



SOUTHWEST GAS CORPORATION

ENGINEERING STAFF

MATERIAL SPECIFICATION

Prepared By: M.R. Haught

Approved By: J.F. Wunderlin *JFW*

Section No:	MS P-4
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COMPRESSED NATURAL GAS (CNG) EQUIPMENT

Vehicle Fuel Containers

1. SCOPE

This material specification contains specifications for the material, design, manufacture and testing of serially-produced, refillable Type ANSI/AGA NGV2 containers (vessels, cylinders) intended only for the storage of compressed natural gas for vehicle operation. These containers are to be permanently attached to the vehicle.

2. APPLICABLE DOCUMENTS

- 2.1 American National Standards Institute (ANSI) AGA NGV2-1992, "Basic Requirements for Compressed Natural Gas Vehicle (NGV) Fuel Containers."
- 2.2 American Society for Testing and Materials (ASTM) A-505, "Specification for General Requirements for Steel Sheet and Strip, alloy, Hot Rolled and Cold Rolled."
- 2.3 American Society for Testing and Materials (ASTM) A-255, "Method of End-Quench test for Hardenability of Steel."
- 2.4 American Society for Testing and Materials (ASTM) D-2343, "Test Method for Tensile Properties of Glass Fiber Strands, Yarns and Rovings Used In Reinforced Plastics."
- 2.5 Suppliers of Advanced Composite Materials Association (SACMA) SRM 16-90, "Recommended Test Method for Tow Tensile Testing of Carbon Fibers."
- 2.6 American Society for Testing and Materials (ASTM) D-2344, "Test Method for Apparent Interlaminar Shear Strength of Parallel Fiver Composites by Short Beam Method."
- 2.7 American Society of Mechanical Engineers (ASME), "Boiler and Pressure Vessel Code, Section IX."
- 2.8 American Society of Mechanical Engineers (ASME), "Boiler and Pressure Vessel Code, Section VIII."
- 2.9 American Society of Mechanical Engineers (ASME), "Boiler and Pressure Vessel Code, Section VIII UW-12."
- 2.10 National Aeronautics and Space Administration (NASA) CF-72124, "Computer Program for the Analysis of Filament-Wound Reinforced Metal Shell Pressure Vessels."



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2. APPLICABLE DOCUMENTS (Cont'd)

- 2.11 Compressed Gas Association (CGA), "Pressure Relief Device Standards, Part 1."
- 2.12 Compressed Gas Association (CGA), "Cylinders for Compressed Gases," Pamphlet No. S-1.1.

NOTE: All applicable documents will be the most recent edition.

3. TERMINOLOGY

3.1 General

- 3.1.1 "Southwest Gas," "Southwest" or "SWG" wherever used in this specification and other related documents will refer exclusively to Southwest Gas Corporation.
- 3.1.2 The terms "approved," "as approved," "satisfactory," "as directed," "or equal" or other similar terms wherever used in this specification and other related documents will mean "as determined by Southwest Gas," unless specifically stated otherwise.
- 3.1.3 "NGV" wherever used in this specification and other related documents will refer to Natural Gas Vehicle.
- 3.1.4 "Product Information Package" or "PIP" wherever used in this specification and other related documents will mean the required technical product information that a manufacturer must submit to SWG to determine if the product is suitable for use by SWG, unless specifically stated otherwise.

4. MATERIALS AND MANUFACTURE

- 4.1 All materials of construction shall be capable of operating within a temperature range of -40 degrees Celsius (-40 Fahrenheit) to 82 degrees Celsius (180 degrees Fahrenheit). Maximum material design temperature shall be 82 degrees Celsius (180 degrees Fahrenheit), or higher.
- 4.2 NGV2-1 are full metal cylinders composed fully of either steel or aluminum.
- 4.3 NGV2-2 are cylinders with a metal liner reinforced with resin impregnated continuous filament "hoop wrapped."



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4. MATERIALS AND MANUFACTURE (Cont'd)

- 4.4 NGV2-3 are cylinders with a metal liner reinforced with resin impregnated continuous filament "full wrapped."
- 4.5 NGV2-4 are cylinders with a resin impregnated continuous filament with a non-metallic liner (full wrapped, full composite).
- 4.6 Steel containers and steel liners per ANSI/AGA NGV2-1992 shall be of uniform quality, only the basic oxygen or electric furnace process are authorized. The steel shall be aluminum killed and produced to predominantly fine grain practice. Incidental elements shall be within the limits specified in the ASTM A505. When carbon-boron steel is used, a hardenability test in accordance with ASTM A-255, shall be performed on the first and last ingot of slab of each heat of steel. The results of this test shall be recorded on the Record of Chemical Analysis of Material for Containers. This hardness test shall be made 7.9 mm (5/16-inch) from the quenched end of the Jominy quench bar and the hardness shall be at least Rc33 and no more than Rc53. When the Jominy test are certified by the material manufacture, the test need not be witnessed by the independent inspector.
- 4.7 Aluminum containers and aluminum liners shall be 6010 alloy, 6061 alloy and T6 temper.
- 4.8 Structural reinforcing filament material types shall be commercial grade E-glass, commercial grade S-glass, aramid fiber or carbon fiber. Filament strength shall be certified as tested in accordance with the ASTM D-2343 pr SAC<A "SRM" 16-90." Fiber coupling agents (sizing) shall be compatible with the resin system. If carbon fiber reinforcement is used, the design shall incorporate means to prevent galvanic corrosion of the metallic components of the fuel container.
- 4.9 The resin system shall be epoxy, polyester, vinyl ester or thermoplastic. The resin system shall be tested on a sample coupon representative of the composite overwrap in accordance with ASTM D-2344, following a 24-hour water boil and shall have a minimum shear strength of 13.8 MPa (2,000 psi).
- 4.10 Nonmetallic liner material and thickness shall be chosen such that permeation of compressed natural gas through the wall of the finished container (at service pressure) is less than .25 normal cc per hour of liter water capacity of the container.



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4. MATERIALS AND MANUFACTURE (Cont'd)

- 4.11 Bosses for Type NGV2-4 containers shall be compatible with the liner and the intended environment and shall be resistant to stress corrosion cracking to avoid failure during the life span of the container.
- 4.12 Adhesive bonding of bosses to nonmetallic lined containers is acceptable and shall comply with Paragraph 4.10. The adhesive bonds shall be of sufficient strength to resist torquing of connections into the boss.
- 4.13 All structural materials shall be traceable to their original manufacturer's certified test reports.
- 4.14 The materials shall be of uniform quality. Materials with injurious defects are not authorized.
- 4.15 Metal containers and metal liner surfaces shall have dirt and scale removed as necessary to afford proper inspection, no defect is acceptable that is likely to weaken the finished container appreciably. Reasonably smooth and uniform surface is required. No interior folding in the neck area is permitted and smooth gathering of the material in the neck in which there are no sharp rooted folds is acceptable. If not originally free from such defects, the liner surface may be machined or otherwise treated to eliminate these defects provided the required minimum wall thickness is maintained. Liner end contour shall be concave to pressure.
- 4.16 Nonmetallic liners shall be free of contaminates as necessary to afford proper inspection. No defect is acceptable that is likely to cause leakage of the liner within the required vessel lifetime. 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.
- 4.17 Composite containers with metallic liners shall be fabricated from a metal liner overwrapped with resin impregnated continuous filament windings. Winding pattern shall be "hoop wrap" for Type NGV2-2 containers, and "helical or in plane" and "hoop wrap" for Type NGV 2-3 containers, supplied under controlled tension to develop the design composite thickness. After winding is complete, composites using thermoset resins shall be cured by a controlled temperature process. Prior to hydrostat test, containers shall be autofrettaged by pressurizing to not less than 105 percent of the prescribed minimum hydrostatic test pressure, or prestressed by other processes. No defect is acceptable that is likely to weaken the finished container appreciably.



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4. MATERIALS AND MANUFACTURE (Cont'd)

- 4.18 Composite containers with nonmetallic liners shall be fabricated from nonmetallic liner overwrapped with resin impregnated continuous filament windings. Winding pattern to be "helical or in plane" and "hoop wrap," applied under controlled tension to develop the design composite thickness. After winding is complete, the composite shall be cured by a controlled temperature process. No defect is acceptable that is likely to weaken the finished container appreciably. The composite container with nonmetallic liner shall be designed such that if, when pressurized, the liner is susceptible to seep and flow, no failure will occur during the prescribed lifetime.
- 4.19 Brazing for any purpose whatsoever is prohibited.
- 4.20 Welding containers and liners constructed of metal is authorized. Welding procedures and operators shall be qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX. Weld efficiencies shall be in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, UM-12. All welds shall be subject to full radiographic, or other acceptable NDT examination in accordance with ASME Boiler and Pressure Code, Section VIII. All designs with welds shall be cycled to failure in the lot acceptance test without the failure initiating at the weld unless the minimum number of cycles is exceeded by at least 50 percent. For Type NGV2-3 liners, longitudinal welds and nonconsumable backing strips or rings are not permitted.
- 4.21 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 ANSI/AGA NGV2-1992, Section 1-6 (a), "Mounting and Protection."



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4. MATERIALS AND MANUFACTURE (Cont'd)

4.22 Lot Definitions

4.22.1 In no case shall a "lot" be permitted to exceed 200 units, or on shift of production, whichever is greater.

4.22.2 Metal liners and containers only. A "lot" for metal liners and containers shall be a group of metal liners or containers successively produced having the same size, configuration, specified material of construction, process of manufacture, heat treatment, and conditions of time, temperature and atmosphere during heat treatment.

4.22.3 Non-metal liners only. A "lot" for non-metal liners shall be a group of non-metal liners successively produced having the same size, configuration, specified material of construction, process of manufacture and equipment manufacture.

4.22.4 Composite cylinders only. A "lot" for composite containers shall be a group of containers successively produced from qualified liners having the same size, configuration, specified materials of construction, process of manufacture to the same container specification and autofrettaged under the same conditions of time, temperature and pressure.

4.23 After all metal forming and welding operations, steel containers and liners shall be uniformly and properly heat treated under the same conditions of time, temperature and atmosphere prior to tests.

4.24 All containers or liners of steel grades "Chrome-Molybdenum" or "Carbon-Boron" shall be quenched in oil or other suitable medium having a cooling rate not in excess of 80 percent that of water. "Carbon-Manganese" steel grades shall be normalized and do not require tempering after normalizing.

4.25 All containers shall be protected from rupture due to overpressure in a fire situation. This protection shall be provided in that each container shall be equipped with pressure relief devices in accordance with CGA Pamphlet No. S-1.1, except that the effectiveness of the pressure relief devices shall be demonstrated in accordance with ANSI/AGA NGV2-1992, Section 1-18.



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4. MATERIALS AND MANUFACTURE (Cont'd)

- 4.26 Container valves, pressure relief devices and connections shall be protected against damage in normal vehicle operations and against breakage in a collision. If this protection is mounted to the container itself, the design and method of attachment shall be approved by the container itself and the container manufacture. Factors to be considered include the abilities of the container to support the transferred impact loads and effect of local stiffening on container stresses and fatigue life.
- 4.27 All materials and processes used in the manufacture of containers shall be in accordance with ANSI/AGA NGV2-1992.
- 4.28 All containers shall be designed for a service life of 15 years from the time of the container's initial hydrostatic test as conducted under ANSI/AGA NGV2-1992, Section 1-11.
- 4.29 Threads shall be clean cut, even, without checks and to gauge. National Gas Tampered (NGT) threads in compliance with FED-STD-H28 are permitted. Other straight threads having six engaged threads are also permitted. All straight threads shall meet shear strength requirements as described in ANSI/AGA NGV2-1992, Section 1-8 (d.1).

5. PERFORMANCE REQUIREMENTS

- 5.1 Type NGV2 containers shall not exceed 1,000 liters (35.4 cu ft) water capacity and service pressure at least 165 Bar (2,400 psig), but not greater than 300 Bar (4,350 psig).
- 5.2 Type NGV2 containers shall be compatible with the temperature, moisture, natural gas and other environments, and fluids found in an automotive environment, such that the performance of the vessel is no degraded.
- 5.3 Welded NGV2-1 vessels shall have a safety factor of 3.5.



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6. DIMENSIONS AND TOLERANCES

- 6.1 Type NGV2-1 vessel minimum wall thickness shall be such that the wall stress at the minimum prescribed hydrostatic test pressure does not exceed 67 percent of the minimum tensile strength of the metal as determined by the mechanical properties described in ANSI/AGA NGV2-1992, Section 1-12 (a).
- 6.2 Liners for Type NGV2-2 vessels shall be such that the longitudinal tensile stress at the minimum design burst pressure does not exceed the ultimate tensile strength of the liner material as determined in ANSI/AGA NGV2-1992, Section 1-12 (a). Minimum thickness of the liner shall be such that the compressive stress in the sidewall of the furnished container at zero pressure will not exceed 95 percent of the yield strength of the liner as determined in ANSI/AGA NGV2-1992, Section 1-12 (a) or 95 percent of the minimum design yield strength determined in ANSI/AGA NGV2-1992, Section 1-18 (h). The maximum tensile stress in the liner at service pressure shall not exceed 66 percent of the yield strength.
 - 6.2.1 The end designs shall incorporate added materials to assure that stresses in these areas at internal pressures between no more than 10 percent of service pressure and service pressures are less than the maximum stress limits in the sidewall as prescribed in Paragraph 6.2.
- 6.3 Lines for Type NGV2-3 vessels shall be such that the compressive stress in the sidewall of the finished container at zero pressure will not exceed 95 percent of the minimum yield strength of the liner as determined in ANSI/AGA NGV2-1992, Section 1-12 (a) or 95 percent of the minimum design yield strength determined in ASNI/AGA NGV2-1992, Section 1-18 (h).
- 6.4 Liners for Type NGV2-4 vessels shall be such that the required service life and permeation rate requirements of this specification are met.
- 6.5 Stresses in the liner and composite reinforcement shall be computed using NASA CF-72124, dated May 1966, or other suitable analysis techniques.



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6. DIMENSIONS AND TOLERANCES (Cont'd)

- 6.6 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 as described in ANSI/AGA NGV2-1992, Section 1.7 (i). Stress ratio is defined as the stress in the fiber at minimum burst pressure divided by the stress in the fiber at service pressure. 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 operating pressure is achieved. The stress ratio requirements (2.65) for E-Glass and S-Glass reinforced Type NGV2-2 vessels may be demonstrated by meeting a minimum hold time at a specified pressure during the burst tests conducted under ANSI/AGA NGV2-1992, Sections 1-12 (c) or 1-18 (e). Acceptable alternative combinations of hold times and pressure are as follows: 1 minute at 2.50 times the operating pressure or 1 hour at 2.25 times the operating pressure.
- 6.7 Containers with greater than 450 liters (15.89 ft) water capacity and all containers employing integral mounts or valve protection shall consider the external loads imposed on the vessel as a function of the service conditions and mounting provisions. This would include bending and torsional stresses. Additional wall thickness shall be added to maintain the required ratio between the burst and operating pressures and the stress ratio, as applicable.
- 6.8 Openings are permitted in the heads only. Centerline of polar boss shall coincide with the longitudinal axis of the container.

7. INSPECTION

- 7.1 Successful review of the Product Information Package (PIP) as well as any future reference by SWG to the Seller's part number or internal code number in any future contract or purchase, will mean only that no conflict with the specification was found and will not relieve the Seller from meeting all the requirements of this specification.
- 7.2 SWG retains the option to inspect the manufacture and testing of NGV storage vessels sold to SWG.



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7. INSPECTION (Cont'd)

7.3 SWG will make appropriate inspections and tests of any and all materials, products or systems supplied to this specification. SWG will have the right, at their option, to reject any material which fails to conform to this specification. Any such rejection may take place at the manufacturer's facility, the vendor's warehouse or any subsequent deliver location, before or after SWG assumes possession. Notice of the rejection will be made promptly to the supplier by SWG's Corporate Purchasing Department. The defective product will be replaced or returned for credit at the manufacturer's expense.

7.4 Any changes in the manufacturing of previously approved NGV storage vessels covered under this document for sale to SWG must be approved by SWG's Engineering Staff. Failure to attain SWG's approval may be cause for rejection and disqualification as an approved supplier.

8. CERTIFICATION

The manufacturer's or supplier's certification will be furnished to SWG. This certification will state that samples representing each lot have been manufactured, tested and inspected in accordance with this specification and that all requirements have been met.

9. MATERIAL SAFETY DATA SHEETS

In accordance with law, the Seller will supply Material Safety Data Sheets for all applicable items supplied under this specification to the following:

- 1) The Receiving Location
- 2) Engineering Staff
- 3) Southwest Gas Corporation
Staff Safety
Mail Station LVA-581
P.O. Box 98510
Las Vegas, NV 89193-8510



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10. PRODUCT MARKING

Each container shall be permanently marked near the end of the container containing the outlet valve by either stamping or labeling the following information:

- “CNG ONLY”
- Standard design (i.e., NGV2-“x”)
- Service pressure
- Manufacturer’s symbol or trademark
- Serial number
- Inspector’s symbol or trademark
- Month and year of manufacture
- Maximum design material temperature
- “Do Not Use After _____,” (where “_____” is the year during which the 15- year design life will expire).

11. PACKAGING AND PACKAGE MARKING

- 11.1 All containers shall be packed in a manner as to prevent damage that may occur during normal shipping and handling.
- 11.2 All palletized containers shall not exceed twelve (12) containers and shall be retained to the pallet in a manner to prevent shifting during normal shipping and handling procedures.
- 11.3 All container packaging shall be labeled with the manufactures name and address, container serial number and reference the SWG original purchase order number.

12. STOCK CLASSIFICATION DESCRIPTION

CYLINDERS, ANSI/AGA NGV2, TYPE _____, RATED WORKING PSI _____, SWG MS P-4.