic Testing of Compressed Gas Cylinders*.)

Minimum Required Burst Pressure. The minimum burst pressure which must be met during a burst test. This is the greater of 2.25 times the service pressure or the pressure needed to demonstrate the required stress ratio.

Operating Pressure. The varying pressure which is developed in a container during service.

Service Pressure. The settled pressure at a uniform gas temperature of 21°C (70°F) and full gas content. It is the pressure for which the equipment has been constructed, under normal conditions. Also referred to as nominal service pressure or working pressure.

Settled Pressure. The gas pressure when a given settled temperature is reached.

Rejectable Damage. Damage as outlined in *CGA C-6.4, Methods for External Visual Inspection of Natural Gas Vehicle Fuel Containers and Their Installations* and in agreement with the manufacturer's recommendations.

Rupture. Sudden and unstable damage propagation in the structural components of the container resulting in loss of contents (see "Leakage").

Stress Ratio. The minimum ultimate strength of the fiber, as determined in pressure container burst tests, divided by the stress in the fiber at service pressure.

Settled Temperature. The uniform gas temperature after any change in temperature caused by filling has dissipated.

4. SERVICE CONDITIONS

4.1 General

4.1.1 Standard Service Conditions

The standard service conditions specified in this section are provided as a basis for the design, manufacture, inspection, testing, and approval of containers that are to be mounted permanently on vehicles and used to store natural gas for use as a fuel on the vehicles. Containers are intended to be installed on vehicles in accordance with *NFPA 52, Compressed Natural Gas (CNG) Vehicular Fuel Systems, FMVSS No. 303, (49CFR571.303), Fuel System Integrity of Compressed Natural Gas Vehicles, FMVSS No. 304, (49CFR571.304), Compressed Natural Gas Fuel Container Integrity* or other equivalent standards.

4.1.2 Use of Containers

This standard may be used by:

(a) Manufacturers of containers,

(b) Owners of containers,

(c) Designers or contractors responsible for the installation of containers,

(d) Designers or owners of equipment used to refuel vehicle containers,

(e) Suppliers of natural gas, and

(f) Regulatory authorities who have jurisdiction over container use.

4.1.3 Service Life.

The service life for the containers shall be specified by the manufacturer and shall not exceed 20 years.

4.1.4 Periodic In-Service Inspections.

Any requirements for periodic re-qualification by inspection or testing during the service life shall be specified by the container designer on the basis of use under service conditions specified herein. Each container shall be visually inspected at least every 36 months, or at the time of any re-installation, for external damage and deterioration. Unless otherwise specified by the vehicle or container manufacturer, visual periodic inspections of the exposed container surface (after the removal of stone shields and other removable protective covers, as necessary) shall be performed. The inspection shall be performed by a qualified container inspector in accordance with (1) the manufacturer's recommendations and (2) the inspection procedures provided in CGA pamphlet *C-6.4*. The container shall not be uninstalled unless required by the qualified container inspector on the basis of visual damage or unless deterioration is noted on the exposed container surface. Inspections shall be documented by the inspector and the documentation shall be made available to the authority having jurisdiction upon request. Alternatively, containers may be inspected as installed using a non-destructive test method approved by the container manufacturer.

Containers without labels containing mandatory information, or with labels containing mandatory information which is illegible in any way, shall be removed from service. If the container can be positively identified by manufacturer and serial number, a replacement label supplied by the manufacturer may be applied to the container, and it may remain in service.

4.1.5 Conditions Requiring Immediate Inspections

Containers which have been involved in collisions, accidents, fires or other damage shall be subjected to inspection procedures provided in CGA pamphlet *C-6.4*. Containers which have not experienced any rejectable damage may be returned to service; otherwise, the container shall be destroyed per CGA Pamphlet *C-6.4* or returned to the manufacturer for evaluation.

4.1.6 Overpressurization.

Any container which is believed to have been subjected to a pressure greater than 125 percent of service pressure shall be depressurized and removed from service.

After inspection by an agency authorized by the manufacturer and, if required, by the authority having jurisdiction, the container may be returned to service if it is determined that the container has not suffered any damage that might reduce its service life. A record of any such incident shall be sent to and retained by the manufacturer according to the provisions of Section 15 (Record of Manufacture).

4.2 Service Pressures.

4.2.1 Nominal Service Pressures.

Nominal service pressures are 20,700 kPa (3000 psi) or 24,800 kPa (3600 psi) at 21°C (70°F).

4.2.2 Maximum Pressures.

Containers may be filled to a pressure not exceeding any of the following conditions:

(a) A pressure that would settle to 1.0 times the nominal service pressure at a settled temperature of 21°C (70°F);

(b) A settled pressure of 1.25 times the nominal service pressure at 57°C (135°F); or

(c) 1.25 times the nominal service pressure immediately after filling, regardless of temperature.

NOTE: The fill pressure shall be temperature compensated to prevent pressures from exceeding the maximum pressures that are defined.

4.3 Maximum Number of Filling Cycles.

Containers may be filled to pressures not exceeding the requirements of section 4.2.2 (Maximum Pressures) for a maximum total of cycles equivalent to 750 times the design life of the container in years, with a minimum number of cycles of 11,250.

4.4 Temperature Range.

4.4.1 Gas Temperatures.

Settled temperature of gas in containers may vary from a low of -40°C (-40°F) to a high of 57°C (135°F).

4.4.2. Container Temperatures.

The temperature of the container materials may vary from -40°C (-40°F) to 82°C (180°F).

Temperatures over 57°C (135°F) shall be sufficiently local, or of short enough duration, that the temperature of gas in the container never exceeds 57°C (135°F).

4.4.3 Transient Temperatures.

Transient temperatures during filling and discharge may vary beyond the limits described in section 4.4.1 (Gas Temperatures) and section 4.4.2 (Container Temperatures).

4.4.4 Test Temperatures.

Unless otherwise specified, all tests shall be conducted at 24 ± 14°C (75 ± 25°F).

4.5 Gas Composition.

Containers made to this standard are designed to be used with gas complying with the *SAE J1616, Recommended Practice for Compressed Natural Gas Vehicle Fuel*, or the Canadian General Standards Board Standard *CGSB-3.513, Natural Gas for Vehicles*, or an equivalent national standard. Methanol and/or glycol shall not be deliberately added to the natural gas at the fueling station. Recognizing that the gas supplied to the vehicle may not always be in compliance with these documents, containers should be designed to tolerate being filled with natural gas meeting both of the following conditions:

(a) Dry Gas - Water vapor would normally be limited to less than 32 mg/m^3 (2 lbs/MMscf), a pressure dewpoint of -9°C (16°F) at 20,700 kPa (3,000 psi). There would be no maximum constituent limits for dry gas, except for:

(i) Hydrogen Sulfide...................... 23 mg/m^3

(ii) Oxygen................................ 1% by volume

(b) Wet Gas - Gas that contains 32 mg/m^3 (2 lbs/MMscf) of water or more normally meets the following maximum constituent limits:

(i) H_2S and other soluble sulfides......... 23 mg/m^3 (1 gr/100scf)

(ii) Total Sulfur........................... 115 mg/m^3 (5 gr/MMscf)

(iii) Oxygen................................. 1% by volume

(iv) CO_2.................................... 3% by volume

(v) Hydrogen............................... 0.1% by volume

Under wet gas conditions, a minimum of 1 mg of compressor oil per kilogram of gas (0.007 grains of compressor oil per pound of gas) is necessary to protect metallic containers, liners, and bosses.

4.6 External Surfaces.

Container external surfaces shall be designed to be resistant to environmental conditions outlined in section 18.4 (Environmental Test). Containers are not designed for exposure to leakage from cargo that may be carried on vehicles.

4.7 Gas Permeation.

Containers may be located in enclosed spaces for extended periods of time. Permeation of gas from the container shall be considered in the design, as outlined in section 18.11 (Penetration Test).

4.8 Installation Requirements.

The installer shall be responsible for the protection of container valves, pressure relief devices, and connections as required by American National Standard *NFPA 52, Compressed Natural Gas (CNG) Vehicular Fuel Systems*, or *CAN/CGA-B149.4, Natural Gas For Vehicles Installation Code*, *FMVSS No. 303, Fuel System Integrity of Compressed Natural Gas Vehicles*, or Transport Canada/*TC, Motor Vehicle Safety Regulations, Section 301.2 of Schedule IV, "CNG Fuel System Integrity"*. If this protection is mounted to the container, the design and method of attachment shall be approved by the container manufacturer. Factors to be considered include the ability of the container to support the transferred impact loads and the effect of local stiffening on container stresses and fatigue life.

Containers shall be protected from accidental cargo spillage and from mechanical damage. This standard contains no requirements for container integrity in a vehicle collision. Container locations and mountings should be designed to provide adequate impact protection to prevent container failure in a collision.

5. COMPLIANCE

5.1 General.

Compliance is required in all details, without exception. If there is evidence of a fault in carrying out a test or an error in measurement, another test shall be performed. If the results of this test are satisfactory, the results of the prior test shall not be a basis for rejection.

5.2 Effective Date.

Containers qualified under previous revisions of this standard may continue to be manufactured for a period of time not to exceed 12 months beyond the approval date of subsequent revisions to this standard. After that time, the manufacturer must re-qualify to new requirements of this standard by conducting the ambient cycling test, the natural gas cycling test, the environmental test, the flaw tolerance test and the drop test in accordance with the requirements for designs and design changes given in Table 2 (Test Requirements for Designs and Design Changes, page 26).

A manufacturer with an approved quality system in accordance with the previous versions of this standard, shall update the quality system to meet the requirements of this standard within 12 months of the effective date of this standard.

5.3 Retroactivity.

Containers qualified under previous revision(s) of this standard and manufactured prior to the end of the 12 month extension may remain in service for their designated lifetime.

6. MATERIAL QUALIFICATION TESTS AND REQUIREMENTS

6.1 General.

All structural materials shall be traceable to their original manufacturer's certified test reports. The materials shall be of uniform quality. Materials not in compliance with the manufacturer's design specifications are not authorized.

Materials shall be selected according to the following criteria:

6.2 Metal Containers and Liners. (Type NGV2-1, NGV2-2 and NGV2-3)

6.2.1 Chemical Analysis.

Steels shall be aluminum killed and produced to predominantly fine grain practice. The chemical composition of all steels shall be declared and defined at least by:

(a) Carbon, manganese, aluminum, and silicon contents in all cases

(b) Nickel, chromium, molybdenum, boron, vanadium, or any other elements that are deliberately added.

The following limits shall not be exceeded in the cast analysis:

	For Steels with Tensile Strength	
	930 MPa (135 Ksi) or less	Greater than 930 MPa (135 Ksi)
Sulfur	0.020%	0.010%
Phosphorus	0.020%	0.015%
Sulfur and Phosphorus	0.030%	0.020%

Aluminum alloys shall be quoted in line with Aluminum Association practice for a given alloy system. The impurity limits for lead and bismuth in any aluminum alloy shall not exceed 0.010 percent. Excess silicon 6xxx series aluminum alloys with yield strengths above 250 MPa (36,250 psi) (e.g., 6351 and 6082) shall not be used in fuel containers or liners.

6.2.2 Impact Test for Steel.

The impact properties of the steel in the finished container or liner shall be determined in general accordance with *ISO 148, Charpy Impact Test (V-Notch)* or *ASTM E23, Standard Test Methods for Notched Bar Impact Testing of Metallic Materials*. The impact test pieces shall be taken from the wall of the container in the transverse direction. The notch plane orientation shall be in the C-L direction (i.e. perpendicular to the circumference and along the length). Test pieces with a width of less than 5 mm (0.2 inch) shall be taken from the longitudinal direction. If the wall thickness does not permit a final test piece width of 10 mm (0.4 inch), the width shall be as near as practicable to the nominal thickness of the container wall. All impact tests shall be conducted at -40°C (-40°F). Impact values shall not be less than that indicated as follows:

Width of test piece (mm)	5.0 - 7.5	7.5 - 10.0
(in)	0.2 - 0.3	0.3 - 0.4
Impact Strength - (J/cm²)	44	50
(ft-lb/in²)	210	240

- Impact values for test pieces of width less than 5 mm (0.2 in.) shall be based on special studies of particular materials and particular specimens.
- Required average results of three specimens.
- Not more than one specimen shall break at less than the average value required and no single specimen shall break at less than 80 percent of the average value.

6.2.3 Sulfide Stress Cracking Resistance for Steels.

The ultimate tensile strength of the steel from a finished container shall not exceed 1200 MPa (175,000 psi). If the upper limit of the ultimate tensile strength exceeds 950 MPa (138,000 psi), the steel shall be tested in accordance with the procedures described in *Method A - NACE Standard Tensile Test of NACE Standard TM0177-96,* except as noted in this section. Tests shall be conducted on tensile specimens with a gauge diameter of 3.81 mm (0.150 in) machined from the wall of a finished container or liner. The specimens shall be placed under a constant tensile load equal to 60 percent of the specified minimum yield strength of the steel, immersed in a solution of distilled water buffered with 0.5 percent (wt/wt) sodium acetate trihydrate and adjusted to an initial pH of 4.0 using acetic acid. The solution shall be continuously saturated at room temperature and pressure with 0.414 kPa (0.06 psia) hydrogen sulfide (balance nitrogen). Three specimens shall be tested and none shall fail within the 144 hour duration of the test. Specimens that fail outside the gauge length are considered invalid tests.

6.2.4 Tensile Tests for Metals.

Tensile strength methods shall be as prescribed by Test Methods of *ASTM E8, Standard Test Methods for Tension Testing of Metallic Materials (Metric)*, and shall meet the requirements of the designs. Alternatively, tensile tests shall be carried out in accordance with *ISO 9809-1, Gas Cylinders - Refillable Seamless Steel Gas Cylinders - Design, Construction and Testing - Part 1: Quenched and Tempered Steel Cylinders with Tensile Strength Less Than 1100 MPa,* for steels, and *ISO 7866, Gas- Cylinders-Refillable Seamless Aluminum Alloy Gas Cylinders —Design, Construction and Testing,* for aluminum.

6.2.5 Sustained Load Cracking (SLC) Test for Aluminum.

The resistance to SLC shall be determined in accordance with Annex D of *ISO 7866, Refillable Seamless Aluminum Alloy Gas Cylinders —Design, Construction and Testing,* and shall meet the requirements therein.

6.2.6 Corrosion Tests for Aluminum.

Corrosion tests for aluminum alloys shall be carried out in accordance with Annex A of *ISO 7866, Refillable Seamless Aluminum Alloy Gas Cylinders —Design, Construction and Testing,* and shall meet the requirements therein.

6.3 Ultraviolet Resistance of External Coatings.

Protective coatings required to meet section 18.4 (Environmental Test) shall be evaluated for resistance to ultraviolet effects using a minimum 1000 hours exposure in accordance with *ASTM G53, Standard Practice for Operating Light- and Water-Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Nonmetallic Materials.* There shall be no evidence of blistering, cracking, chalking or softening.

6.4 Fibers.

Structural reinforcing filament material types shall be glass fiber, aramid fiber or carbon fiber. If carbon fiber reinforcement is used, the design shall incorporate means to prevent galvanic corrosion of metallic components of the fuel container.

6.5 Resins.

The material for impregnation may be thermosetting or thermoplastic resin. Examples of suitable matrix materials are epoxy, modified epoxy, polyester and vinylester thermosetting plastics, and polyethylene and polyamide thermoplastic material. Resin system materials shall be tested on a sample test panel, representative of the composite overwrap, in accordance with *ASTM D2344, Standard Test Method for Apparent Interlaminar Shear Strength of Parallel Fiber Composites by Short-Beam Method.* Following a 24 hour water boil, the composite shall have a minimum shear strength of 13.8 MPa (2000 psi).

6.6 Nonmetallic Liners (Type NGV2-4).

The nonmetallic liner material shall be compatible with the service conditions specified in Section 4. The softening temperature shall be at least 90°C (194°F), and the melting temperature at least 100°C (212°F), when tested in accordance with the method described in *ISO 306, Determination of Vicat Softening Temperature*, or using an alternative method. The tensile yield strength and ultimate elongation shall be determined in accordance with *ASTM D638, Standard Test Method for Tensile Properties of Plastics*. Tensile or impact testing shall be conducted on samples of the nonmetallic liner material to demonstrate that the material fails in a ductile, rather than brittle, mode at temperatures down to and including -50°C (-58°F).

6.7 Bosses for Type NGV2-4 Containers.

Materials shall be compatible with the liner and the intended environment and shall be resistant to stress corrosion cracking.

Acceptable materials include steel alloys, stainless steel alloys, nickel alloys, and aluminum alloys. Steel and stainless steel alloys must meet the requirements of section 6.2.3. Aluminum alloys must meet the requirements of sections 6.2.5 [Sustained Load Cracking (SLC) Test for Aluminum] and 6.2.6 (Corrosion Tests for Aluminum). Austenitic stainless steels shall be tested for resistance to chloride stress corrosion cracking.

7. WALL THICKNESS

7.1 NGV2-1 Containers.

The minimum wall thickness shall be sufficient to comply with all applicable qualification tests within this specification. Welded NGV2-1 Containers shall have a minimum burst/service pressure ratio of 3.5.

7.2 Liners for NGV2-2, -3, and -4 Containers.

Minimum thickness of the liner shall be such that the required qualification test requirements of this specification are met.

7.3 Composite Reinforcement for Type NGV2-2, NGV2-3, and NGV2-4 Containers.

7.3.1 Stress Analysis.

Stresses in the liner and composite reinforcement shall be computed using suitable analysis techniques which have been demonstrated to adequately predict the stresses and strains in both the liner and the composite overwrap at the following pressures: autofrettage, zero (after autofrettage), service, hydrostatic, and minimum burst.

7.3.2 Stress Ratios.

The composite overwrap shall be designed for high reliability under sustained loading and cyclic loading. This reliability shall be achieved by meeting or exceeding the following composite reinforcement stress ratio values shown below.

Stress Ratio

Material	Type NGV2-2	Type NGV2-3	Type NGV2-4
E-Glass	2.65	3.5	3.5
S-Glass	2.65	3.5	3.5
Aramid	2.25	3.0	3.0
Carbon	2.25	2.25	2.25

7.3.3 Modified Stress Ratio Test

At the option of the manufacturer, or for designs in which the required minimum container burst pressure may not be sufficient to cause tensile failure in the fiber, a modified burst test procedure may be used to verify that the fiber stress ratio at service pressure is achieved. The stress ratio requirements (2.65) for E-glass and S-glass, reinforced Type NGV2-2 containers, may be demonstrated by meeting a minimum hold time at a specified pressure during the burst tests conducted under section 12.4 (Burst Test) or 18.6 (Hydrostatic Burst Test). Acceptable alternative combinations of hold times and pressures are as follows:

1 minute at 2.50 times service pressure; or

1 hour at 2.25 times service pressure.

As an alternative, the strength of the fiber may be verified by the testing of containers, with the composite thickness reduced by no more than 50 percent, to assure failure initiation in the composite.

7.3.4 Hybrid Designs.

Hybrid construction (using more than one type of reinforcing fiber) is permitted. The strength of the individual types of fibers used in hybrid construction may be verified by testing of containers reinforced with a single type of fiber. In a hybrid construction, the applicable stress ratio requirements must be met in one of the two following ways:

(i) If load sharing between the various fiber reinforcing materials is considered a fundamental part of the design, each fiber must meet the stated stress ratio requirements.

(ii) If load sharing between fibers is not considered as a fundamental part of the design, then one of the reinforcing fibers must be capable of meeting the stress ratio requirements even if all other fiber reinforcing materials are removed.

7.4 Containers Greater than 450 Liters Water Capacity.

Containers with greater than 450 liters (15.93 cu ft) water capacity and all containers employing integral mounts or valve protection [as permitted by section 10.9 (Mounting and Protection)] shall consider the external loads imposed on the container as a function of the service conditions and mounting provisions. This would include bending and torsional stresses.

8. OPENINGS

8.1 Locations.

Openings are permitted in domes only. The centerlines of the bosses shall coincide with the longitudinal axis of the container.

8.2 Threads.

Threads shall be clean cut, even, and to gauge.

All threads shall comply with a recognized international or national standard.

Tapered threads are only permitted on steel containers, steel liners and steel bosses.

9. INSPECTION REQUIREMENTS

9.1 Inspection During Qualification.

All design qualification tests shall either be conducted or witnessed by a representative of a nationally recognized testing agency or an independent inspection agency. The nationally recognized testing agency shall be accredited [e.g., by the American National Standards Institute (ANSI), or the Standards Council of Canada (SCC)]. The independent inspection agency shall comply with the requirements of section 17.2(a) [Independent Inspection (Option 2)]. Chemical analysis and tests as specified shall be made within the United States or Canada unless otherwise approved in writing by the approving agency or independent agency.

9.2 Inspection During Manufacturing.

If the manufacturer's quality system is approved in accordance with section 17.1 (Quality Assurance, General) - Option 1 (Approved Quality System), the manufacturer may perform all inspections and verifications during manufacturing, subject to monitoring by the accredited registrar.

If the manufacturer's quality system is in accordance with section 17.1 (Quality Assurance, General) - Option 2 (Independent Inspection) and section 17.2 (Quality Assurance, Independent Inspection), all inspections and verifications during manufacturing must be performed by a representative of a qualified independent inspection agency. The independent inspection agency shall comply with the requirements of section 17.2(a) [Independent Inspection (Option 2)].

9.2.1 Duties of Inspector During Manufacturing.

9.2.1.1 Duties Performed by All Manufacturing Inspectors.

The following duties apply during manufacture to the inspectors employed by a manufacturer with an approved quality system in accordance with section 17.1 (Quality Assurance, General) - Option 1 (Approved Quality System), or to third party inspectors employed by manufacturers operating quality systems in accordance with section 17.1 (Quality Assurance, General) - Option 2 (Independent Inspection) and 17.2 (Quality Assurance, Independent Inspection).

(a) Verify proper identification and compliance of all materials with the requirements specified in section 6 (Material Qualification Tests and Requirements). Chemical analysis of metals may be verified by obtaining the producer's certified analysis.

(b) Verify compliance with manufacturing design specifications on the interior and exterior surfaces of liners and completed containers. Verify the minimum prescribed wall thickness and acceptability of welds.

(c) Verify winding process of Types NGV2-2, NGV2-3 and NGV2-4 containers to assure that composite material is of required thickness and wrap pattern, and in accordance with the composite structure present in containers subjected to the design qualification tests.

(d) Verify compliance of threads, by gauge.

(e) Verify proper thermal treatment of materials.

(f) Verify that each container has been hydrostatically tested and the data recorded as specified by the manufacturer.

(g) Select all test samples, witness all tests and obtain copies of all test results and certifications.

(h) Verify compliance of each container with all requirements, including marking.

(i) Prior to the initial shipment of any container of a new design, or with a design change, verify that the applicable design qualification tests specified in section 18 (Design Qualification Tests) have been performed with acceptable results.

(j) Furnish complete inspector's record [section 15 (Record of Manufacture)] to the manufacturer of the container.

9.2.1.2 Additional Duties (to section 9.2.1.1) Performed by Third Party Inspectors.

The following duties apply to third party inspectors employed by manufacturers operating quality systems in accordance with section 17.1 (Quality Assurance, General) - Option 2 (Independent Inspection) and 17.2 (Quality Assurance, Independent Inspection). These items shall be audited at least every 12 months. [Note: For manufacturers with approved quality systems in accordance with section 17.1 (Quality Assurance, General) - Option 1 (Approved Quality System), the following duties and periodic audits are already required as part of certification of the quality system.]

(a) Verify that the manufacturer's quality manual addresses design, purchasing, process control, inspection, test, and configuration management, and that the quality manual and practices of the manufacturer are consistent with one another.

(b) Verify that product drawings adequately define the configuration to be manufactured and that containers meet the drawing requirements.

(c) Verify that design documents contain appropriate acceptance criteria.

(d) Verify that purchased parts are inspected for conformance to specified requirements.

(e) Verify that adequate written instructions are provided for manufacture of containers which are in conformance with specified requirements.

(f) Verify that incoming product and material have been inspected or otherwise verified as conforming to specified requirements.

(g) Verify that no product is shipped until all specified inspections and tests are completed and the containers are found to be compliant with specifications.

(h) Verify that procedures for non-conforming material control are being followed.

(i) Verify that inspection and test equipment are properly calibrated.

(j) Verify that records are kept which give evidence that the product has passed inspection and test requirements with defined acceptance criteria.

(k) Verify that procedures are followed which control documents and data related to the manufacturer of containers. These procedures apply to both initial document release and to revisions.

10. MANUFACTURE

10.1 General.

Manufacturing processes shall be the same as those used to produce the containers subjected to design qualification tests, and shall be specified by the manufacturer in sufficient detail to ensure consistent product. No defect is acceptable that is likely to cause failure within the lifetime of the container.

10.2 Metal Containers and Metal Liners.

Surfaces shall have dirt and scale removed, as necessary, to afford proper inspection. A reasonably smooth and uniform surface finish is required. No interior folding is permitted. Smooth gathering of the material, in the neck or dome area in which there are no sharp rooted folds, is acceptable. If not originally free from such defects, the liner or container surface may be machined or otherwise treated to eliminate these defects provided the required minimum wall thickness is maintained. The liner or container end contour shall be concave to pressure.

10.3 Nonmetallic Liners.

Nonmetallic liners shall be free of contaminants as necessary to afford proper inspection. Interior folds, laps or sharp surface indentations are not permitted. If not originally free from such defects, the liner surface may be reworked to eliminate these defects providing the liner then meets all design requirements. Welded construction of non-metallic liners is permissible.

Liner weld processes, particularly time, temperature, and joining force, shall be monitored during the welding process and controlled within the parameters established by the manufacturer. Tensile tests of liner weld specimens shall be conducted on samples manufactured at the extreme limits of the process within which the manufacturer will control the weld process. Tensile testing of liner weld specimens shall be conducted during qualification of the weld process at -50°C (-58°F) or colder, at ambient temperature, and at 57°C (135°F) or hotter. Tensile specimens shall fail either outside the weld joint, or with a ductile failure if the failure is within the weld.

10.4 Composite Containers with Metallic Liners.

The container shall be fabricated from a metal liner overwrapped with resin impregnated continuous filament windings. The winding pattern shall be in the "hoop" direction for "hoop-wrapped" containers, or in the "helical or in-plane" and "hoop" directions for "full wrapped" containers. The windings shall be applied under controlled tension to develop the design composite thickness. After the winding is complete, composites using thermoset resins shall be cured by a controlled temperature process.

10.5 Composite Containers with Nonmetallic Liners.

Type NGV2-4 composite containers shall be fabricated from a nonmetallic liner overwrapped with resin impregnated continuous filament windings. The winding pattern shall be "helical" or "in-plane" and "hoop" wrap, applied under controlled tension to develop the design composite thickness. After the winding is complete, composites using thermoset resins shall be cured by a controlled temperature process that does not exceed the softening temperature of the nonmetallic liner.

Composite containers with nonmetallic liners shall be designed such that if, when pressurized, the liner is susceptible to creep and flow, no leakage will occur during the prescribed lifetime.

10.6 Brazing.

Brazing for any purpose whatsoever is prohibited.

10.7 Welding.

Welded construction of metal containers and liners is authorized. Welding procedures and operators shall be qualified in accordance with the American Society of Mechanical Engineers *(ASME) Boiler and Pressure Vessel Code*, Section IX. Weld efficiencies shall be in accordance with *ASME Boiler and Pressure Vessel Code*, Section VIII, UW-12. All welds shall be subjected to 100 percent radiographic, or other acceptable non-destructive examination. All designs with welds shall be cycled to failure in the periodic acceptance test section 12.5 (Cycle Test) without the failure initiating at the weld unless the minimum number of cycles is exceeded by at least 50 percent. For Type NGV2-2 and NGV2-3 liners, longitudinal welds and non-consumable backing strips or rings are not permitted.

10.8 End Closing By Forming.

The ends of aluminum containers or liners shall not be closed by a forming process. The base ends of steel containers or liners which have been closed by forming, except those containers or liners designed in accordance with *ISO 9809, Gas Cylinders -Refillable Seamless Steel Gas Cylinders —Design, Construction and Testing - Part I: Quenched and Tempered Steel Cylinders with Tensile Strength Less Than 1100 MPa*, shall be NDE Inspected or Equivalent. Metal shall not be added in the process of closure at the end. Each container or liner shall be examined before end forming operations for thickness and surface finish.

10.9 Mounting and Protection.

If mounting provisions and/or valve protecting shrouds are required, they shall be permitted to be manufactured as part of the container, providing they are not detrimental to the performance of the container. If manufactured as part of the container, structural integrity shall be demonstrated by compliance with qualification tests specified in Table 2 (Test Requirement for Designs and Design Changes, page 26).

10.10 Batch Definitions.

(a) Metal liners and containers only. A "batch" shall be a group of metal liners or containers successively produced having the same design, specified material of construction, process of manufacture, process of heat treatment, equipment of manufacture and equipment of heat treatment, and conditions of time, temperature and atmosphere during heat treatment as the batch acceptance sample, with the only variation being length up to ± 50 percent.

(b) Non-metal liners only. A "batch" shall be a group of non-metal liners successively produced having the same design, specified material of construction, process of manufacture and equipment of manufacture as the batch acceptance sample, with the only variation being length up to ± 50 percent.

(c) Composite container only. A "batch" shall be a group of containers successively produced from liners having the same design, specified materials of construction, process of manufacture, and autofrettage process as the batch acceptance sample, with the only variation, applicable to NGV2-2 containers only, being length up to ± 50 percent.

(d) In no case shall a "batch" be permitted to exceed 200 units, plus destructive test units, or one shift of production, whichever is greater.

10.11 Design Qualification Tests.

Prior to initial shipment of any specific container design, qualification tests as prescribed in Section 18 shall be performed with satisfactory results.

11. PRODUCTION TESTS AND EXAMINATIONS

11.1 General.

Production examinations and tests shall be carried out, by the following means, on all containers produced in a batch.

(a) Verification through non-destructive examination that flaws in metal containers and liners do not exceed the manufacturer's specified limits as determined in accordance with section 18.15 [Defect Size for Non-Destructive Examination (NDE)];

(b) Verification through visual or non-destructive examination that non-metallic liners are free of flaws exceeding the manufacturer's specified limits. See section 10.3 (Nonmetallic Liners) for types of flaws;

(c) Verification that the critical dimensions and parameters specified by the manufacturer of the completed container and of any liner and overwrapping are within design tolerances. Statistical sampling of critical dimensions is acceptable provided that the process is demonstrated capable of a process capability ratio (cpk) of 1.33 or more;

(d) Verification of compliance with specified surface finish with special attention to deep drawn surfaces and folds or laps in the neck or dome area of forged or spun end closures or openings;

(e) Verification of coating quality (if required);

(f) Verification of markings; and

(g) Verification of strength (heat treatment) of metal containers and liners. For NGV2-1 containers, a hardness test or equivalent is required.

A summary of critical production inspection requirements to be performed on every container is provided in Table 2 (Production Inspection Requirements)..

Any container not meeting the specifications in this Table must be rejected.

TABLE 1 - Production Inspection Requirements*

		NGV2 Container TYPE:			
PRODUCTION INSPECTION REQUIREMENT(S):	Provision	NGV2-1	NGV2-2	NGV2-3	NGV2-4
Dimensions	11.1 (c)	X	X	X	X
Flaws	11.1 (a) and (b)	X	X	X	X
Strength (Heat Treatment) of Metal Containers, Metal Liners, and Metal Bosses	11.1 (g)	X	X	X	X
Hydrostatic Test	11.2	X	X	X	X
Leak Test	11.3	*	*	*	X
Coatings (where required)	11.1(e)	X	X	X	X
Surface Finish	11.1(d)	X	X	X	
End Closing By Forming (Steel)	10.8	X	X	X	
Markings	11.1(f)	X	X	X	X

* Leak test shall be conducted on these container types which are welded.

11.2 Hydrostatic Test.

Each finished container shall be hydrostatically tested to at least 1.5 times service pressure. Measuring systems for pressure and expansion shall meet the accuracy and periodic calibration requirements of CGA Pamphlet *C-1, Method for Hydrostatic Testing of Compressed Gas Cylinders*.

Pressure shall be maintained for 30 seconds and sufficiently longer to ensure complete expansion. If the test pressure cannot be maintained due to failure of the test apparatus, it is permissible to repeat the test at a pressure increased by 690 kPa (100 psi) minimum.

The manufacturer shall define and record the appropriate limit of elastic and permanent volumetric expansion for the test pressure used. Any containers not meeting the defined rejection limit shall be destroyed.

11.3 Leak Test.

Type NGV2-4 containers and any container type which uses welded construction shall be leak tested using procedures (a) and either (b) or (c), or an acceptable alternative method:

(a) Containers shall be thoroughly dried and pressurized to service pressure with dry air or nitrogen, and containing a detectable gas such as helium.

(b) Containers shall be placed in an enclosure to permit detection of any leaks.

(c) Weld seams or spun enclosures in exposed metal parts may be tested using liquid immersion or bubble soap solution.

Any leakage detected shall be cause for rejection. Note: Leakage is a release of gas through a crack, pore, unbond, or similar defect. Permeation through the wall in compliance with section 18.12 (Permeation Test) is not considered to be leakage.

12. BATCH TESTS

12.1 General.

Batch testing shall be conducted on finished containers or liners which are representative of normal production and are complete with identification marks. The test containers, and liners, as appropriate, shall be randomly selected from each batch. If more containers are subjected to the tests than are required by this standard, all results shall be documented.

When the test results fail to meet requirements, the container or liner batch shall be rejected. One retest of a rejected batch is authorized if an improper test was made due to the presence of a defect in the specimen. A batch shall be 100 percent inspected to remove defective containers or liners from the batch. A second sample shall then be permitted to be selected from the batch and tested. The batch is considered acceptable if the second sample meets the batch criteria.

12.2 Batch Material Tests.

The container or liner shall meet the requirements of the design when subjected to the following tests.

(a) Dimensions checked against the design.

(b) For metal containers and liners, tensile test two specimens in accordance with the appropriate method specified under section 6.2.4 (Tensile Tests for Metals).

(c) For steel containers and liners, three impact tests in accordance with the method specified under section 6.2.2 (Impact Test for Steel).

12.3 Coated Containers.

When a protective coating is a part of the design, the following tests shall be performed (in order) on a finished container or a representative test panel from each coating batch:

(a) Coating thickness tests shall be in accordance with the following appropriate test method:
ASTM D1186 - Measurement of Dry Film Thickness on Ferrous Base
ASTM D1400 - Measurement of Dry Film Thickness on Nonferrous Base
ASTM D4138 - Destructive Measurement of Dry Film Thickness of Protective Coating

Containers which do not meet the manufacturer's specified coating thickness requirement may be recoated after appropriate surface preparation without prior restripping.

(b) The coating adhesion test in accordance with *ASTM D3359 - Measuring Adhesion by Tape Test*, shall provide a minimum rating of 4 when measured using either Test Method A or B, as appropriate.

Repair of tested surfaces is permitted to a manufacturer's approved procedure.

Where the coating fails to meet the requirements, the batch shall be 100 percent inspected to remove similarly defective containers. The coating on all defective containers may be stripped, using a method that does not affect the integrity of composite wrapped containers, and re-coated. The coating batch test shall then be repeated.

12.4 Burst Test.

12.4.1 Batch Burst Test.

One container selected from each batch shall be hydrostatically pressurized to burst in accordance with the test procedure described in section 18.6(a) (Hydrostatic Burst Test). Rupture may occur in any region of the container. The burst pressure shall meet or exceed the minimum required burst pressure, otherwise, the batch shall be rejected.

The container used for the cycle test in section 12.5 (Cycle Test) may be used for the burst test. If the burst pressure of the cycled container is less than the minimum required burst pressure, an additional burst test shall be conducted on another container selected from the batch. The burst pressure on the additional container shall meet or exceed the minimum required burst pressure, otherwise the batch shall be rejected.

12.4.2 Periodic Burst Test (Applicable to NGV2-1 Containers Only).

12.4.2.1 The requirement in section 12.4.1 (Batch Burst Test) to burst a container from each batch may be replaced by periodic burst testing. For the first five sequential batches of a design family (i.e. similar materials, processes, and stress levels, but allowing different sizes) one container from each batch shall be burst tested in accordance with the requirements of section 12.4.1 (Batch Burst Test). If the container from any batch fails to meet the minimum required burst pressure, the batch shall be rejected.

12.4.2.2 If five sequential batches pass the burst test, then subsequent burst tests are only required on every tenth batch manufactured. If more than three months have passed since the last batch of containers was burst tested, then a container from the next batch of containers manufactured shall be burst tested.

12.4.2.3 If a container fails to meet the minimum burst test requirement, then the batch is rejected and a sample from every batch manufactured since the previous periodic burst test shall be tested. Any failure to meet the minimum burst test requirement shall also cause rejection of the corresponding batch. A representative container from each of the next ten batches must be burst tested.

12.5 Cycle Test.

12.5.1 Batch Cycle Test.

One container selected from each batch shall be pressure cycle tested in accordance with the following. Leakage or rupture may occur in any region of the container. The number of cycles attained before failure shall meet or exceed the number specified below, otherwise, the batch shall be rejected.

12.5.2 Periodic Pressure Cycling Test.

12.5.2.1 The container shall be pressure cycle tested in accordance with the following procedures:

(a) Fill the container to be tested with a non-corrosive fluid such as oil, inhibited water or glycol;

(b) Cycle the pressure in the container between less than or equal to 10 percent of the maximum fill pressure and greater than or equal to the maximum fill pressure (1.25 times service pressure) for a total number of cycles equivalent to 750 times the design life of the container in years, with a minimum number of cycles of 11,250.

12.5.2.2 The first five sequential batches of a design family (i.e. similar materials, processes, and stress levels, but allowing different sizes) shall be tested to a minimum of 15,000 cycles at a rate not to exceed 10 cycles per minute. If the container from any batch fails to meet this requirement, the batch shall be rejected.

12.5.2.3 If five sequential batches pass the cycling test, then subsequent pressure cycling tests are only required on every tenth batch manufactured. If more than three months have passed since the last batch of containers was cycle tested, then a container from the next batch of containers manufactured shall be cycle tested.

12.5.2.4 If a container fails to meet the cycle requirement, then the batch is rejected and a representative container from each of the next 10 batches shall be cycle tested.

13. REJECTED CONTAINERS AND LINERS

13.1 Physical Test.

Reheat treatment of metal containers or metal liners is authorized; subsequent thereto, acceptable containers or liners shall pass all prescribed tests. One additional heat treatment is allowed for aluminum and two additional heat treatments are allowed for steel. Additional heat treatments require validation by material properties testing [section 6.2.4 (Tensile Tests for Metals) for aluminum and Charpy test section 6.2.2 (Impact Test for Steel) for steels].

13.2 Leak Test.

Containers with leaks (see section 11.3, Leak Test) shall not be placed in service.

13.3 Hydrostatic Test.

Rejected containers (see section 11.2, Hydrostatic Test) shall not be placed in service.

13.4 Cycle Test.

Containers from rejected batches (see section 12.5, Cycle Test) shall not be placed in service.

13.5 Burst Test.

Containers from rejected batches (see section 12.4, Burst Test) shall not be placed in service.

14. PRESSURE RELIEF DEVICES.

All containers shall be protected from rupture in a fire situation. This protection shall be provided in that each container shall be equipped with pressure relief devices in accordance with *ANSI/IAS PRD 1, Basic Requirements for Pressure Relief Devices for Natural Gas Vehicle (NGV) Fuel Containers*. The effectiveness of the pressure relief devices shall be demonstrated in accordance with section 18.9 (Bonfire Test).

A manufacturer may specify alternative or additional PRD locations for specific vehicle installations to optimize safety considerations.

15. RECORDS OF MANUFACTURE

The manufacturer shall record appropriate information on the materials, manufacturing processes, and test results for the fuel containers. These records shall be clear, legible, and in general accordance with the forms in Annex.

The inspector shall furnish completed test reports to the container manufacturer.

The inspector's record shall be retained by the container manufacturer and the inspector for a minimum of 22 years from the original test date on the containers.

16. MARKING AND DISPATCH

16.1 Markings.

On each container the manufacturer shall provide clear permanent markings. Multiple labels are allowed and should be located such that they are not obscured by mounting brackets.

16.1.1 Marking Information.

Each container complying with this standard shall be marked as follows:

(a) Mandatory information

(i) Marking in accordance with *FMVSS 304, Compressed Natural Gas Fuel Container Integrity*,

(ii) NGV2-xx (where "xx" denotes the year of this standard to which the container is designed),

(iii) Manufacturer's part number, and batch number or serial number,

(iv) The statement "For Use Only With The Container Manufacturer's Approved Pressure Relief Devices and Valves".

(b) Non-mandatory information can be added but it shall be presented in such a form that it will not be confused with mandatory information. All non-mandatory information shall follow or be separate from the mandatory information sequence.

The markings shall be placed in the listed sequence but the specific arrangement may be varied to match the space available.

16.2 Dispatch.

Prior to dispatch from the manufacturer's shop, every container shall be internally clean and dry, and every container shall be inspected as required by the manufacturer. Containers not immediately closed by the fitting of a valve, and safety devices if applicable, shall be closed using a method that will prevent condensation, prevent entry of fluids, and protect threads. Prior to dispatch, a corrosion inhibitor (e.g., oil), which coats the entire inside surface area, shall be sprayed into all steel containers and liners.

17. QUALITY ASSURANCE

17.1 General.

Quality system programs shall be established and operated to ensure containers will be produced in accordance with the qualified design.

Quality systems shall be in accordance with one of the following options:

Option 1: Approved Quality System. Quality management systems shall be registered for compliance with *ISO 9001 - 9002* by an accredited registrar. Other systems which incorporate *ISO 9001*, such as *QS 9000*, are acceptable.

Option 2: Independent Inspection. The manufacturer shall employ an independent inspector with responsibilities for inspection and review of the manufacturer's quality system.

17.2 Independent Inspection (Option 2).

(a) The manufacturer shall arrange independent inspection of container production and testing. The independent inspector shall be employed by a nationally recognized independent inspection agency. Such organizations include, but are not limited to, the National Board of Boiler and Pressure Vessel Inspectors, CSA International, Underwriters Laboratories, the Quality Management Institute (Canada), the British Standards Institute, and independent inspection agencies which have been approved for inspection of compressed gas container manufacturing by the Research and Special Programs Administration (RSPA) of the U.S. Department of Transportation (DOT), or Transport of Dangerous Goods Directorate, Department of Transport, Transport Canada (TC).

(b) The manufacturer's quality system manual shall document all elements, requirements and provisions of the manufacturer's quality system. At a minimum, the manual shall address policies for design, purchasing, process control, inspection, test, and configuration management. The system shall be described in a comprehensive and orderly manner in the form of written policies, procedures and instructions that will permit a clear and consistent understanding of the manufacturer's intent with respect to quality assurance.

(c) The independent inspector must perform or witness the inspections required in section 9.1 (Inspection During Qualification), review the quality system manual for completeness, and monitor the quality system of the manufacturer in accordance with section 9.2 (Inspection During Manufacturing). The independent inspector shall notify the manufacturer of deficiencies in the quality system and shall maintain a written record of deficiencies and corrective action.

18. DESIGN QUALIFICATION TESTS

18.1 General.

Qualification testing shall be conducted on finished containers which are representative of normal production (including a protective coating if part of the design unless otherwise specified) and complete with identification marks. All design qualification tests shall be witnessed by the independent inspection agency. Test records shall be kept on file by the container manufacturer. If not otherwise specified, the pressure cycling rate shall be at the discretion of the manufacturer but shall not exceed 10 cycles per minute. Caution shall be taken to ensure that the specified test temperature is maintained.

18.2 Test Requirements.

Containers representative of each design and design change shall be subjected to tests as prescribed in Table 2 (Test Requirements for Design and Design Changes). Designs which are sufficiently similar to an existing fully qualified design shall be permitted to be qualified through a reduced test program as defined in Table 2 (Test Requirements for Design and Design Changes). Design changes not falling within the guidelines in Table 2 (Test Requirements for Design and Design Changes) shall be qualified as an original design. If a minor design change is not defined in Table 2 (Test Requirements for Design and Design Changes), then the independent inspection agency will determine the level of reduced testing required for requalification.

Composite reinforcement on containers subjected to qualification tests shall be fully cured. Completeness of cure shall be verified on all units used in qualification tests.

18.3 Ambient Cycling Test.

Two finished containers shall be pressure cycled at ambient temperature to failure, or 45,000 cycles. Pressure cycling shall be performed in accordance with the following procedure:

(a) Fill the container to be tested with a non-corrosive fluid such as oil, inhibited water or glycol;

(b) Cycle the pressure in the container between less than or equal to 10 percent of the maximum fill pressure and greater than or equal to the maximum fill pressure (1.25 times service pressure) at a rate not greater than 10 cycles per minute.

The containers shall not fail before reaching a number of cycles equivalent to 750 times the design life of the container in years, with a minimum number of cycles of 11,250. Containers exceeding the required number of cycles shall not rupture, but may fail by leakage. For types NGV2-2, NGV2-3 and NGV2-4 containers, the fibers in the overwrap are not allowed to fail. Containers which do not fail within 45,000 cycles shall be destroyed either by continuing the cycling until failure occurs, or by hydrostatically pressuring to burst. Containers exceeding 45,000 cycles are permitted to fail by rupture.

The number of cycles to failure shall be reported, along with the location and description of the failure initiation.

TABLE 2. TEST REQUIREMENTS FOR DESIGNS AND DESIGN CHANGES

Test	Original Design	Fiber Material or Manufacturer	Resin System Material	Liner or Metal Container Material	Dia. ≤20% Change (7)	Dia. >20% Change (7)	Service Pressure ≤20% Change (7)	Length ≤50% Change	Length >50% Change	Integral Mounting Brackets & Valve Protection Shrouds	Pressure Relief Devices or Valves	External Coating	Boss
Ambient Cycling Test (Section 18.3)	X	X(1)		X	X(5)	X	X(5)			X(5)			X(5)
Environmental Test (Section 18.4) (4)	X	X	X(10)	X(2)								X	
Extreme Temperature Cycling (Section 18.5) (4)	X	X	X(10)	X		X							
Hydrostatic Burst Test (Section 18.6)	X	X	X	X	X(5)	X	X(5)	X(5)	X(5)	X(5)			X(5)
Composite Flaw Tolerance Test (Section 18.7) (4)	X	X(1)	X(10)	X(2)		X							
Drop Test (Section 18.8) (4)	X	X	X(10)	X(11)		X			X				
Bonfire Test (Section 18.9)	X	X(1)		X(2)		X		X(3)	X		X(8)		
Accelerated Stress Rupture Test (Section 18.10) (4)	X	X(1)	X	X(11)									
Penetration Test (Section 18.11)	X	X(1)	X(10)	X(2)	X(9)	X							
Permeation Test (Section 18.12) (6)	X			X									
Natural Gas Cycling Test (Section 18.13) (6)	X			X(11)									X (12)
Leak Before Break (Section 18.14)	X	X(1)		X		X							

Notes For Table 2:

(1) Test required only when fiber type is changed.
(2) Tests required only when liner material type is changed, e.g., steel to aluminum or metal to polymer.
(3) Fire test not required provided safety relief devices or device configuration passed the required fire test on a container with equal or greater internal water volume.
(4) Test required only on composite reinforced containers.
(5) Only one unit required for qualification.
(6) Test required only for NGV2-4 containers.
(7) When changes in diameter or pressure are made the structural wall elements must be operating at the same or lower nominal stress levels as the original design (e.g., if pressure or diameter increase, the wall thickness must increase proportionally.)
(8) Required if the new valve design has reduced relief channel flow area compared with previously qualified valves or if the mass of the valve and PRD increase by more than 30%, or when pressure relief device is changed.
(9) Test required only if diameter decreases.
(10) Test not required when chemically equivalent materials are substituted.
(11) Test required only when change is made to polymer.
(12) Test required for NGV2-4 containers when the boss to liner interface is affected by design changes.

18.4 Environmental Test.

This test shall apply to Types NGV2-2, 3, and 4 containers only.

18.4.1 Container Set-Up and Preparation.

One container shall be tested, including coating if applicable.

The upper section of the container is to be divided into five distinct areas and marked for pendulum impact preconditioning and fluid exposure (see Figure 1). The areas shall be nominally 4 inches in diameter. While convenient for testing, the areas need not be oriented along a single line, but shall not overlap.

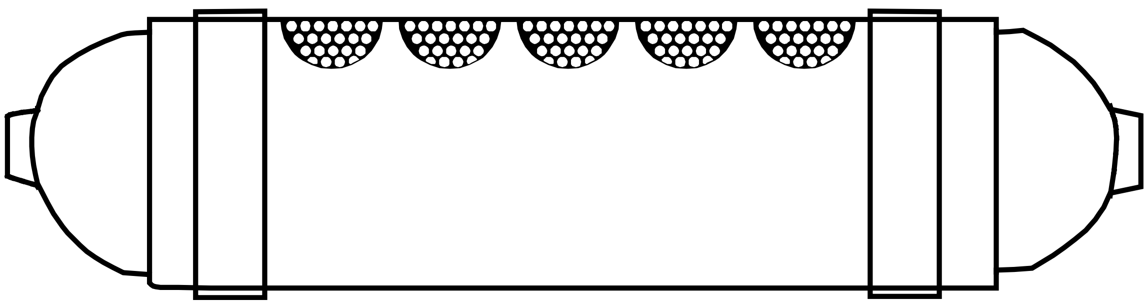

Figure 1. Container orientation and layout of exposure areas

Although preconditioning and other fluid exposure is performed on the cylindrical section of the container, all of the container, including the domed sections, should be as resistant to the exposure environments as the exposed areas.

18.4.2 Pendulum Impact Preconditioning.

The impact body shall be of steel and have the shape of a pyramid with equilateral triangle faces and a square base, the summit and the edges being rounded to a radius of 3 mm (0.12 in). The center of percussion of the pendulum shall coincide with the center of gravity of the pyramid; its distance from the axis of rotation of the pendulum shall be 1 m (39.37 in). The total mass of the pendulum referred to its center of percussion shall be 15 kg (33 lbs). The energy of the pendulum at the moment of impact shall be not less than 30 Nm (22.1 ft-lb) and as close to that value as possible.

During pendulum impact, the container shall be held in position by the end bosses or by the intended mounting brackets. Each of the five areas identified in Figure 1 shall be preconditioned by impact of the pendulum body summit at the center of the area. The container shall be unpressurized during preconditioning.

18.4.3 Environmental Fluids for Exposure.

Each marked area is to be exposed to one of five solutions. The five solutions are:

(a) Sulfuric acid - 19% solution by volume in water
(b) Sodium hydroxide - 25% solution by weight in water
(c) Methanol/gasoline - 5/95% concentration of M5 fuel meeting the requirements of *ASTM D4814, Automotive Spark-Ignition Engine Fuel*
(d) Ammonium nitrate - 28% by weight in water
(e) Windshield washer fluid (50% by volume solution of methyl alcohol and water).

When exposed, the test sample will be oriented with the exposure area uppermost. A pad of glass wool approx. 0.5 mm ($^1/_{64}$ in) thick and between 90 and 100 mm [3.5 and 4.0 in] in diameter is to be placed on the exposure area. Apply an amount of the test fluid to the glass wool sufficient to ensure that the pad is wetted evenly across its surface and through its thickness for the duration of the test, and to ensure that the concentration of the fluid is not changed significantly during the duration of the test

18.4.4 Pressure Cycle and Pressure Hold.

Containers shall be hydraulically pressure cycled between less than or equal to 10% of service pressure and 125% of service pressure for a total of 3,000 cycles. The maximum pressurization rate shall be 27.5 bar (400 psi) per second. After pressure cycling, containers shall be pressurized to 125% of service pressure, and held at that pressure until the elapsed exposure time (pressure cycling and pressure hold) to the environmental fluids equals 48 hours.

18.4.5 Acceptable Result

Fuel containers shall not leak or rupture during the test.

18.5 Extreme Temperature Cycling.

One representative container shall be cycle tested, without leakage or rupture, as follows:

(a) Stabilize the container at zero pressure and 82±5°C (180±10°F).
(b) Hydraulically pressure cycle between less than or equal to 10 percent of service pressure and 125 percent of service pressure for 4,000 cycles.
(c) Stabilize the container at zero pressure and ambient conditions.
(d) Stabilize the container at zero pressure and -40±5°C (-40±10°F).
(e) Hydraulically pressure cycle between less than or equal to 10 percent of service pressure and 80 percent of service pressure for 4,000 cycles.

The temperature measurements are to be made on the outer surface of the container and the temperature limits in “a” and “d” above shall be maintained throughout the cycling in “b” and “e,” respectively. The cycling rate shall not exceed 10 cycles per minute.

18.6 Hydrostatic Burst Test.

(a) Three representative containers shall be hydrostatically pressurized to failure. The rate of pressurization shall not exceed 1,400 kPa per second (200 psi/second) at pressures in excess of 80%

of the minimum required (calculated burst) pressure. If the rate of pressurization at pressures in excess of 80% of the required burst pressure exceeds 350 kPa per second (50 psi/second), then either the container must be placed schematically between the pressure source and the pressure measurement device, or there must be a five second hold at the minimum required burst pressure.

(b) The minimum required burst pressure shall be at least 2.25 times the service pressure, and in no case less than the value necessary to meet the burst/service pressure ratio requirement of section 7.1 (NGV2-1 Containers) for NGV2-1 containers or the stress ratio requirement of section 7.3.2 (Stress Ratios) for NGV 2.2, 2.3 and 2.4 Containers, when analyzed in accordance with the requirements of section 7.3.1 (Stress Analysis). Actual burst pressure shall be recorded.

(c) For NGV2-2 designs, one liner shall also be hydrostatically burst. The burst pressure shall exceed 1.25 times service pressure.

18.7 Composite Flaw Tolerance Test.

For types NGV2-2, NGV2-3 and NGV2-4 only, one uncoated container shall have two flaws in the longitudinal direction cut into the composite sidewall. One flaw shall be a minimum 25 mm (1 in) long and minimum 1.25 mm (0.05 in) in depth, and the other flaw shall be a minimum 200 mm (8 in) long and minimum 0.75 mm (0.03 in) in depth.

The flawed container shall then be pressure cycled, from not more than 10% of 1.25 times the service pressure to not less than 1.25 times the service pressure for a number of cycles equivalent to 750 times the design life of the container in years, with a minimum number of cycles of 11,250. The cylinder shall not leak or rupture within the first 3,000 cycles, but may fail by leakage up to the maximum number of cycles. All containers which complete this test shall be destroyed.

18.8 Drop Test

For types NGV2-2, NGV2-3 and NGV2-4 containers only, one or more finished containers shall be drop tested at ambient temperature without internal pressurization or attached valves. The surface onto which the containers are dropped shall be a smooth, horizontal concrete pad or flooring. One container shall be dropped in a horizontal position with the lowest point of the container no less than 1.83 m (72 in) above the surface onto which it is dropped. One container shall be dropped vertically on each end at a sufficient height above the floor or pad so that the potential energy is 488 joules (360 ft-lbs), but in no case shall the height of the lower end be greater than 1.83 m (72 in). One container shall be dropped at a 45 degree angle onto a dome from a height such that the center of gravity is at 1.83 m (72 in): however, if the lower end is closer to the ground than 0.6 m (24 in), the drop angle shall be changed to maintain a minimum height of 0.6 m (24 in) and a center of gravity of 1.83 m (72 in). The container(s) shall be allowed to bounce on the concrete pad or flooring after the initial impact. No attempt shall be made to prevent this secondary impacting.

Following the drop impact, the container(s) shall be pressure cycled, from not more than 10% of 1.25 times the service pressure to not less than 1.25 times the service pressure for a number of cycles equivalent to 750 times the design life of the container in years, with a minimum number of cycles of 11,250. The cylinder shall not leak or rupture within the first 3,000 cycles, but may fail by leakage up to the maximum number of cycles. All containers which complete this test shall be destroyed.

| **18.9** **Bonfire Test.**

| **18.9.1** **General.**

The bonfire tests are designed to demonstrate that finished containers complete with the pressure relief devices specified in the design will prevent the rupture of the container when tested under the specified fire conditions.

Extreme caution must be exercised during fire testing. Container rupture may occur.

| **18.9.2** **Container Set-Up.**

Containers shall be placed horizontally with the container bottom approximately 100 mm (4 in) above the fire source.

Metallic shielding shall be used to prevent direct flame impingement on container valves, fittings, and/or pressure relief devices. The metallic shielding shall not be in direct contact with the specified fire protection system (pressure relief devices or container valve).

| **18.9.3** **Fire Source.**

A uniform fire source of 1.65 m (65 in) length shall provide direct flame impingement on the container surface across its entire diameter.

Any fuel which provides uniform heat and sufficient temperature as required in section 18.9.5 (Bonfire Test, General Test Requirements) may be used for the fire source. The test shall continue until the container fully vents (until the container pressure falls below 100 psi).

Any failure or inconsistency of the fire source during a test shall invalidate the result.

| **18.9.4** **Temperature and Pressure Measurements.**

Flame temperatures shall be monitored by at least three thermocouples suspended in the flame approximately 25 mm (1 in) below the bottom of the container. The thermocouples may be attached to steel cubes up to 25 mm (1 in) on a side.

Thermocouple temperatures and the container pressure shall be recorded every 30 seconds during the test.

| **18.9.5** **General Test Requirements.**

Containers shall be pressurized with natural gas or methane and tested in the horizontal position at both;

(a) The service pressure, and

(b) 25 percent of the service pressure (not required if a thermally activated device is used).

Immediately following ignition, the fire shall produce flame impingement on the surface of the container along the 1.65 m (65 in) length of the fire source and across the container diameter.

Within five minutes of ignition the temperature at two of the three thermocouples shall average at least 430°C (800°F) over any one minute interval. This average temperature shall be maintained for the remaining duration of the test. Tests may be conducted with ambient temperatures between –7 and 43°C (20 and 110°F), but the container settled pressure shall be temperature compensated to 21°C (70°F).

18.9.6 Containers 1.65 m (65 in) Length or Less.

The center of the container shall be positioned over the center of the fire source.

18.9.7 Containers Greater Than 1.65 m (65 in) Length.

If the container is fitted with a pressure relief device at one end, the fire source shall commence at the opposite end of the container.

If the container is fitted with pressure relief devices at both ends, or at more than one location along the length of the container, the center of the fire source shall be centered midway between the pressure relief devices that are separated by the greatest horizontal distance.

18.9.8 Acceptable Results.

The container shall vent through a pressure relief device without bursting.

In the event that complete venting occurs in less than five minutes, the minimum temperature requirements do not apply.

18.10 Accelerated Stress Rupture Test.

For type NGV2-2, NGV2-3 and NGV2-4 designs only, one finished container shall be hydrostatically pressurized to 1.25 times service pressure while at a temperature of 65°C (149°F). The container shall be held at this pressure and temperature for 1,000 hours. The container shall then exceed 75% of the minimum burst pressure when tested in accordance with the hydrostatic burst test in section 18.6 (Hydrostatic Burst Test).

18.11 Penetration Test.

A container pressurized to service pressure with air or nitrogen shall be penetrated by an armor piercing bullet with a diameter of 7.62 mm (0.3 in) or greater. The bullet shall completely pass through at least one side wall of the container. For NGV2-2, -3, and -4 designs the projectile shall impact the sidewall at an approximate angle of 45 degree. The cylinder shall not rupture.

18.12 Permeation Test.

This test is only required on type NGV2-4 containers. One container shall be preconditioned with the boss subjected to twice the installation torque specified for the fittings. The container shall then be filled with compressed natural gas or a helium/nitrogen mixture to the service pressure, placed in an enclosed sealed container at ambient temperature, and monitored for leakage for a time sufficient to establish a steady state permeation rate. The permeation rate shall be less than 0.25 cc of natural gas per hour per liter (0.432 cu in per hour per cubic foot) water capacity of the container.

Note: If a helium/nitrogen mixture is used to measure permeation, the measured helium permeation rate must be converted to an equivalent natural gas permeation rate by using a viscous flow model, e.g., using a ratio of gas viscosities, and by ratioing based on the percentage of helium in the gas mixture.

18.13 Natural Gas Cycling Test.

For type NGV2-4 designs, one finished container shall be pressure cycled using compressed natural gas from 10 percent of service pressure to service pressure for 1,000 cycles. The end boss at the valve end (the end where the fill/discharge occurs) may be grounded. Each cycle, consisting of the filling and venting of the container, shall not exceed 1 hour. Following completion of the test, the container shall meet the requirements of the leak test in section 11.3 (Leak Test). The container shall then be sectioned and the liner and liner/end boss interface inspected for evidence of any deterioration, such as fatigue cracking, disbonding of plastic, deterioration of seals, or damage from electrostatic discharge. If there is evidence of deterioration, the test shall be repeated except that the number of cycles shall be equivalent to 750 times the design life of the container in years.

18.14 Leak Before Break.

This test only applies to Type 1 containers, Type 2 containers, and hoop-wrapped Type 3 containers.

Three finished containers shall be pressure cycled between not more than 10 percent of service pressure and 150 percent of service pressure at a rate not to exceed 10 cycles per minute in accordance with section 18.3 (Ambient Cycling Test).

All containers shall either fail by leakage or exceed 45,000 pressure cycles.

18.15 Defect Size for Non-Destructive Examination (NDE).

For type NGV2-1, NGV2-2 and NGV2-3 designs, the NDE defect size required for production inspection under section 11.1 (General) may be determined using a method as described under section 18.15.1 (NDE Defect Size by Engineering Critical Assessment), 18.15.2 (NDE Defect Size by Flawed Container Cycling) or other suitable methods.

18.15.1 NDE Defect Size by Engineering Critical Assessment.

Calculations shall be performed in accordance with British Standard *PD6493-1991, Guidance Methods for Assessing the Acceptability of Flaws in Fusion Welding Structures*, Section 3, using the following steps:

(a) Fatigue cracks shall be modelled at the high stress location in the wall/liner as planar flaws.

(b) The applied stress range at the fatigue sensitive site, due to a pressure between 10 percent of service pressure and service pressure, shall be established from the stress analysis as outlined above.

(c) The bending and membrane stress component may be used separately.

(d) The minimum number of pressure cycles is equivalent to 750 times the design life of the container in years, with a minimum number of cycles of 11,250.

(e) The fatigue crack propagation data shall be determined in air in accordance with *ASTM E647, Standard Test Method for Measurement of Fatigue Crack Growth Rates*. The crack plane orientation shall be in the C-L direction (i.e., crack plane perpendicular to the circumferences and along the axis of the container), as illustrated in *ASTM E399, Standard Test Method for Plane - Strain Fracture Toughness of Metallic Materials*. The rate shall be determined as an average of 3 specimen tests. Where specific fatigue crack propagation data are available for the material and service condition, they may be used in the assessment.

(f) The amount of crack growth in the thickness direction and in the length direction per pressure cycle shall be determined in accordance with the steps outlined in Section 14.2 of the BS *PD6493-1991, Guidance Methods for Assessing the Acceptability of Flaws in Fusion Welded Structures,* document by integrating the relationship between the rate of fatigue crack propagation, as established in -(e) above, and the range of crack driving force corresponding to the applied pressure cycle.

(g) Using the above steps, calculate the maximum allowable defect depth and length which shall not cause the failure of the container during the design life due to either fatigue or rupture. The defect size for NDE shall be equal to or less than the calculated maximum allowable defect size for the design.

| **18.15.2 NDE Defect Size by Flawed Container Cycling.**

For type NGV2-1, NGV2-2 and NGV2-3 designs, three containers containing artificial defects that exceed the defect length and depth detection capability of the NDE inspection method required in section 11.1 (General), shall be pressure cycled to failure in accordance with the test method in section 18.3 (Ambient Cycling Test). For type NGV2-1 designs having a fatigue sensitive site in the cylindrical part, external flaws shall be introduced in the side wall. For type NGV2-1 designs having the fatigue sensitive site outside the side wall, and for type NGV2-2 and NGV2-3 designs, internal flaws shall be introduced. Internal flaws may be machined prior to the heat treating and closing of the end of the container.

The containers shall not leak or rupture in less than a number of cycles equivalent to 750 times the design life of the container in years, with a minimum number of cycles of 11,250.

The allowable defect size for NDE shall be equal to or less than the artificial flaw size at that location.

| **18.16 Qualification Test Results.**

A record of all tests for each design describing test setup, procedure and results shall be kept on file by the container manufacturer. These records shall include the complete Inspector's Record and the following basic information on each container design tested:

BASIC CONTAINER DESIGN INFORMATION

Container Type (check one): NGV2-1 ____ NGV2-2 ____ NGV2-3 ____ NGV2-4 ____

Manufacturer ______________________________ Part No. __________
Service Pressure ______________ kPa (psig)
Hydrostatic Test Pressure ______________ kPa (psig)
Autofrettage Pressure ______________ kPa (psig)
Minimum Prescribed Burst Pressure ______________ kPa (psig)
Volume (water) ______________ liters (cu ft)
Length ______________ mm (in)
Inside Diameter ______________ mm (in)
Outside Diameter ______________ mm (in)
Liner Material ______________
Boss Material ______________
Filament Material ______________
Resin System Material ______________
Container Weight (nominal)______________ kg (lb)
Liner Weight (nominal)______________ kg (lb)
Composite Weight (nominal)______________ kg (lb)
Liner Sidewall Thickness (minimum)______________ mm (in)
Liner Yield Strength (minimum)______________ MPa (psi)
Composite Longitudinal Thickness (nominal)______________ mm (in)
Composite Circumferential Thickness (nominal)______________ mm (in)
Composite Resin Shear Strength Water Boil (minimum)______________ MPa (psi)

	STRESS DISTRIBUTION					
	Direction		Distribution (MPa)		Distribution (%)	
Pressure	Long.	Circ.	Liner	Overwrap	Liner	Overwrap
Zero	X	-				
	-	X				
Service	X	-				
	-	X				
Test	X	-				
	-	X				
Burst	X	-				
	-	X				

Inspector ______________________________ Date __________

ANNEX - RECORDS OF MANUFACTURE

RECORD OF MANUFACTURE OF TYPE NGV2 COMPRESSED NATURAL GAS VEHICLE FUEL CONTAINERS

Manufactured by ______________________________
Located at ______________________________
Certification Number or symbol ______________________________
Manufacturer's Number ______________________________
Serial Numbers ______________ to ______________ inclusive

Container Type (check one): NGV2-1 ____ NGV2-2 ____ NGV2-3 ____ NGV2-4 ____

Size: _______ mm (_______ inches) outside diameter by _______ mm (_______ inches) overall length (excluding container appurtenances).

Marks stamped on the shoulder or on labels of the container are:

CNG Only
"DO NOT USE AFTER" ______________________________
Manufacturer ______________________________
Serial Number ______________________________
Service Pressure at Temperature ______________________________
Standard Designation, Certification Registration # or symbol, and Container Type ______________
____
Qualified Pressure Relief Device and/or Valves or Pertinent Information ______________
____

Each container was made in compliance with all details of ANSI/CSA NGV2 in accordance with the specified type. Required records of test results are attached.

I hereby certify that all these containers proved satisfactory in every way and are in compliance with the requirements of ANSI/CSA NGV2.

Comments: ______________________________
____
Inspection Agency ______________________________
Inspector's Signature ______________________________
Manufacturer's Signature ______________________________
Place ______________________________ Date ______________

RECORD OF CHEMICAL ANALYSIS OF MATERIAL FOR METALLIC CONTAINERS, LINERS AND BOSSES

Container Type (check one): NGV2-1 ____ NGV2-2 ____ NGV2-3 ____ NGV2-4 ____

Size: _______ mm (_______ inches) outside diameter by _______ mm (_______ inches) overall length (excluding container appurtenances).

Material Description ____

Steel

Test No.	Heat No.	Jominy Hardness (HRC)		Check Analysis Number	Containers Represented (Serial Nos.)	Chemical Analysis								
		first	last			C	P	S	Si	Mn	Cr	Mo	B	Al

Aluminum

Alloy Designation (Per Alum. Assoc.)	Containers Represented (Serial Nos.)	Chemical Analysis											
		Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Pb	Bi	Others	
												Ea.	Total

Inspection Agency ____

Inspector's Signature ____

Manufacturer's Signature ____

Place ______________________________ Date ____________________

RECORD OF MECHANICAL PROPERTIES OF MATERIAL FOR METALLIC CONTAINERS, LINERS AND BOSSES

Container Type (check one): NGV2-1 ____ NGV2-2 ____ NGV2-3 ____ NGV2-4 ____

Size: _______ mm (_______ inches) outside diameter by _______ mm (_______ inches) overall length (excluding container appurtenances).

Material Description ____

Tensile Specimen size: Width _______ mm (______ inches) by _______ mm (_______ inches) gauge length.
Impact Specimen size: 10 mm (0.4 inches) deep by _______ mm (_______ inches) wide. (Not applicable to Aluminum.)

Heat or Batch Code Number	Containers Represented (Serial Nos.)	Yield Strength at 0.2% Offset MPa(psig)	Tensile Strength MPa(psig)	Elongation (percent)

Charpy V-Notch Test		
Energy		Lateral Expansion
Average Value for 3 Specimens J/cm^2 $(Ft\text{-}Lb/in^2)$	Minimum Value for 1 Specimen J/cm^2 $(Ft\text{-}Lb/in^2)$	Range Value for 3 Specimens mm (Mils)

Heat codes stamped into each container (yes or no)

Inspection Agency ____
Inspector's Signature ____
Manufacturer's Signature ____
Place ______________________________ Date ____________________

RECORD OF PHYSICAL AND MECHANICAL PROPERTIES OF MATERIAL FOR NONMETALLIC LINERS

Container Type: NGV2-4, Numbered ________________ to ____________________ inclusive.

Size: _______ mm (_______ inches) outside diameter by _______ mm (_______ inches) overall length (excluding container appurtenances).

Liner Material Description ____

Boss Material Description ____

Minimum Liner Thickness ____
Melt Temperature, _______°C (_______°F)

Batch Code Number	Containers Represented Serial Nos.	Tensile Strength MPa (psig)	Elongation (percent)

Inspection Agency ____
Inspector's Signature ____
Manufacturer's Signature ____
Place ________________________________ Date ________________

RECORD OF COMPOSITE ANALYSIS

Container Type (check one): NGV2-1 ____ NGV2-2 ____ NGV2-3 ____ NGV2-4 ____

Size: _______ mm (_______ inches) outside diameter by _______ mm (_______ inches) overall length (excluding container appurtenances).

Filament Type ______________________________

Manufacturing Batch No. (units)	Tensile Strength MPa (psig)	Interlaminar Shear Strength MPa (psig)

Resin system description ______________________________

	Type	Batch No(s).
Resin		
Curing Agent		
Accelerator		

Cure Temperature _______°C (_______°F)

Composite properties ______________________________

Inspection Agency ______________________________
Inspector's Signature ______________________________
Manufacturer's Signature ______________________________
Place ______________________________ Date ______________

RECORD OF HYDROSTATIC TESTS ON CONTAINERS

Container Type (check one): NGV2-1 ____ NGV2-2 ____ NGV2-3 ____ NGV2-4 ____

Numbered ______________ to ______________ inclusive.
Size: _______ mm (_______ inches) outside diameter by _______ mm (_______ inches) overall length (excluding container appurtenances).

Water Volume ______________________________ Minimum ____________________________ Maximum
Manufacturer ____

Minimum prescribed test pressure, kPa (psig) ______ (_____)
Autofrettage pressure, kPa _______ (_______ psig)(NGV2-2 and NGV2-3 only)

HYDROSTATIC TEST								
S/N	Weights			Volume	Total Expansion cc (in^3)	Perm. Expansion cc (in^3)	Elastic Expansion	Ratio of Permanent to total (%)

CYCLING AND BURST TESTS			
Test Type	Serial No.	No. of Cycles	Burst Pressure, kPa (psig)
Cycling			
Hydro-static Burst			

Inspection Agency ____
Inspector's Signature ____
Manufacturer's Signature ____
Place ____ Date __________________