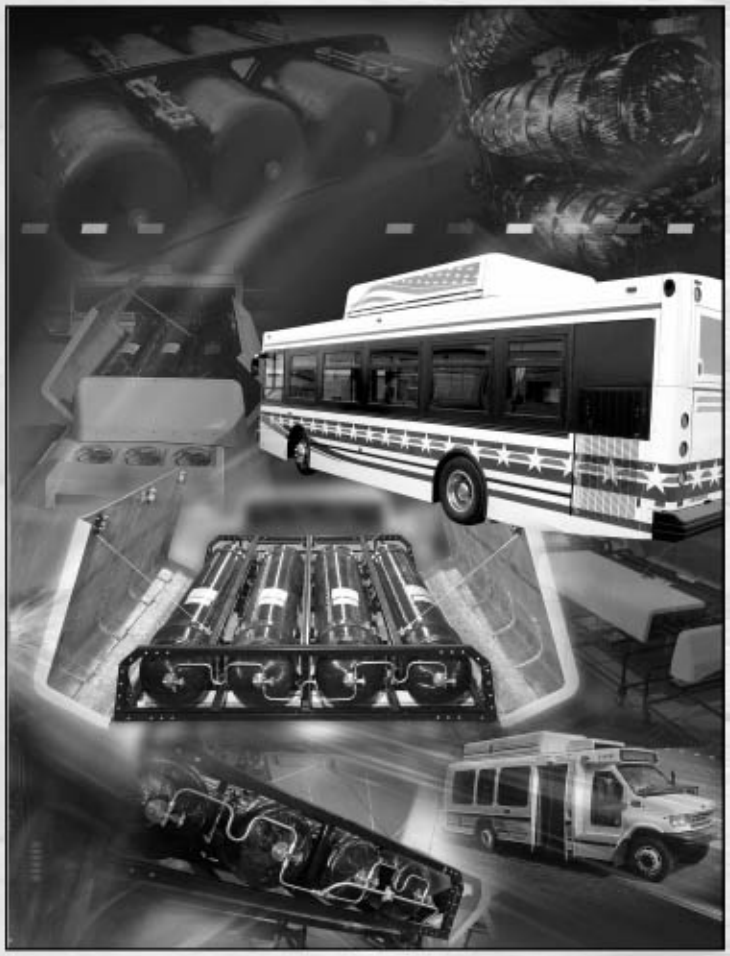
P/N R15653 Rev C

ISO 9001

Registered Company

TÜV Rheinland of North America, Inc.

NGV Fuel Container Inspection Guidelines



For

All-Composite

(Type 4)

TUFFSHELL™

NGV Fuel Containers

and

Fuel Storage Systems

Certified To DOT FMVSS 304,

ANSI/CSA NGV2,

METI-KHK Tech. STD #9 &

CSA B51 Part 2, ISO 11439

and other National Standards

TUFFSHELL

GENERAL DYNAMICS
Armament and Technical Products

CONTENTS

1.0 Introduction

Composite reinforced pressure vessels have been used in commercial service since 1976. The technology for these vessels was originally developed by the aerospace industry for weight critical applications. This technology has evolved significantly and has been increasingly used in commercial applications as more efficient and cost effective materials and manufacturing methods have been developed.

General Dynamics Lincoln Operations (formerly Lincoln Composites) designs and manufactures many types of composite pressure vessels, including light-weight all-composite fuel tanks for vehicles powered by compressed natural gas (CNG) and compressed hydrogen (CH2). Natural Gas Vehicle (NGV) fuel tanks may be designed and qualified to a number of appropriate specifications. These include, but are not limited to, ANSI/CSA NGV2, CSA B51-Part 2, NFPA-52, the US Department of Transportation, (NHTSA), FMVSS 304,TC 301.2 , and ISO 11439. When referencing these documents please refer to the most current revision.

Note: Applications that necessitate deviation from the guidelines listed in this manual must fall within the requirements of the applicable specifications listed above.

The guidelines herein are for the inspection, installation, and service of TUFFSHELL™ NGV Type-4 fuel tanks and tank packs manufactured by General Dynamics.

2.0 Scope

The purpose of this publication is to provide sufficient information about TUFFSHELL™ NGV fuel tanks and tank packs manufactured by General Dynamics so that ` a trained inspector can effectively:

- Examine composite fuel tanks and assess their condition and determine if they are safe for continued service.
- Identify minor repair procedures which may be used to prolong the useful life of fuel tanks with minor surface damage.
- Install, maintain, and assess their condition and determine if the fuel tanks are safe for continued service.
- Replace a tank in the General Dynamics Lincoln Operations tank pack assembly.

In conjunction with other applicable standards and specifications, these guidelines include information regarding proper TUFFSHELL™ NGV fuel tank installation, which is not directly related to inspection of the composite fuel tank. This additional information is provided only as a reminder of critical installation issues and is not intended to supersede or replace other applicable specifications. In particular, any inspector of fuel tanks should be knowledgeable of the requirements of NFPA 52 and/or CAN/CGA-B109. See section 3.0.

Please read and understand all aspects of these guidelines prior to performing any inspection or maintenance on a composite TUFFSHELL™ NGV fuel tank or tank pack assembly manufactured by General Dynamics. Inspectors should be registered through General Dynamics or certified through a nationally recognized training program. To be a General Dynamics registered inspector, an individual must attend the General Dynamics' NGV Fuel Tank Training course and have successfully completed the General Dynamics NGV Inspection Examination to verify his or her knowledge of the material covered within this manual.

Note: It is the responsibility of the company seeking training from General Dynamics to assess the general level of ability of each trainee to perform fuel tank re-certification and to see that only qualified personnel attend General Dynamics training for registration. General Dynamics assumes no liability for improperly inspected tanks.

A description of terms used in these guidelines is provided within. Any questions pertaining to training and registration of inspectors and interpretation or use of these guidelines should be directed to:

General Dynamics Lincoln Operations
Attn.: NGV Customer Service
4300 Industrial Avenue
Lincoln, Nebraska 68504-1197
800 279 TANK 8265 or 402 464 8211
FAX 402 464 6777
Email: tuffshell@gdatp.com
Web Address: www.gdatp.com

3.0 Pertinent Specifications/Documents

The guidelines of this document should be used in conjunction with other applicable standards and specifications invoked by governing regulations in the area of use. The following documents may be useful in performing an inspection and servicing of TUFFSHELL™ fuel tanks manufactured by General Dynamics.

a. "Methods For Visual Inspection Of Natural Gas Vehicle (NGV) Fuel Tanks And Their Installations," CGA C-6.4, available from:
Compressed Gas Association, Inc.
4221 Walney Road, 5th floor
Chantilly, VA 20151-2928
Phone: 703 788 2700
www.cganet.com

b. "Recommendations for the Disposition of Unserviceable Tanks," CGA C-2, available from:
Compressed Gas Association, Inc.
4221 Walney Road, 5th floor
Chantilly, VA 20151-2928
Phone: 703 788 2700
www.cganet.com

c. "Compressed Natural Gas (CNG) Vehicular Fuel Systems," ANSI/NFPA 52, available from:
National Fire Protection Association
1 Batterymarch Park, P.O. Box 9101
Quincy, MA 02269-9101
Phone: 800 344 3555
www.nfpa.org

d. "Basic Requirements For Compressed Natural Gas Vehicle (NGV) Fuel Tanks," ANSI/CSA NGV2, specification available from:
CSAAmerica, Inc.
8501 East Pleasant Valley Road
Cleveland, OH 44131
Phone: 216 524 4990
www.csa-america.org

e. "High Pressure Tanks for the On-Board Storage of Natural Gas as a Fuel for Automotive Vehicles," CSA B51 Part 2, available from:
Canadian Standards Association
178 Rexdale Boulevard
Rexdale (Toronto), Ontario, Canada
M9W 1R3 CANADA.
Phone: 800 463 6727
www.csa.ca

f. "Federal Motor Vehicle Safety Standards: Compressed Natural Gas Fuel Tanks," DOT FMVSS 304, available from:
Department Of Transportation, National Highway Traffic Safety Administration
400 Seventh Street, SW, Washington D.C. 20590.
Phone: 202 366 4000
www.dot.gov

g. "METI/KHK TECH. STD. #9" Technical Standard and Interpretation of Compressed Natural Gas Fuel Tanks. The High Pressure Gas Safety Law High Pressure Gas Safety Institute of Japan.
Toranomon, Minato-ku, Tokyo Japan 105-8447
Phone: 81 3 3436 2201
www.khk.or.jp/e-khk.htm

h. Service Bulletin 95-001 "Painting NGV Fuel Tanks"

i. Service Bulletin 97-07-001 "Pressure Relief Device Replacement For Superior (P/N 1120SX6SF) and GFI (P/N T1-100) Manual Valves With Circle Seal (P/N RV 99-245) and Mirada (P/N B-51715) PRDs"

j. Service Bulletin 97-08-001 "Venting Procedures"

k. Service Bulletin 97-08-002 "Fill Procedures"

l. Service Bulletin 00-02-001 "Inspection for Water in the Vent Line and Pressure Relief Device"

m. Service Bulletin 96-12-001 "Label Installation Procedures TUFFSHELL™ NGV Fuel Tanks"

n. Service Bulletin 00-11-001"Honda Provided Superior/ GFI Solenoid Valve on General Dynamics CNG Fuel Containers"

o. Service Bulletin 03-06-001 "Crush Washer Replacement Procedure"

p. "TUFFSHELL™ all-composite NGV Fuel Tanks" size and capacity chart

q. NGV Tank Inspection Record

4.0 Description of Terms

Abrasion Damage. Damage to composite caused by wearing, grinding or rubbing away of the composite material by friction.

All-composite (Type 4) Tank. A fuel tank made primarily from non-metallic materials such as plastic and high strength fiber reinforced composites. The tank may incorporate metal ports for attachment of valves and other plumbing devices.

Boss (Also see **"Ports").** The aluminum fittings at the ends of the tank, which contain the ports for installation of valves, pressure relief devices, and blank plugs.

4.0 Description of Terms Cont.

Blank Plug (Also see **"Solid Plug"**). A threaded plug with o-ring seal used to block tank ports not occupied by a valve or pressure relief device.

Blunt Impact. A forceful blow to the surface of the tank, which does not cut, gouge, or significantly indent the surface. This type of impact may induce damage, such as delaminations, which is not readily apparent by visual examination.

Carbon Fiber. One type of reinforcement fiber used in the composite overwrap.

Clips. The portion of the bracket assembly that interfaces the strap to the Rail Cleat or bracket base.

CNG. Compressed Natural Gas

Condemned Tank. A tank that has been damaged beyond repair and must be removed from service and rendered unusable.

Crazing. Hairline cracking of the resin, giving it an opaque, "frosty" appearance.

Cut Damage. Damage caused by a sharp object in contact with the composite surface that breaks or cuts the composite fibers.

Cylinder Region. The cylindrical portion of the tank.

Door. A fiberglass structure hinged and latched protecting the top and sides of the tank pack assembly.

Delamination. An induced separation between composite layers. This type of damage occurs from localized impact or resin burn out.

Destroyed. Alteration of a fuel tank to make it physically unusable. Drilling two or more holes one half inch in diameter or larger completely through the composite wall and liner is an acceptable means of destroying a Condemned Tank.

Domes. The closed end portions of the fuel tank.

Entrapped Air. As referred to in this document, it is the air volume that is trapped between the HDPE liner and the corresponding composite overwrap.

Factory Inspection. An inspection and evaluation performed at an approved General Dynamics facility, utilizing comprehensive testing techniques that are not available for field inspection.

Fairing (Assembly). Metal frame / fiberglass covered assembly. Typically installed on the front and rear of some tank pack assemblies.

Field Inspection. Inspection performed at a location other than a General Dynamics facility.

Filament Winding. An automated process used for orienting strands of high strength fibers and plastic resin to construct composite tanks.

Fill Line Assembly. A high-pressure line used to conduct gas into the tank through the valve assembly or assemblies.

Foam Insert. Impact absorbing material located under the fiberglass wrap designed to protect the tangent area from damage.

Frame. General term that is used to describe the metal structure of the tank pack. The frame encloses and supports the tanks, brackets and pressure lines, fairings, and doors also attach to the frame.

Glass Fiber. One type of reinforcement fibers used in the structural wrap. Also fiber used in the external sacrificial wrap. Glass fiber is also referred to as fiberglass.

Hardware. General description of valves, PRDs and any other component that will attach to the tank or the tanks related systems.

Impact Damage. Damage caused by dropping or by a blow from another object. Impact damage may be at the surface, internal to the structure, or both.

Inspection Stamp. The stamp applied to the label by a registered inspector indicating acceptance of the three-year required inspection. The stamp shall identify the inspecting individual.

Level 1 Damage. Minor damage that is considered inconsequential to the safe operation of the tank.

Level 2 Damage. Damage which is more severe than level 1 damage. This level of damage is rejectable. Additional evaluation and/or rework may allow the tank to be returned to service.

Level 3 Damage. Damage which is sufficiently severe that it is not repairable and renders a tank unfit for continued service. Tanks with level 3 damage must be condemned and destroyed.

Liner. An internal component of the tank that serves as a permeation barrier, preventing leakage of gas through the composite tank structure.

Manufacturer's Label(s). The label(s) containing the official markings required by the U.S. DOT, FMVSS304, ANSI/CSA NGV2, ISO 11439, CSA B51-Part 2 (Canada), and/ or other national standards as may apply. The label markings shall include a "CNG Only" designation, manufacturer's symbol or trademark, manufacturer's model number, type designation, serial number, month and year of manufacture, service pressure, the inspector's symbol or trademark and the date when the service life of the tank will expire.

4.0 Description of Terms Cont.

Maximum Fill Pressure. The fill pressure allowed to obtain the settled Service Pressure at 70º F (21º C). For all tanks, maximum fill pressure under ANSI/ CSA NGV2 is 125% of the rated Service Pressure.

Mounting Bolts. These are the bolts that secure the mounting bracket bases to the frame of a vehicle.

Mounting Brackets. The devices used to secure fuel tanks in a vehicle. The brackets are specially designed to restrain composite tanks without causing damage and to accommodate tank growth caused by changes in internal pressure. The mounting brackets include: bases, straps, strap bolts, and related hardware.

NGV. Natural Gas Vehicle.

Ports (Also see **"Bosses"**). Openings at the boss of the tank in which valves, pressure relief devices, blank plugs, or other hardware is installed.

PRD Supports. Vertical frame supports for Tank Packs attaching the mounting blocks to support the pressure lines.

Pressure Relief Device (PRD). A device installed in direct contact with internal pressure in the tank that will release the contained gas in specific emergency conditions. Excessive temperature, excessive internal pressure, or both may activate the device depending on the PRD design. Thermally activated pressure relief devices are required in all installations.

Rail Cleat. Bottom frame members on a tank pack to which tank bracket Clips are attached.

Registered Inspector. An individual who has completed the General Dynamics NGV Fuel Tank Training class and is registered with General Dynamics with a certificate in response to passing the training class exam. A registered inspector will have received proper training and a registered stamp that will allow inspections on General Dynamics' fuel tanks.

Rejected Tank. A tank that must be removed from service and evaluated further before final disposition.

Resin. Epoxy material in the composite overwrap which fills the space and transfers the load between individual reinforcing fibers.

Service Life. Specified number of years from the date of manufacture that the tank may be used. The expiration date for a specific tank is printed on the manufacturer's label. A fuel tank is to be destroyed at the end of its service life.

Service Pressure. The settled pressure at a uniform gas temperature of 70º F (21º C) and full gas content. Also referred to as nominal, operating, or working pressure.

Skirts. A fiberglass structure that runs the length of the tank pack (both sides) and fastens to the skirt brackets if so equipped. Skirts cover the gap between the bottom of the tank pack and the roof top.

Solid Plug (Also see **"Blank Plug"**). A threaded plug with o-ring seal used to block tank ports not occupied by a valve or pressure relief device.

Strap. The part of the bracket assembly that connects with the base or clips and wraps around the tank to hold the tank to the frame or base.

Strap Bolt. The bolt that secures the straps to the tank.

Tangent Area. The area of the tank where the cylinder section meets the dome section of the tank.

Tank Pack. A general description to apply to all multiple tank systems contained within a frame that include the related pressure and vent lines assemblies.

Tap Test. An inspection technique in which the surface of a General Dynamics tank is tapped with a small solid object, such as a "Coin", to detect delaminations. A delaminated area will emit a different sound than an area that is not damaged. This inspection can only be performed on the cylinder region of a TUFFSHELL™ tank and not in the domes.

Thermal Trigger. The thermal trigger is the portion of a thermally activated pressure relief device that is actuated by excessive heat input and activates the relief device.

Transition Bracket. An attachment bracket used to interface between the tank pack and the vehicle frame.

Valve, Manual. A device installed in one of the ports of the tank that is used to open or close off the gas flow into or out of the tank. The valve is turned on or off manually with a handle.

Valve, Solenoid. A device installed in one of the tank ports that is used to open or close off gas flow into or out of the tank. The valve is turned on or off electrically. The valve can be closed manually, if necessary with special tools following a defined procedure.

Vent Line. A high-pressure line used to conduct gas from a pressure relief device to a location outside of the vehicle where gas may be safely discharged. Vent lines are required where pressure-carrying components are installed in a closed compartment.

Vent Enclosure. A low-pressure, gas-tight enclosure used to collect and conduct gas that may permeate through o-rings or leak from plumbing connections to a location where gas may be safely discharged outside the vehicle. The enclosure typically made of low-density polyethylene encloses the neck of the boss port on the valve, plug, and all CNG fittings. The vent enclosure must not interfere with heating or operation of the PRD. This vent system is required for installations where the tank is installed in a closed compartment.

TUFFSHELL™ NGV FUEL TANKS

5.0 General Design Information

General Dynamics' all-composite TUFFSHELL™ NGV fuel tanks are used to store compressed natural gas in natural gas fueled vehicles. Tanks may also be used to store compressed hydrogen if labeled appropriately. They are designed and qualified to DOT FMVSS 304, ANSI/CSA NGV2 Canadian CSA B51-Part 2, METI/KHK, NFPA 52, and the requirements for a Type 4 NGV2 fuel tank. A Type 4 NGV2 fuel tank is defined as "Resin impregnated continuous filament with a non-metallic liner".

TUFFSHELL™ fuel tanks are compliant with and can be certified to ISO 11439 or other national or international standards. From this point on all the standards aforementioned will be referred to as "applicable standards."

General Dynamics' compressed natural gas fuel tanks are constructed with a high-density polyethylene (HDPE) liner, aluminum bosses, and a high strength composite wall consisting of carbon and fiberglass reinforcements in an epoxy resin. General Dynamics' TUFFSHELL™ NGV Fuel Tanks are illustrated in Figure 5-1.

All General Dynamics Lincoln Operations NGV fuel tanks manufactured during or after December 1993 include the patented TUFFSHELL™ feature (see Figure 5-2) to maximize resistance to damage inducing events.

These features include: a damage resistant outer layer, impact resistant, energy absorbing materials in the dome regions, and an external coating to minimize the effect of the environment and exposure to sunlight. TUFFSHELL™ does not eliminate, but significantly reduces, the possibility of a serious accident caused by mishaps during installation, use and/or maintenance of the composite tank. Periodic inspection is an important part of the maintenance requirements for safe operation of a TUFFSHELL™ NGV fuel tank. Safe operation of a composite fuel tank is also dependent on proper installation and use of safety devices.

Figure 5-1 NGV Fuel Tank

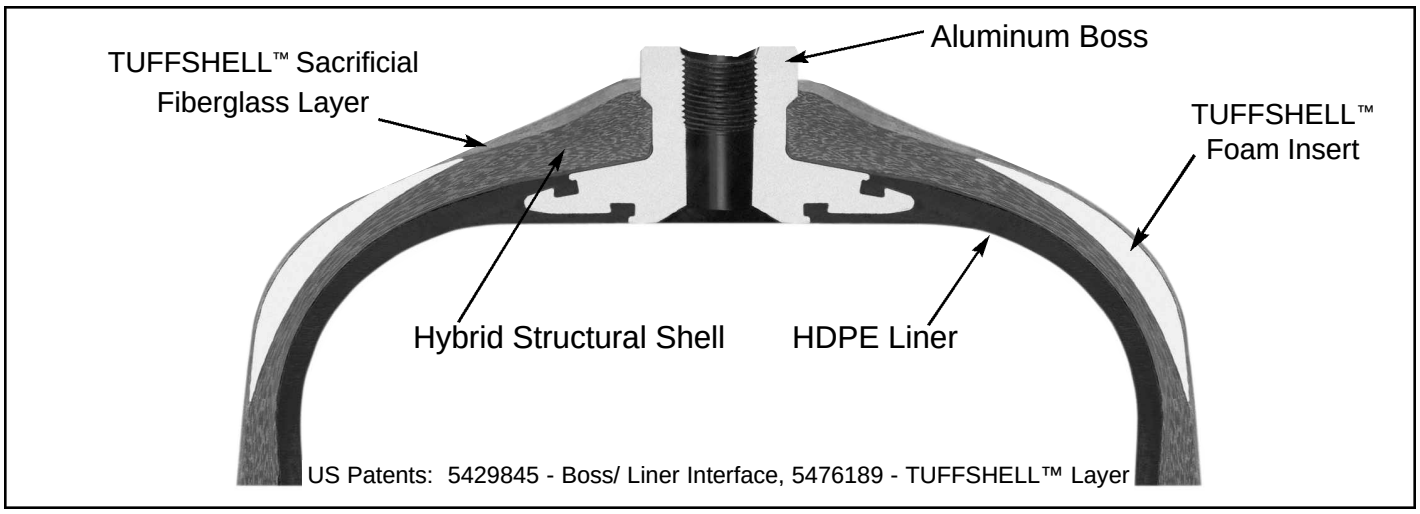


Figure 5-2 TUFFSHELL™ Tank Cut-Away

6.0 Inspection Procedures

6.1 When Tanks Should Be Inspected

A trained inspector should inspect tanks at maximum intervals of 36 months. Each tank must have permanent labels in accordance with the applicable regulations. These labels give valuable information to the inspector and the manufacturer. General Dynamics' labels are illustrated in Figure 6-1.

The tank should also be inspected promptly if:

1. The fuel tank, or vehicle in which it is installed, is involved in a fire, subjected to impact, exposed to excessive heat or believed to have been potentially damaged by any means.

   Note: Tanks that have been involved in an incident which may have the potential of Level 2 or Level 3 damage (reference Figure 6-11 for definition of damage levels) should be depressurized prior to inspection.

2. The fuel tank exhibits any unusual behavior. Unusual behavior may include, but is not limited to, emission of natural gas odor, unexpected loss of gas pressure, rattling or other indications of looseness or unusual snapping or hissing sounds.
3. The fuel tank is transferred to another vehicle or the tank installation is altered significantly.

   Note: Failure to perform inspections on a regular basis, or promptly in the case of a potentially damaging incident or unusual behavior, may result in a serious accident causing severe damage and injury.

The tank owner/vehicle operator should be questioned regarding any known conditions or incidents that may have caused damage to the tank. These include, but are not limited to, dropping the tank, impacts to the tank, exposure to excessive heat or fire, vehicle accidents, and exposure to harsh chemicals. The tank owner/ vehicle operator should also be questioned regarding any unusual observations regarding the tank, service history of the tank and any repairs that may have been made since its last inspection.

Important Note: Venting Procedure Before depressurizing the tank, ground the venting orifice with a 3-gage wire minimum to an appropriate ground source at least 8 feet (2.44 Meters) in the ground. Rapid discharge can generate a static electrical charge, which may be sufficient to ignite the escaping gas. When venting the tank, it must be in a well ventilated area free of ignition and heat sources. Do not vent the tank in an area where the flammable gas may accumulate and ignite.

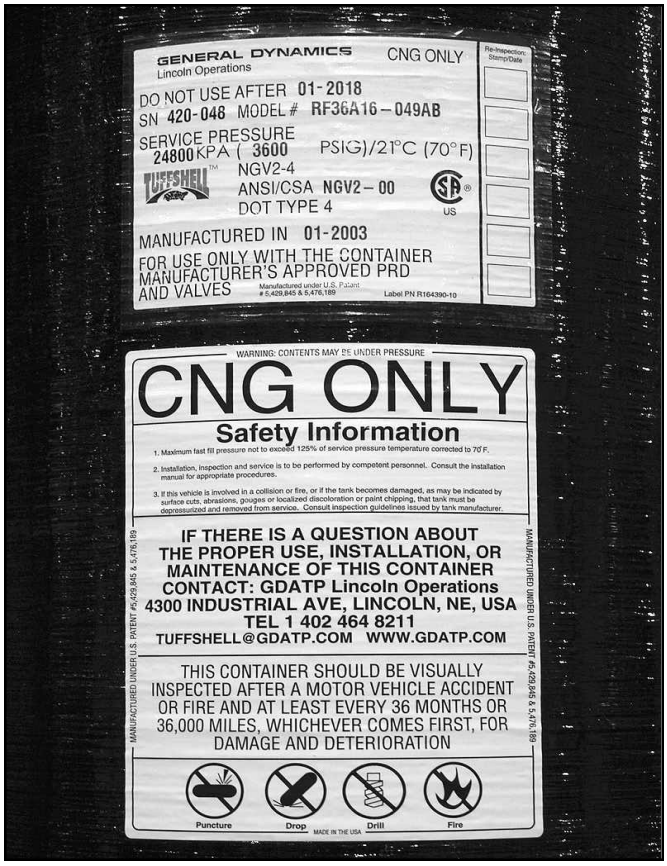


Figure 6-1 Typical Label Configuration

6.2 Preparation for Inspection

The surface of the tank should be clean and free of dirt or other debris that impedes the ability to clearly determine the condition of the external surface of the tank. Remove shields or covers, where possible, to ensure maximum access to the tank surface area for inspection. It is not necessary to remove the tank from the vehicle if it is possible to determine that the vehicle protects visually inaccessible surfaces, and that there is little potential for damage to the inaccessible surfaces.

The following tools identified in Figure 6-2 should be available in order to perform a comprehensive inspection.

Inspection Tools:

Mirror with extending handle
Measuring Device, 6 inch (15.24 cm) scale,
10 foot (3 Meter) tape measure
Liquid Leak Detector and plain water to rinse the leak detector solution from fittings and hardware
A small metal object for tap testing (A large “Coin” works best)
Cloth Rags
Flashlight/Drop Light,
Depth Gage

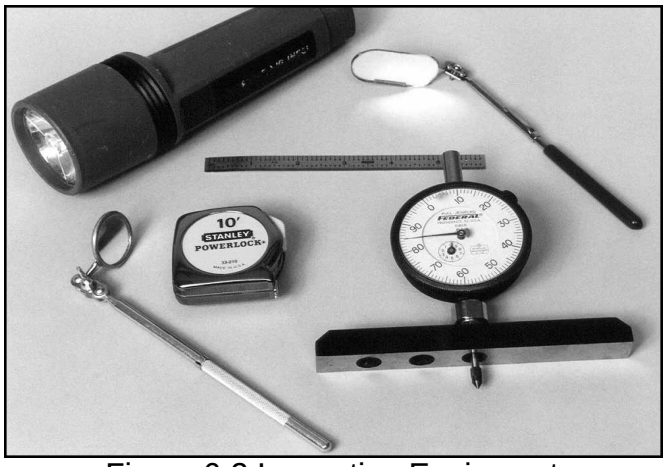


Figure 6-2 Inspection Equipment

6.3 General Installation Inspection

The initial inspection should include examination of the general fuel tank installation. This inspection should include:

1. A record of the inspection (by tank serial number) should be generated or up-dated if any inspection is performed on a tank or tank hardware. For an example of an inspection record, reference the inspection form in the back of this manual in Appendix II.
2. Determine that the installation is compliant with applicable regulations.
3. Verify that the fuel tank is being used only for the storage of compressed natural gas or hydrogen.
4. Verify that "General Dynamics Lincoln Operations" manufactured the tank to be inspected (See note below for additional information on additional tanks that apply to these guidelines). The guidelines in this manual were formulated specifically for the General Dynamics Type 4 tank, and may not be appropriate for tanks from other manufacturers. Verify that the service pressure and tank serial number are clearly legible on the tank label. The tank must be destroyed if the identity (i.e. model/part number and serial number) cannot be clearly established. Contact General Dynamics NGV Customer Service for label replacement if the label is damaged or not firmly attached.

   Note: This manual and instructions also apply to tanks manufactured by Lincoln Composites and Brunswick.

   Note: For tanks manufactured after July of 1999: If the label is missing or damaged, the serial number of the tank is etched on one of the bosses, and a replacement label can be supplied.
5. Verify that the tank service life has not expired. The label will identify the service life as "Do not use after xx-xxxx." The tank must be removed from service and destroyed when the service life expires.
6. Verify that the service pressure rating listed on the tank label is greater than or equal to vehicle markings for service pressure.
7. Determine potential for damage due to location in vehicle. Damage to a tank could result from shifts of cargo, proximity to the exhaust system, or road debris.
8. Verify that the surface of the tank is not in contact or close proximity to objects that could cut, gouge, or abrade the surface of the tank. This includes shields, cables, tubing, vehicle components, or mounting bracket components. A minimum of 1/2-inch (127 mm) clearance completely around the tank is recommended. Additional clearance may be required in areas where the vehicle can flex during operation. An 8 inch (20.32 cm) minimum ground clearance is recommended for under vehicle installations.
9. Verify that installations in which tanks are enclosed in a vehicle are vented externally to the vehicle. The vent line from the pressure relief device (PRD) should be a high-pressure line, which is adequately secured to the vehicle (every 12 inches [30.48 cm] for lengths of tube over 24 inches [60.96 cm] long) to prevent whipping in the event of PRD activation. The vent line exit should be free of debris and be oriented in such a manner that the vent line will not trap fluids.
   A lightweight cap that can easily be expelled by pressure in the vent line may be used to prevent accumulation of debris in the vent line. A vent line cap must not inhibit gas flow from escaping should the system vent. Verify the presence of a vent enclosure.
10. Verify that lines connected to the tank are installed in a manner to prevent damage to the plumbing when the vehicle flexes or the tank expands under pressurization.

6.4 Mounting Bracket Inspection

It is not normally necessary to remove the tanks from the mounting brackets for this inspection. If the mounting bracket has areas of surface rust use the following guidelines for repair.

1. For areas up to 0.125 inches in diameter (3.18 millimeters), it is acceptable to have a pit 1/2 the thickness of the metal thickness.
2. If surface rust is over a larger area than 0.125 inches (3.18 millimeters) of the bracket then the depth of the surface rust can not exceed over 0.035 inches (0.89 millimeters) in depth.

If the area of rust meets the above two criteria then it is acceptable to sand the bracket in place (if possible), removing all traces of rust. Paint the repaired area with high quality rust inhibiting epoxy paint.

Be sure to record any repaired damage on the tank inspection record (Appendix II).

If a tank is removed, be sure the mounting bolts are re-torqued according to the values in Figure 6-4. New rubber pads should be installed if the rubber pad has been permanently deformed (see Figure 6-5) and/or if the rubber is damaged from wear that may have occurred during the life of the installation. Replacement rubber pads are available from:

General Dynamics Customer Service
800 279 TANK (8265) or 402 464 8211.

If the strap bolts are loosened or removed and the rubber pads are not inspected or replaced, then the torque values listed in Figure 6-4 will not be correct to properly secure the tank. Do not install the tank pressurized, as the recommended torque in Figure 6-4 will not be sufficient to hold the tank in place when depressurized.

The nuts used in the mounting hardware are equipped with a self-locking feature. This makes it necessary to replace them when the tank is removed. The tank must be mounted in a manner that adequately restrains it but does not induce damage. Because the tank expands and contracts as the internal pressure increases or decreases, the tank's diameter and length will vary.

Note: A good rule to follow for tank expansion is 0.006 inches times the length dimension for linear growth or the diameter expansion at service pressure. A tank that is at 3600 psi and is 15.7 inch diameter will grow 0.094 inch diameter. If the tank is 120 inches long then this tank at service pressure will increase in length by 0.72 inches.

The tank mounting system must be able to accommodate this movement without inducing excessive loads to the bracket or causing abrasion to the tank. General Dynamics offers mounting brackets specifically designed for use with General Dynamics' tanks. Use of other brackets may result in bracket damage or improper restraint of the tank, either of which could result in a hazardous situation.

Mounting Bracket Inspection Must Include:

1. Verification that the tank is firmly restrained. The centerline of the mounting straps should be located a minimum of two-thirds of the tank diameter inboard from the boss face and a maximum of one-third the total tank length inboard from the boss face (see Figure 6-3). All dimensions are to be relative to the boss closest to the tank end in question. The tank and mounting brackets should be firmly attached to the vehicle. The tank must not be allowed to rock, shift, or show any evidence of instability.

If a tank is loose within the brackets, then the tank must be vented and removed from the vehicle, and a visual inspection of the tank and the brackets must be initiated and recorded. Rubber pad inspection must also be included (Figure 6-5).

NOTE: Do not verify the torque of the strap bolts. The rubber pad located between the tank and the bracket is designed to compress during tank expansion. Proper torque of the strap bolts can only be accomplished during initial installation. After the rubber pads are in use, the rubber will take a set, which will reduce the torque value originally applied to the strap bolt. This change in the rubber pad will not affect the proper restraint of the tank.

2. Verification of the bolts, which secure the brackets to the vehicle, are present and tight. Brackets bolted to sheet metal panels should use large washers (3 inches [7.62 cm] outside diameter minimum) to prevent pull-through of the bolts. With the split strap style brackets, a large washer (3 inches [7.62 cm]) must be used between the bolt and mounting brackets to prevent the bolt from pulling through the slot in the base of the mounting bracket.
3. Verification of the rubber pads are in place and centered on the brackets. Replacement pads, if required, may be obtained from General Dynamics.
4. Verification of the brackets are in good condition and suitable for continued service. Hardware bolts or vehicle attachment points exhibiting severe corrosion or cracking in the mounting region should be repaired or replaced.

Note: General Dynamics Customer Service may be contacted for specific bracket kit mounting instructions. General Dynamics brackets may be mounted in any orientation. Tank expansion must be a consideration for proper bracket location. See note for tank expansion section 6.4, Mounting Bracket Inspection.

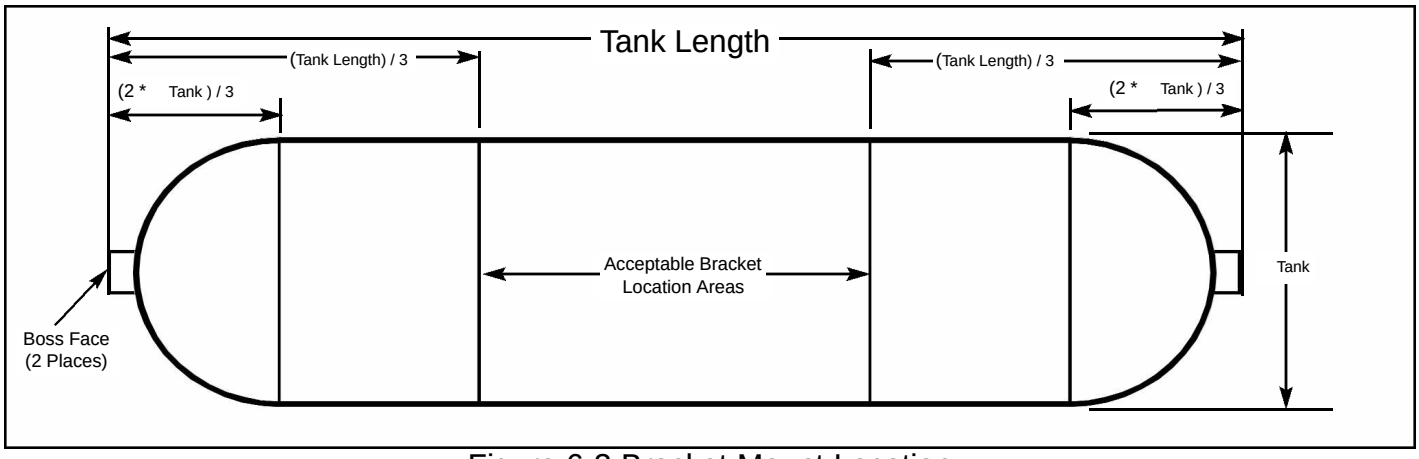


Figure 6-3 Bracket Mount Location

Thread Size		Detail
1/8-27 NPTF	2-3 Turns from finger tight	Adapter Port
1/4-18 NPTF	2-3 Turns from finger tight	Manual Valve Outlet

Thread Size	Torque ft-lbs	Torque Nm	Detail
7/16-20 UNF	15-20	20-27	Manual Valve Fuel Outlet
1/2-13 UNC	70-80	94-108	Bracket Base Mounting Bolt
1/2-13 UNC	40-50	54-68	Strap Bolt and Clip Carriage Nut
9/16-18 UNF	20-30	27-41	Solenoid Valve Outlet, Female SAE
0.650-19 UNS	39-42	53-57	Manual Valve Outlet, Male, PRD
3/4-16 UNF	35-45	47-61	Solenoid Valve Outlet, Female SAE
1-1/16-12 UN	90-110	122-149	Green Boss Port, Female, SAE
1-1/8-12 UN	100-120	136-163	Black Boss Port, Female, SAE "Special"
1-3/16-12 UN	110-130	149-176	Blue Boss Port, Female, SAE
2.0-12 UN	200-220	271-298	Black Boss Port, Female, SAE "Special"

Figure 6-4 Torque Values

Rubber pad in good condition

Rubber pad in need of replacement

Figure 6-5 Rubber Set Example

6.5 Valve, Solid Plug, and PRD Inspection

Each fuel tank must be protected by at least one quick response thermally activated pressure relief device (PRD) approved by General Dynamics for use with its tanks (see Figure 6-6). This device may be installed on the tank valve or may be installed in the port opposite that occupied by the tank valve. The PRD may also be installed in a manifold assembly that is connected directly to the tank's internal pressure. If the tank is greater than 65 inches (1651 mm) in length, multiple PRDs are usually required.

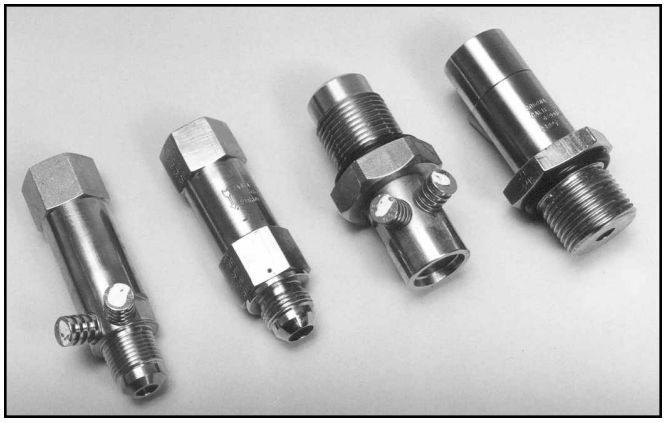


Figure 6-6 Pressure Relief Devices (PRD)

Use of multiple PRDs is also required in installations where it is possible for the tank, but not a single PRD, to be exposed to elevated temperatures. All PRDs must be connected to the tank or tank valve in a manner that ensures that the PRD can vent the contents of the tank regardless of whether the tank valve is in the closed or open position.

Note: Only quick response PRDs approved by General Dynamics are to be used with TUFFSHELL™ NGV fuel tanks manufactured by General Dynamics. Customer Service may be contacted for specific information concerning approved PRDs.

Each fuel tank must use either a manual or solenoid (electronically activated) shut off valve. The valve controls the flow of gas into and out of the tank (see Figure 6-7 for examples).

Note: The PRD may be contained within the valve body.

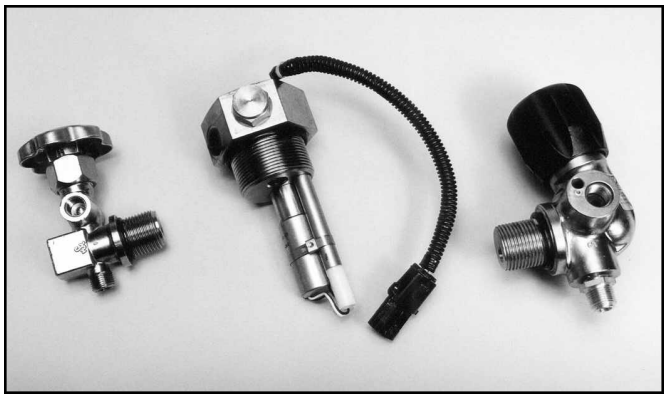


Figure 6- 7 Valves

The vent enclosure may need to be removed from the hardware at the ends of the tank for inspection of the valve and plug/PRD. This inspection includes the following:

1. Examination of the valve and PRD assemblies for damage. The valve and PRD assemblies should not be deformed or show other signs of damage. Damaged valves and PRD assemblies must be replaced. The tanks must also be examined for impact damage (see section 6.6.3 Impact Damage).
2. Examination of the interfaces between the valve and tank port and the solid plug/PRD plug and tank port. These interfaces should be tightly seated with no gaps or evidence of being loose. Inspect for displacement of, or cracks in, the orange torque seal which indicates looseness. There should also be no rubber shavings or other evidence of o-ring seal damage at these interfaces. If there is evidence of looseness or seal damage, the tank should be depressurized (see Important Note for Venting Procedure section 6.1) and the suspicious area disassembled and checked. The o-ring seal should be replaced with the appropriate replacement seal (contact General Dynamics NGV Customer Service, Section 2.0). The o-ring should be coated lightly with General Dynamics recommended lubricant and the valve, solid plug, or PRD plug re-installed and torqued. The proper torque values are identified in Figure 6-4.
3. Leak testing the interfaces between the valve and tank port and between the plug/PRD and tank port. The fuel line and PRD connections to the tank valve should also be checked for leakage. These interfaces should be serviced if any leakage is observed. Utilize an electronic leak detector or a leak solution to perform this test.

4. For PRDs equipped with external thermal triggers (see Figure 6-8), examine triggers for partial actuation. If the trigger has been partially actuated, there is an extrusion of the eutectic on the top of the trigger through the white marking. This may be evidence that the tank has been subjected to extreme temperatures.

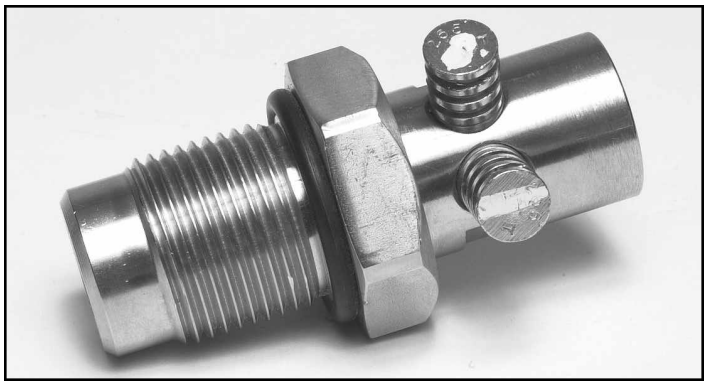


Figure 6-8 Pressure Relief Device (PRD)

If there is evidence of partial actuation, depressurize the tank immediately and remove the tank from service. Inspect the composite surface of the tank for excessive heat damage (See section 6.6.4 Fire and Excessive Heat Damage). If the tank inspection shows no sign of heat damage as specified in section 6.6.4 of this manual, then the tank is acceptable to be returned to service after the PRD is replaced.

5. Vent lines must also be inspected to assure proper performance during a fire. Verify that there is no damage to the vent lines and that no debris is blocking the outlet. Remove the vent line from the PRD once a year to drain water that may accumulate in the vent line system.

Note: When removing the vent line from the PRD, be careful not to loosen the PRD from the pressure side of the system.

Tools required for the purpose of removing and replacing hardware (see Figure 6-9).

Torque Wrench capable of 210 ft-pounds (285 Nm)
Ratchet
O-ring Lube (Available from General Dynamics Customer Service, part number R13082 5.3 oz.)
Special Sockets may be required to remove or install certain valves
3/4 inch Crow's Foot
1 inch Crow's Foot
Open End Wrench set from 7/16 inch -1inch
Grounding Straps (3-gage minimum), Cables and an appropriate grounding source

Figure 6-9 Hardware Tool List

6.6 Composite Tank Inspection

The composite fuel tank may be damaged without showing significant damage on the surface. Therefore, this inspection must be performed carefully. Since the inspection depends primarily on visual observation, the surface of the tank should be accessible, clean and well illuminated. Removal of paint or fiber for visual inspection is not permitted unless to determine accurate damage depth. However, an area of damage may require small amounts of material to be removed for an accurate evaluation of the damage.

The tank inspection consists of four primary elements.

1. Tank Service History- The inspector should review inspection/service records for the tank prior to inspection. Knowledge of the service history and interviews of the vehicle owner/ operator may provide insight that will aid the inspection process (section 6.3).
2. Visual Examination- Visual examination of the composite tank surface is the primary means of detecting tank damage. Evidence of potential damage includes cuts, scuffs, scratches, surface distortions, material removal, discoloration of the tank surface, and deterioration of the surface. If visual examination reveals damage, the area of damage must be carefully measured for depth using the gauge shown in Figure 6-10.

Figure 6-10 Inspection of Damage Depth

Note: The tap test should only be performed in the cylinder area of the tank where damage is suspected. The energy absorbing features of the dome (end) areas of the tank make it extremely difficult to detect delaminations. False indications may be heard if the test is performed in the dome areas.

4. Factory Inspection- Tanks which are known or suspected to have been subjected to a potentially damaging incident, or which exhibit evidence of damage not specifically identified as acceptable by these guidelines, should be removed and may be sent to General Dynamics for more extensive evaluation. Arrangements for factory inspection/services may be made by contacting General Dynamics NGV Customer Service (see section 2.0).

6.6.1 Damage Identification and Categorization

Any damage to the tank, bosses or attached hardware should be inspected and the level of damage should be determined before the tank is placed back into service. A record of the inspection (by tank serial number and location on the vehicle) should be generated or up-dated when any inspection is performed on a tank or tank hardware. For an example of a blank inspection record, refer to the inspection record in the back of this manual (Appendix II).

Damage to the composite surface can be categorized into five main types.

1. Cut, scratch and abrasion damage (see section 6.6.2)
2. Impact damage (see section 6.6.3)
3. Fire and excessive heat damage (see section 6.6.4)
4. Chemical damage (see section 6.6.6)
5. Weathering damage (see section 6.6.7)

The depth of the area determines the damage level assigned to the composite fibers in question. Accurate depth measurement of damage requires removing all loose fibers associated with the damage. Once the loose fibers are removed, the damage level can be determined per Figure 6-11. See Figure 6-12 for an example of inspecting damage depth.

Note: Before any rework to the tank and/or related hardware, the tank must be vented of all pressure (see important note in section 6.1).

Disposition of damage is defined in four categories:

Level 1 - Minor damage that is considered inconsequential to the safe operation of the tank (see Figure 6-12).

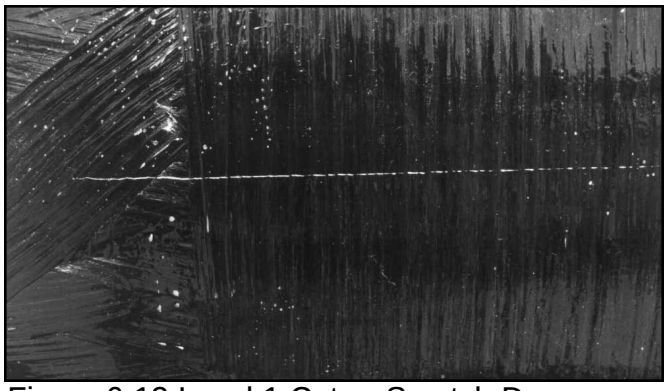


Figure 6-12 Level 1 Cut or Scratch Damage

Level 2a - Loose fibers may be removed and edges of a cut or gouge may be tapered by hand filing or sanding. Paint area with polyurethane paint (see Figure 6-13).

Figure 6-13 Level 2a Loose Fiber Damage (Customer Rework)

Damage Levels

Damage Levels (Rework Types)	Scratch, Gouge and Abrasion Depth Figure(s)	Inches	Millimeters
Level 1	6-12	0 ≤ 0.010	0 ≤ 0.25
Level 2a (Rework in the Field)	6-13	0.011 ≤ 0.035	0.26 ≤ 0.89
Level 2b (Factory Inspection)	6-14	0.036 ≤ 0.050	0.90 ≤ 1.27
Level 3 (Condemn)	6-15 6-16	Greater than 0.05	Greater than 1.27

Figure 6-11 Damage Levels

Level 2b - Remove tank from service and contact General Dynamics' Customer Service for factory inspection. Tank will be evaluated by engineering for possible rework procedures (see Figure 6-14).

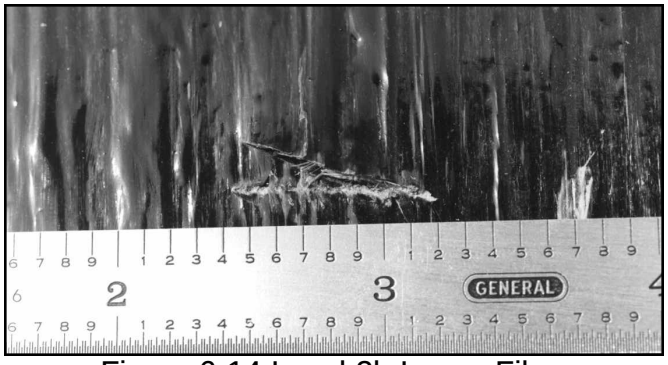


Figure 6-14 Level 2b Loose Fiber From Gouge Damage

Level 3 - Tank is to be removed from service and condemned (see Figures 6-15 and 6-16).

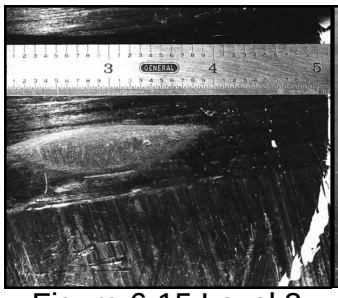


Figure 6-15 Level 3 Abrasion Damage (Condemn)

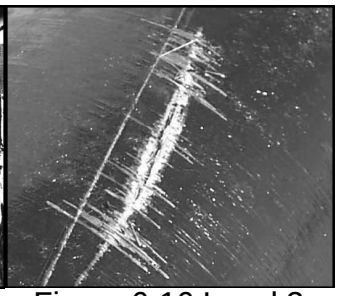


Figure 6-16 Level 3 Impact Damage Gouge (Condemn)

Note: If level 3 damage is restricted to the dome regions of the tank, contact General Dynamics Customer Service before condemning.

6.6.2 Cut, Scratch, and Abrasion Damage

Cut damage will cause deeper fiber breaks than scratch damage. This type of damage is more difficult to measure because of the loose fibers in the damaged area. Scratches in the composite surface result in surface fiber damage. Scratches will typically be less than 0.010 inches (0.25 mm) in depth and cause only minor fiber breaks.

Abrasion damage may be the result of many cycles of an object rubbing lightly on the surface of the tank or due to a few cycles under high load. Surfaces subjected to abrasion under light loading will tend to be smooth and somewhat polished in appearance. Surfaces abraded under high loads will tend to appear as a group of parallel gouges or cuts as opposed to a polished surface. Tanks exhibiting evidence of abrasion under high loads should also be examined as though the surface was subjected to impact damage (see section 6.6.3).

6.6.3 Impact Damage

General Dynamic's composite tanks are resistant to damage from impacts. Severe structural damage can be caused from impact and could pose a safety hazard if subjected to excessive localized loading. Impact damage may be incurred during shipping, handling or while in service. These impacts may be the result of dropping the tank prior to installation or due to in-service conditions such as a vehicle accident. Impact damage differs from other forms of tank damage in that more severe damage may occur within the wall of the tank than at the surface of the tank. This is particularly true if the surface of the object impacting the tank is blunt and relatively smooth. The surface of a composite tank tends to return to its original shape after an impact and, therefore, typically does not dent like an all-metal tank. However, localized surface deformation can occur and may not exceed level 2a damage (Figure 6-11) to be acceptable for use.

Impact damage may cause delaminations and fractures to the composite layers of the tank. Surface damage associated with impact loads may include cutting, gouging, scraping, scuffing, chipping, punctures, fiber breakage, loose fibers, resin cracking or change in coloration or appearance. The surface must be carefully examined for these types of indications. Accurate depth measurement of damage requires removing all loose fibers associated with the damage. Once the loose fibers are removed, the damage level can be determined per Figure 6-11. Known areas of impact should be marked to aid in the inspection process.

Known areas of impact and zones of detectable surface damage must be inspected for evidence of damage within the wall. Evidence of damage within the wall includes:

1. Permanent deformation of the tank surface resembling denting of an all-metal tank is evidence of severe internal damage. Tanks exhibiting this type of damage should be investigated closely for level 3 damage.

   Note: This condition does not include highly localized imprinting at the surface that might result from events such as impact by a small stone.
2. Softness or deflection of the tank wall. The tank wall should be rigid and not easily deformable. Softness of the tank wall is evidence of severe internal damage.

Tanks exhibiting this condition have level 3 damage and are to be condemned and destroyed. If damage to the tank is localized to the dome areas only, this damage or softness of the dome wall may be repairable.

3. Damage to tank bosses. Impact to the ends of the tank, including the valves, plumbing, and pressure relief devices, should be investigated to ensure composite damage has not been sustained.
4. Localized areas of surface crazing. Tanks which incur impact damage may exhibit circular, oval, or linear zones of crazing of the composite surface. These zones may also be accompanied by a change in coloration. Each area exhibiting these types of indications should be subjected to the tap test. Questionable areas should also be subjected to factory inspection.

Note: Small random hairline cracks in the resin surface parallel to the reinforcing fibers are common in composite pressure tanks and are not a cause for concern. A group of cracks that are more closely spaced than generally observed on the tank and have a localized circular, oval, or linear pattern as described above are evidence of impact damage.

5. Differences in sound emitted by performance of a tap test in the potentially damaged area relative to the surrounding area. The tap test is a tool used to identify delaminations within the composite wall and should be performed only when the composite surface has been impacted. The tap test will not reveal delaminations from abrasion damage because abrasion damage will not delaminate underlying layers. The tap test is performed by tapping the surface of the composite with a quarter or similarly sized metal object grasped between the fingers. The tapping sound emitted by the surface should be compared in zones of potential damage relative to surrounding areas where damage is not suspected. The tap test must be confined to the cylinder portion of the tank. False indications may be heard if this is attempted in the dome (end) areas. Differences in sound are evidence of damage within the composite wall. Tanks exhibiting this type of damage must be removed from service. The tanks may be subjected to further field evaluation, factory inspection at General Dynamics, or be condemned and destroyed.

Note: Only a registered or experienced inspector should perform the tap test. Any uncertainties that result from these inspections shall be resolved by removing the tank from service and performance of a factory inspection.

Contact General Dynamics NGV Customer Service regarding questions arising during the inspection and to make arrangements for factory inspection services and return authorization if necessary.

6.6.4 Fire and Excessive Heat Damage

All NGV Fuel tanks manufactured under NGV2 or ISO 11439 have a maximum service temperature of 180°F (82.20°C). Excessive heating may occur if the tank is not properly located relative to an exhaust system or is involved in a fire. Evidence of heat damage is darkening, charring, or sooting of the surface in the area of exposure as shown in Figure 6-17. Severe exposure may result in resin removal and loose fibers. Other signs of heat damage are melting of the plastic on the labels and discoloration of the bosses. Tanks showing evidence of fire or excessive heat exposure are defined as having Level 3 damage and are to be removed from service, condemned and destroyed.

Figure 6-17 Level 3 Heat Damage
Discoloration and Resin Burnout (Condemn)

6.6.5 Gas Leakage

Tanks that exhibit apparent gas leakage must be removed from service. Contact General Dynamics NGV Customer Service to report the condition and obtain information regarding additional tank testing and disposition. Tanks with confirmed gas leaks are condemned and must be destroyed.

Note: Bubbles are typically observed on the composite surface for several hours after pressurization, particularly after the initial pressurization following installation, or if the tank is empty or nearly empty. The bubbles are caused by air trapped between the liner and composite being forced through the composite when the tank is pressurized and the liner expands.

6.6.6 Chemical Damage

The tank should be examined for evidence of chemical attack. The materials used in the construction of the tank are resistant to chemical agents encountered in the normal fuel tank environment. The tank, however, should be maintained in a clean state and should not be allowed to have prolonged exposure to moisture, automotive fluids or corrosive agents. The installation should drain freely and should not trap fluids or debris. Chemical damage of the composite will appear as alterations of the surface properties. This appearance includes discoloration, etching, blistering, swelling, softening, and resin removal. In extreme cases, the composite may exhibit fractures and broken or loose fibers. Minor discoloration and etching is defined as Level 1 damage and is considered acceptable provided the chemical has been removed and the tank surface cleaned.

Note: Any evidence of blistering, swelling, softening, resin removal, or fractures is Level 3 damage. The tank must be condemned, removed from service and destroyed.

6.6.7 Weathering Damage

The tank may exhibit degradation of the external coating after prolonged exposure to sunlight and weathering. This degradation may result in discoloration and/or flaking of the coating. This condition is Level 1 damage. The affected surface may be reworked after completion of the inspection process by hand filing or sanding. Paint the area with a polyurethane paint.

7.0 Non-Structural Anomalies

Frequently, tanks may exhibit superficial anomalies that have no effect on the structural quality of the tank.

Non-structural anomalies include the following:

1. Fiber gaps on the surface of the dome area. Fiber gaps do not include loose fiber that has separated from the surface of the composite (see Figure 7-1).
2. Resin and paint runs, which may appear as a hard circle or spot on the tank surface.

Figure 7-1 Fiber Gaps

3. Excessive resin on the composite surface.
4. Splices on the external TUFFSHELL™ wrap.

8.0 Tank Disposition

Tanks inspected in accordance with these guidelines will have one of four dispositions.

These are:

1. The tank has no damage or level 1 damage and is deemed acceptable. The tank may remain in service.
2. The tank has level 2a damage that may be reworked in the field and the tank can be returned to service.
3. The tank has level 2b damage that cannot be fully assessed in a field inspection and must be subjected to factory inspection.
4. The tank has level 3 damage and is condemned, removed from service and destroyed.

9.0 Tank Destruction

Before condemning a tank, the owner of the tank must be notified. Tanks that are condemned must be clearly marked as “CONDEMNED” at the time of inspection. The marking shall be affixed to the manufacturer's label and the duplicate manufacturer's label, if used.

To prevent unauthorized pressurization, the tank must be destroyed by drilling two or more holes one-half inch or greater in diameter completely through the tank wall and internal liner (see Figure 9-1).

Caution: Residual natural gas and/or air can be trapped between the liner and the composite after venting. Allow the vented tank (open to atmosphere) to sit for 8 hours to allow the trapped gas to escape before drilling the condemned tank. Reference note in section 6.6.5.

Note: The vessel will contain residual gas fumes after depressurization. Precautions should be taken to ensure that residual fumes are not ignited during destruction. Vent all pressure from the tank and displace residual fumes with compressed nitrogen. If compressed nitrogen is not available, flushing the tank with water will also displace residual fumes.

The following supplies should be available if condemning a tank:

Tank Condemn Tool List
Drill with 1/2 inch (1.27 cm) bit
Compressed nitrogen (see 9.0 Note) supply to remove as much natural gas as possible. If nitrogen is not available then flush the tank with water.

Figure 9-1 Container Condemn Tool List

TUFFSHELL™ Tank Packs

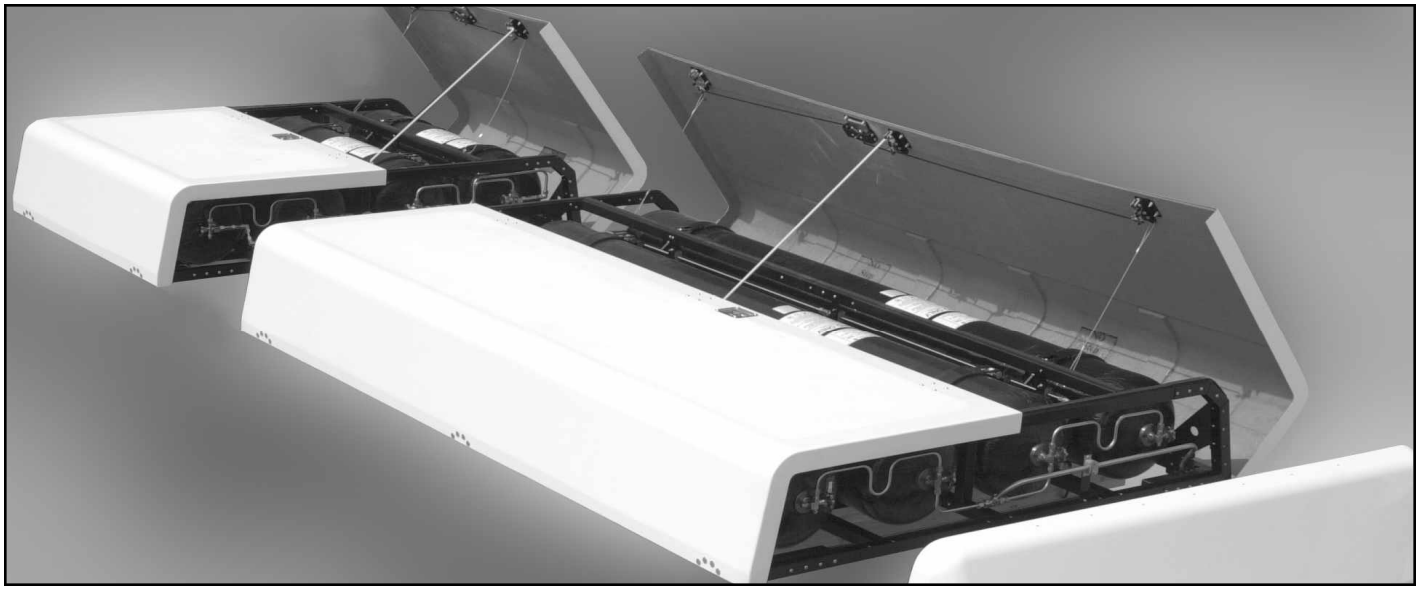


Figure 10-1 Roof Pack Assembly

10.0 Tank Pack Components

General Information

The following section applies to General Dynamics' standard line of tank packs. While some of the procedures and descriptions may apply to non-standard, custom designed tank packs, this document does not specifically apply to them.

Six main components to the General Dynamics tank pack are shown in Figure 10-1. These are:

1. Frame: Riveted steel construction with black powder coat finish and unitized mounting rail for vehicle integration
2. Tank Brackets: Steel construction with black powder coat finish. Mounting brackets, two (2) per tank.
3. Tanks: All-composite, NGV-2 Type 4 for 3000 psi (207 Bar) or 3600 psi (248 Bar) working pressure.
4. Valves: Manual or solenoid valves are available. One valve per cylinder.
5. Plumbing System: Type 300 stainless steel tubing supported with polyethylene bushings. Stainless steel compression fittings, flare fittings, SAE ports, and NPT fittings. The plumbing system includes a fill connection and vent lines.
6. Cover Set: Reinforced fiberglass doors with hardware, skirts, brackets, nose fairing, and support frame. Depending on the tank pack configuration, each door can have up to three (3) latches actuated with a single "T" handle.

Important Note: Doors are held open with a single prop rod at the center of each door. The prop rod inserts into the middle door latch to hold the door open safely. To close the door, the "T" handle will have to be turned to release the prop rod. The prop rod will have to be properly stowed by inserting it into the prop rod storage clip located on the frame rail.

10.1 Fitting Information

General Information

Specific information necessary for the assembly and replacement of compression fittings is available from the fitting manufacturer.

10.2 Frame Inspection

The metal frame is composed of many individual sections that are riveted or welded together. Inspection of the tank pack frame must include weld inspection, rivet inspection, and inspection for damage to metal frame sections.

1. Weld Inspection: Ensure that all welds (that are visually accessible) are not cracked or broken.
2. Rivet Inspection: Ensure that the rivet is holding the sections of the frame together and a loose condition does not exist.
3. Frame Inspection: Ensure that the frame is in good condition and has not been damaged. Areas that had the powder coat finish removed should be cleaned and sanded thoroughly and repainted with high quality rust inhibiting epoxy paint. Questions of specific damage to the frame should be directed to General Dynamics Customer Service.

11.0 Tank Removal From and Installation in Standard Roof Packs

Note: Insure tank pack assembly is vented of all fuel before loosening any fittings or brackets. See "Important Note" on venting in section 6.1.

11.1 Door Removal

1. Remove door cover on the same side as the tank to be removed.
2. Stand on the opposite side of door to be opened and pull the "T" handle out of the recess of the door (of door to be removed). Rotate the "T" handle to open the door. The door will swing away from where you are standing. With the door open remove the prop rod from its holder and engage the prop rod in the latch until the latch closes around the prop rod pin.
3. With the door open, locate the set screws on the inside of the hinges. The setscrews can only be accessed with the door open. Loosen the set screws enough to be able to remove the door hinge pin shown in Figure 11-1.

   NOTE: Do not remove the hinge pins at this time.

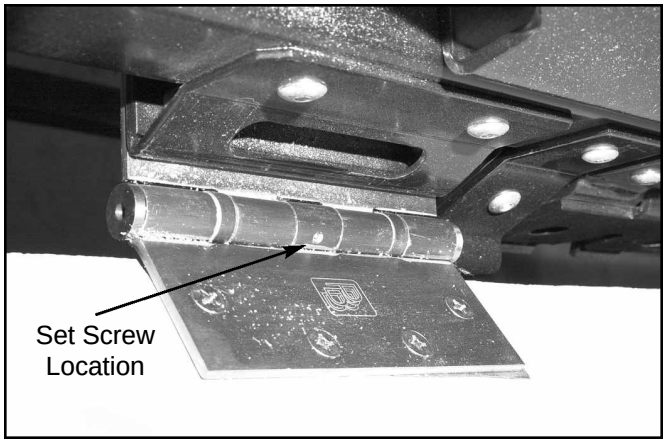


Figure 11-1 Set Screw Location

NOTE: If tank pack has skirts along the length of the tank pack, it may be necessary to remove the skirts to access the cover door hinges. To remove the skirt rivets, reference section 13.1 of this manual. Hinge pins can be accessed through the inside with the door covers open. If the hinge pins need to be removed with the cover doors open, then the door will have to be held in position while the pins are removed.

4. With the door open, use 2 each 7/16 inch wrenches to remove both eyebolts that attach door cables. Ensure that the door is restrained in such a position to allow for the slack in the cables before removing the eyebolts.
5. Close the door cover and latch into place.
6. With the door cover in the closed position, locate the door hinges at the bottom outside edge of the tank pack assembly. Remove the hinge pins by inserting a 0.1 inch (2.54 mm) punch into the hinge pin opening. With a 16 oz. hammer, pound the pin out the opposite side of the hinge. Repeat this step to remove all hinge pins for each door. Reference Figure 11-2 for the correct location to place the end of the center punch to remove (drive out) the hinge pin.
7. Stand on the opposite side of the door to be opened and the pull "T" handle out of the recess of the door (of door to be removed) and rotate the "T" handle to the left to disengage the latches.
8. The door cover is ready to be removed from frame.

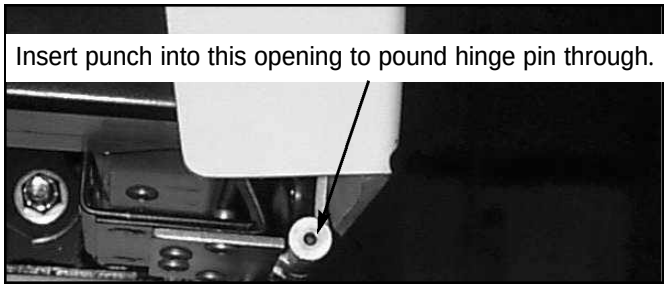


Figure 11-2
Hinge Pin Location for Punch

9. Remove the door cover and place it where it will not be disturbed.

11.2 Outer Tank Removal

1. Loosen fitting nuts "A" and "B" (reference Figure 11-3). After nuts are loose, slide the nuts away from the fitting on the vent line.

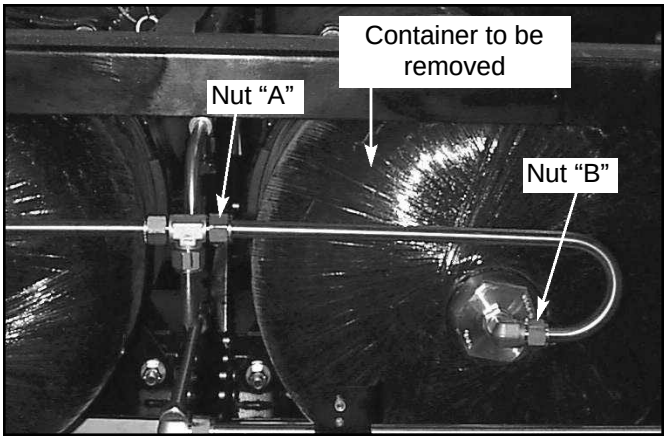


Figure 11-3 Vent Line Removal

2. The connecting vent line may now be removed by pulling the tube assembly away from the center of the tank pack assembly. Once the tube assembly has been removed, place the assemblies on a clean surface for re-use during installation.
3. On the valve end, loosen both nuts “C” (reference Figure 11-4). After the nuts are loose, slide the nuts away the from fittings.

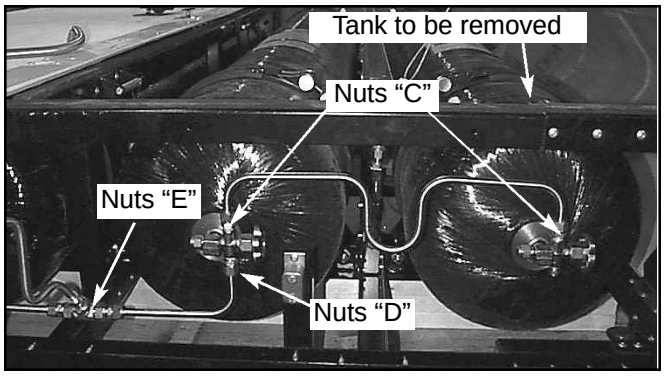


Figure 11-4 Fuel Line Removal

4. The connecting fuel line may now be removed by pulling the tube assembly up and away from the fittings. Once the tube assembly has been removed, place the assemblies on a clean surface for re-use during installation.
5. Remove the 1/2" Nylok nuts from carriage bolts (Figure 11-5) (4 ea. per tank) attaching the clips to the tank pack frame assembly. These Nylok nuts should be replaced when removed.

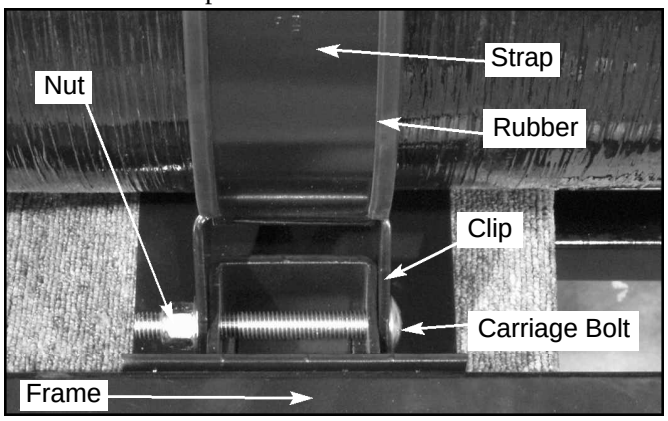


Figure 11-5 Clip to Frame Carriage Bolt

6. Attach a nylon lifting sling to the center of the tank to remove and lift most of the weight of the tank so as to remove the carriage bolts (Figure 11- 5) that attach the clips to the tank pack frame. Place bolts on a clean surface for re-use during installation. The tank is ready to be removed from the tank pack by lifting the tank up and out of the tank pack frame.
7. Loosen and remove both strap bolts (Figure 11-6) if required. After removal, the rockers and bolts should be placed on a clean surface for re-use during installation. The 1/2" Nylok nuts should be replaced after removal.

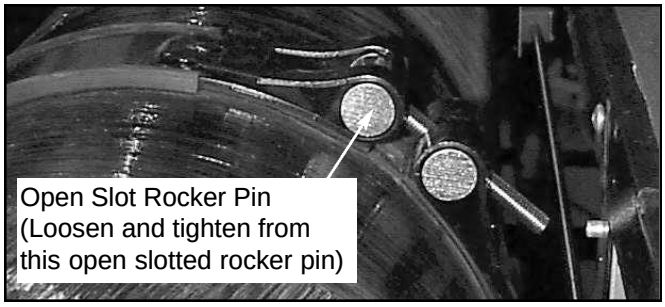


Figure 11-6 Strap Bolt Removal

Note: Rotation of the tank within the straps may be necessary if it becomes necessary to remove and replace a valve from the tank. The new valve orientation to the fuel lines will probably not line up for re-assembly without rotating the tank within the straps.

8. While the tank is removed, perform a visual inspection of the entire surface of the tank per section 6.6 of this manual. Record inspection results on the vehicle log or the individual tank inspection log.
9. Inspect and re-paint the mounting brackets as required per section 6.4 of this manual.
10. Inspect and replace strap rubber as required per section 6.4 of this manual.

11.3 Inner Tank Removal

1. If the inner tank is to be removed, loosen the fittings, nuts “A” and “B” on the vent line on the inner tank (reference Figure 11-3). After the nuts are loose, slide the nuts away from the fittings.
2. The connecting vent line may now be removed by pulling the tube assembly toward the center of the tank pack assembly. Once the tube assembly has been removed, place the assemblies on a clean surface for re-use during installation.
3. Loosen both nuts “C” (reference Figure 11-4). After the nuts are loose, slide the nuts away from the fitting. Loosen the 3/4" fill line. Loosen nuts D and E. Drop the lower 1/2" lines down.
4. The connecting fuel line may now be removed by pulling the tube assembly away from the fittings. Once the tube assembly has been removed, place the assemblies on a clean surface for re-use during installation.
5. Loosen nuts “D” and “E” (reference Figure 11-4). After the nuts are loose, slide the nuts away from the fittings.
6. Remove the nuts from the carriage bolts (4 ea. per tank) attaching the clips to the tank pack frame assembly. The Nylok nuts should be replaced when ever removed (reference Figure 11-5).

7. Attach a lifting sling to the center of the tank to be removed and lift most of the weight of the tank so as to remove the carriage bolts (Figure 11-5) that attach the clips to the tank pack frame. Place the bolts on a clean surface for re-use during installation. The tank is ready to be removed from the tank pack by lifting the tank straight up and guiding the tank past the latch pins and prop rod assemblies.
8. Loosen and remove both strap bolts (Figure 11-6) if required. After removal, the straps, rubber, and bolts should be placed on a clean surface for re-use during installation. The 1/2" Nylok nuts should be replaced after removal.

   Note: Rotation of the tank within the straps may be necessary if it becomes necessary to remove and replace a valve from the tank. The new valve orientation to the fuel lines will probably not line up for re-assembly without rotating the tank within the straps.
9. While the tank is removed, perform a visual inspection of the entire surface of the tank per section 6.6 of this manual. Record inspection results on the vehicle log or the individual tank inspection log.
10. Inspect and re-paint the mounting brackets as required per section 6.4 of this manual.
11. Inspect and replace strap rubber as required per section 6.4 of this manual.

11.4 Tank Installation

After repair or replacement of damaged components, reinstall the tank per the following steps:

1. If the strap assemblies were removed, install the strap assemblies onto the tank. Note the position of the valve fuel line fittings and match the position of the tank within the straps to fit the existing fuel line fitting orientation on the tank pack.
2. Install the tank on to the tank pack and line up the clips with the corresponding holes in the frame. With the clips aligned, insert the carriage bolts (4 ea. per tank) through the clips and frame holes with the carriage bolt head inserted in the carriage holding hole.
3. Install the 1/2" Nylok nuts on to the carriage bolts and torque to the correct specifications as listed in Figure 6-4.
4. Attach and tighten nut “D” while ensuring proper alignment and nut “E” if necessary per the fitting manufacturers specifications (see Figure 11-4).
5. Insert the fuel line section removed in step 4 of section 11.2 or step 4 of 11.3. Tighten nuts “C” per the fitting manufacturer’s specifications (see Figure 11-4).
6. While ensuring proper alignment; reinstall the vent line assembly removed in step 4 of section 11.2 or step 2 of section 11.3 of this manual. Tighten nuts “A” and “B” (Figure 11-3) per the fitting manufacturer’s specifications.

   Note: It may be necessary to adjust the position of the positional elbow that nut “B” attaches to. If this fitting does not line up to the vent tube assembly, adjust the position of the fitting per the fitting manufacturer's specifications.

11.5 Door Cover Installation

After replacing tank pack components, follow these steps to replace the door covers:

1. Assemble the door onto the tank pack with the door cover in the closed position. Align the door hinges at the bottom outside edge of the tank pack assembly and install the hinge pins removed in step 6 section 11.1. With a 16 oz hammer, tap the head of the hinge until fully seated against the hinge, repeat for all hinges.
2. Stand on the opposite side of the door to be opened and pull the “T” handle out of the recess of the door (of the door just installed) and rotate the “T” handle to open the door. The door will swing away from where you are standing. Remove the prop rod from the holder and engage it into the latch until the latch closes around the prop rod pin.
3. With door open, locate the set screws on the inside of the hinge shown in Figure 11-1. The set screws can only be accessed with the door open. Tighten the set screw to secure hinge pin in position.
4. With the door open, use 2 each 7/16 inch wrenches, to install both eyebolts that were removed in step 5 of section 11.1 that the door cables are attached to. Ensure that the door is restrained in such a position to allow for slack in the cable while installing the eyebolts. The prop rod may be used to hold the door open during the eyebolt installation.

11.6 Tank Pack Assembly Leak Test

This operation provides the specific information necessary for bubble leak testing of the tank pack. It will be necessary to leak check the entire tank pack system to inspect for leaks.

Leak Procedures

1. Close the tank valves and pressurize the tank supply lines to 500 psig with CNG. Inspect for leaks at all fitting locations with emphasis on fittings that were loosened or replaced.

Repair leaks as needed. Raise the pressure to operating pressure and check for leaks. Repair leaks as needed. Rinse all fittings that have been sprayed with liquid leak detector with water to wash off all residues that could corrode brass surfaces.

WARNING: IF BUBBLES ARE DETECTED DO NOT ATTEMPT TO TIGHTEN THE FITTING UNDER PRESSURE.

2. If no leaks are detected in the lines, then open the valves and pressurize to 500 psig and check for leaks. Allow the system to set for approximately a minute at full pressure and then proceed with a bubble test of all fittings and tanks.

WARNING: ANY ATTEMPT TO TIGHTEN OR LOOSEN A FITTING UNDER PRESSURE IS EXTREMELY DANGEROUS. DO NOT ROTATE A FITTING UNDER PRESSURE.

3. If a leak is detected, release the pressure from the system by draining the tank pressure. Ensure the tank is properly grounded per "Important Note" in section 6.1 of this manual before draining or venting the assembly. Verify that the pressure in the system (lines and tanks) is fully vented before proceeding.
4. After the tank is safely vented, re-tighten the leaking fitting per the manufacturer's specifications, and repeat the leak test per 11.6 items 1 and 2. If the fitting has a persistent leak that will not quit after proper tightening techniques are applied, then replace the fitting and line as necessary.
5. Pressurize the system to 500 psig again and check for leaks. If no leaks exist, pressurize to operating pressure and check for leaks. Continue the process until no leaks exist.

12.0 PRD Manifold Assembly Repair General Information

This operation provides the specific information necessary to repair the PRD manifold assembly. The necessary tools for the PRD manifold assembly repair are listed in Figure 12-1.

7/8 inch Open-End Wrench(es)
1 inch Open End Wrench(es)
Torque Wrench
7/8 inch Crow's Foot

Figure 12-1 Hardware Tool List

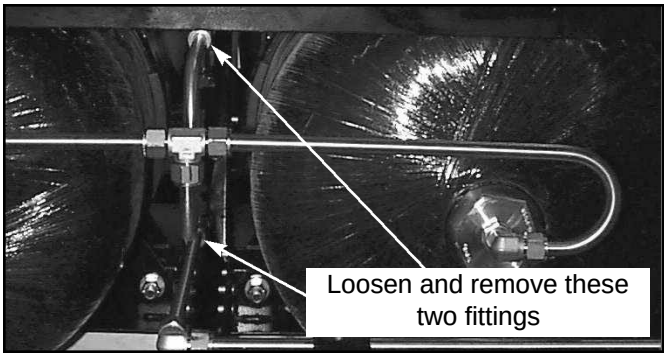


Figure 12-2 Fitting Removal

12.1 PRD Manifold Assembly Replacement Procedures

1. Before any repairs to the PRD assembly can be accomplished, the tank pack must be vented of all pressurized gas. See "Important Note" in section 6.1 on venting pressure.
2. Remove the tank located on the same side as the PRD manifold line clamps per instructions in section 11 of this manual.
3. Determine what parts need to be replaced. Remove all damaged parts.
4. Be careful not to loosen other connections to components that don't need repair. It may be necessary to remove the entire PRD manifold from the tank pack assembly to repair the manifold. Follow steps 4a through 4d to remove the manifold.
   - 4a. Loosen and remove the fittings (2ea.) at the end of the PRD manifold (Figure 12-2).
   - 4b. Loosen and remove all of the line clamps located on the PRD vertical supports (Figure 12-3).
   - 4c. Carefully remove PRD manifold. Avoid twisting lines when removing the manifold.
   - 4d. Lay out the removed manifold on a clean, flat surface for replacement or repair.

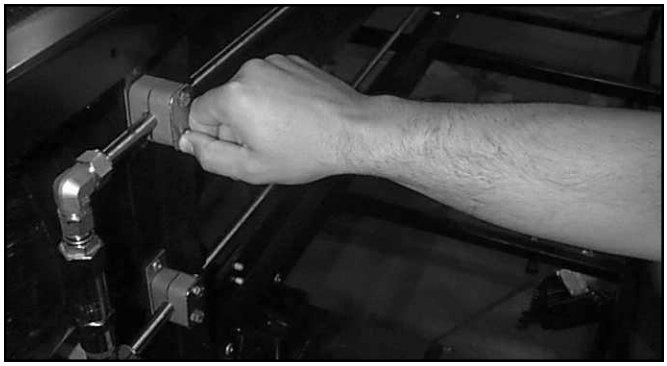


Figure 12-3 Line Clamps

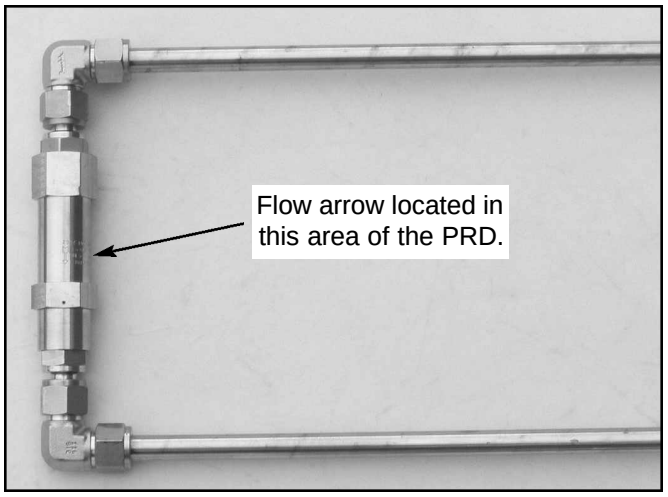


Figure 12-4 PRD Manifold Assembly (end view)

5. Obtain the replacement parts required to complete the repairs on the assembly (i.e. SAE connections, tube connections, etc).

   Note: ENSURE THAT THE PRD IS INSTALLED IN DIRECTION OF GAS FLOW. See Figures 12-3 and 12-4 for correct orientation of the PRD. If the PRD is not pointed in the correct direction it will not work properly. An arrow on the PRD indicates the direction of gas flow through the PRD. This arrow must always point away from the high-pressure gas side of the fitting assembly.

6. Repair the PRD manifold following all guidelines specified in this manual and the fitting manufacturer's specifications.

   Note: Ensure that when tightening the manifold, the manifold is not twisted with respect to the other end of the manifold. Twisting within the maniflold will cause the fittings to not mate up correctly and increase the possibility of leakage.

7. After the PRD manifold has been repaired install the manifold to the frame following these five steps:
   - 7a. Insure all fitting connections meet the manufacturer's specifications.
   - 7b. Verify that all PRDs in each individual PRD manifold are from the same manufacturer. The PRDs are traced by their "Date Code". The date code is etched on the body of the PRD and is used for traceability. If replacing a PRD, make a note of the change in the vehicle record log including:
     1. Date code of the PRD removed.
     2. Date Code of the replacement PRD.
     3. Date repair was made.

   Note: This information is critical for traceability and must be recorded properly.

   - 7c. Install the PRD manifold into the line clamps without tightening the clamps.
   - 7d. Re-install both fittings (2ea.) at the end of the PRD manifold per section 10 this manual.
   - 7e. Tighten the line clamps with 70 inch pounds of torque (8 Nm).
8. Re-install the fuel tank per section 11.4 of this manual.

13.0 Covers, Skirts, and Fairing

General Information

0.1 inch (2.54 mm) diameter punch, 4 inches long
PPG Color Paint Standard, TUH592175
2 ea. 7/16 inch wrenches
16 oz. hammer
5/64 inch Allen wrench
Long pull rivet gun
1/4 inch structural grade rivets
5/32 (3.84 mm) drill bit
1/4 inch (6.35 mm) drill bit
Drill

Figure 13-1 Hardware Tool List

This operation provides the specific information necessary for inspection and replacement of door covers and fairing(s). The necessary tools for repair of the covers, skirts, and fairings are listed in Figure 12-1.

13.1 Door Cover and Fairing Inspection.

Surface cracking is acceptable in the gel coat, if the cracking is not into the fiberglass. If the fiberglass is also cracked then contact General Dynamics for instructions.

Fiberglass repair procedures are not supplied with this manual. If paint repair is required, use PPG Color Paint Standard, TUH592175 for visual comparison.

13.2 Rivet Removal and Installation

General Information

This operation provides the specific information necessary to remove and install rivets that secure fairing(s), skirts and hinges.

Rivet Removal

The following steps should be followed for rivet removal.

1. Identify what rivets are in need of replacement.
2. To remove the rivets, the rivet stem must be drilled out using a 5/32" (3.84 mm) drill bit.
3. With the stem removed drill out the rivet hole with a 1/4 inch (6.35 mm) drill bit.

Rivet Installation

1. Install the rivet into the rivet gun and insert the rivet into the hole.
2. Actuate the rivet gun while keeping pressure against the rivet.

13.3 Skirt Removal and Installation

General Information

This operation provides the specific information necessary to remove and install skirts. Figure 13-2 is an example of a typical skirt location.

Skirt Removal

Note: Some tank pack configurations do not have skirts. If there are no skirts on your application, skip this section.

The following steps should be followed for skirt removal. The skirt is located at the outer edge of the tank pack, between the tank pack and roof of the vehicle.

1. Remove all rivets holding the skirt in place per section 13.2 of this manual. The skirt will have to be held in place while removing the rivets to keep from damaging the skirt and/or the vehicle.
2. Remove the skirt from tank pack assembly.

Skirt Installation

1. Align the skirt holes with existing holes in the skirt mounting frame of the tank pack assembly.
2. Install the rivet into the rivet gun and insert the rivet into the hole in the skirt and through the skirt mounting frame hole.
3. Actuate the rivet gun while keeping pressure against the rivet.

13.4 Fairing Removal and Installation

General Information

This operation provides the specific information necessary to remove and install the fairing. The fairing is comprised of two main pieces, a fiberglass portion and a fairing support frame located underneath.

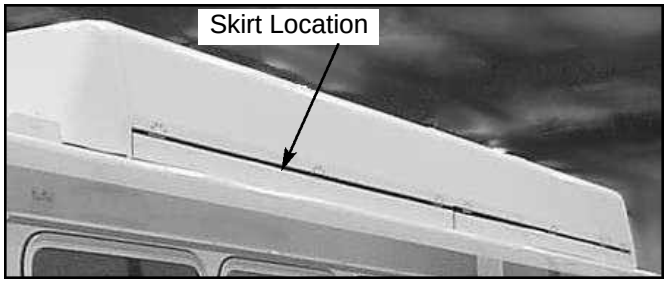


Figure 13-2 Skirt Location

Fairing Removal

The following steps should be followed for fairing removal:

1. Loosen attaching bolts at both sides of the fairing from the “U” bracket support that is attached to the frame assembly shown in Figure 13-3. The “U” bracket need not be removed unless damaged. If damaged, the “U” bracket can be removed from the header rail with 2 each 7/16 inches wrenches. Place the removed bolts and washers on a clean surface for re-assembly later. All 1/4" Nylok nuts should be replaced after removal.
2. Remove the skirt rivets attached to the “L” bracket that is attached to the fairing as required.
3. Remove the rivets at the top and face of the fairing per section 13.2 of this manual. These rivets attach the fairing to the support bracket. With rivets and attaching bolts removed the fiberglass portion of the fairing can be removed.

The fairing is to be installed in the reverse order of removal.

13.5 Fairing Support Frame Removal and Installation

Support Frame Removal

The following steps should be followed for removal of the support frame:

1. Remove all rivets attaching the support frame to the tank pack assembly. The two bottom rivets will have to be drilled out from the back side of the rivet.
2. With all rivets removed, the frame assembly is ready to be removed from the tank pack.

Support Frame Installation

The following steps should be followed for installation of the fairing support frame.

1. Install the rivets per section 13.2 of this manual. Install all rivets except the 2 rivets that were drilled from the back side in step 1 of the support frame removal.
2. Obtain 2 each 1/4 inch bolt 3/4 inch long with 2 each locking nuts and 4 each 1/4 inch washers. Use obtained hardware to attach the frame support at the bottom side.

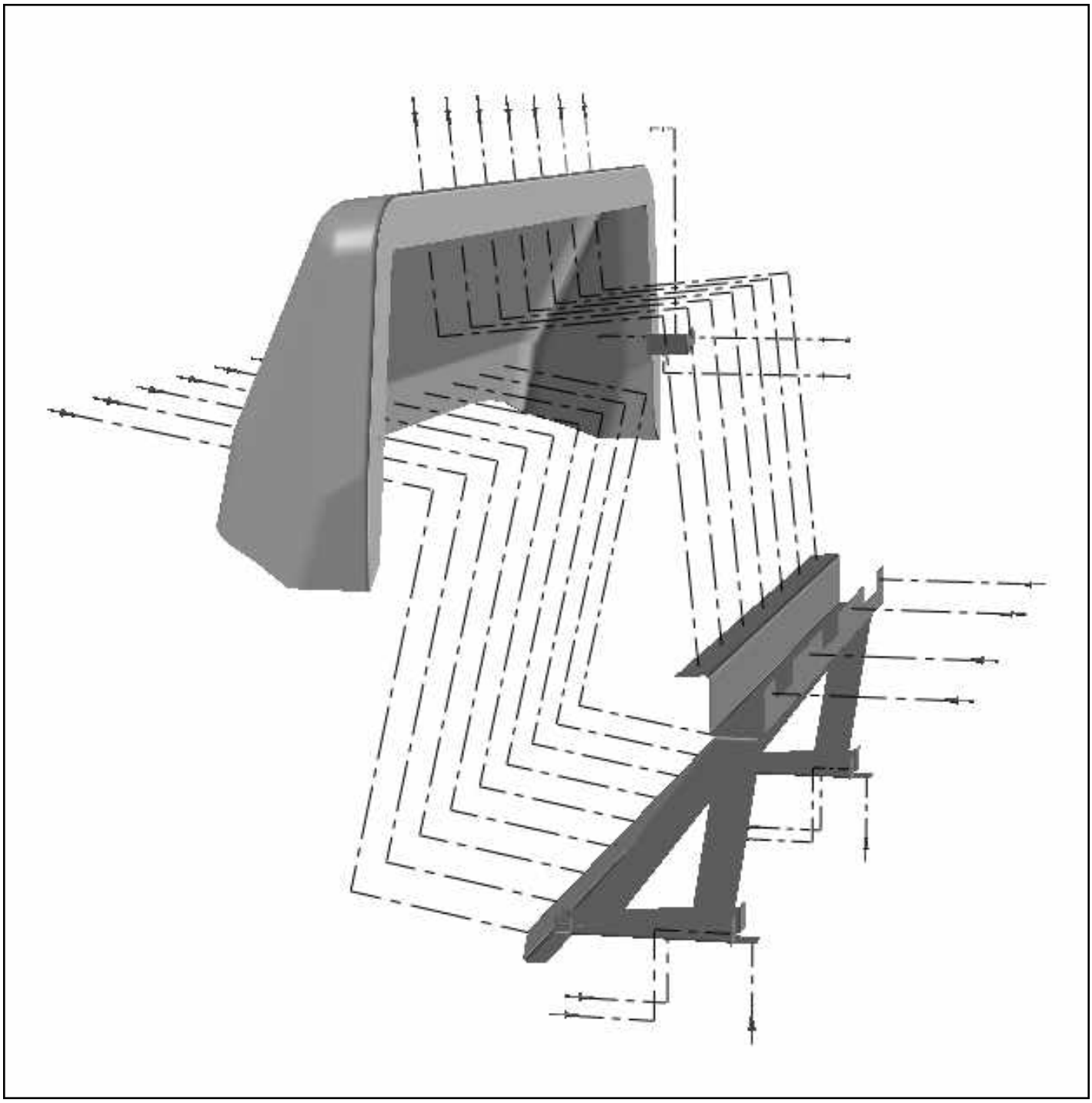


Figure 13-3 Fairing Assembly

14.0 Summary

This manual has been written to assist all users of General Dynamics Lincoln Operations compressed natural gas fuel tanks and tank packs. This manual is a derivative of the “NGV Fuel Container Inspection Guidelines”. Although great effort has been invested in this document to provide the reader with the most up to date specifications and requirements, it is recommended that all possible avenues of education concerning CNG tanks are utilized. A complete understanding of our products and all related products and the regulations and guidelines that control the processes that affect your individual use are important for the safe use and operation of your individual CNG application.

TUFFSHELL™ Fuel Tanks

All-Composite

All sizes meet the requirements of ANSI/CSA NGV2, US DOT FMVSS 304, and/or CAN B51, TC 301.2, METI-KHK, ISO 11439 and ECE R110. Dimensions, weights and capacities are nominal.

3000 PSI / 207 BAR											
Size (O.D. x Length)		Weight		Water Volume		Gas Capacity		Gasoline Equivalent		Diesel Equivalent	
Inches	Millimeters	Lbs.	Kg.	Cu. In.	Liters	SCF**	SCM	Gallons	Liters	Gallons	Liters
9.5 x 57	241 x 1448	46	20.9	2913	47.7	438	12.4	3.5	13.3	3.1	11.6
15.6 x 35	396 x 889	73	33.1	4400	72.1	661	18.7	5.3	20.2	4.8	18.0
15.6 x 52	396 x 1321	108	49.0	7070	115.9	1063	30.1	8.6	32.4	7.6	28.9
15.6 x 55	396 x 1397	105	47.6	7540	123.6	1133	32.1	9.1	34.6	8.2	30.9
*15.6 x 71	396 x 1803	137	62.1	10112	165.7	1520	43.0	12.3	46.4	10.9	41.4
15.6 x 84	396 x 2134	160	72.6	12200	199.9	1834	51.9	14.8	56.0	13.2	49.9
*16.0 x 60	406 x 1524	106	48.1	9097	149.1	1368	38.7	11.0	41.7	9.8	37.2
*16.0 x 71	406 x 1803	124	56.2	10969	179.7	1649	46.7	13.3	50.3	11.9	44.9
*16.0 x 82	406 x 2083	144	65.3	12977	212.7	1951	55.2	15.7	59.6	14.0	53.1

3600 PSI / 248 BAR											
Size (O.D. x Length)		Weight		Water Volume		Gas Capacity		Gasoline Equivalent		Diesel Equivalent	
Inches	Millimeters	Lbs.	Kg.	Cu. In.	Liters	SCF**	SCM	Gallons	Liters	Gallons	Liters
9.2 x 35	234 x 889	37	16.8	1425	23.4	244	6.9	2.0	7.5	1.8	6.7
9.2 x 40	234 x 1016	42	19.1	1655	27.1	284	8.0	2.3	8.7	2.0	7.7
9.2 x 64	234 x 1626	68	30.8	2810	46.0	482	13.7	3.9	14.7	3.5	13.1
13.9 x 35	353 x 889	65	29.5	3345	54.8	574	16.3	4.6	17.5	4.1	15.6
13.9 x 40	353 x 1016	74	33.6	3932	64.4	675	19.1	5.4	20.6	4.9	18.4
13.9 x 45	353 x 1143	84	38.1	4515	74.0	775	21.9	6.2	23.6	5.6	21.1
13.9 x 55	353 x 1397	102	46.3	5695	93.3	977	27.7	7.9	29.8	7.0	26.6
13.9 x 82	353 x 2083	153	69.4	8920	146.2	1530	43.3	12.3	46.7	11.0	41.7
15.7 x 35	399 x 889	69	31.3	4390	71.9	753	21.3	6.1	23.0	5.4	20.5
15.7 x 40	399 x 1016	78	35.4	5175	84.8	888	25.1	7.2	27.1	6.4	24.2
*15.7 x 49	399 x 1245	95	43.1	6685	109.5	1147	32.5	9.2	35.0	8.3	31.2
15.7 x 52	399 x 1321	118	53.5	7108	116.5	1219	34.5	9.8	37.2	8.8	33.2
15.7 x 55	399 x 1397	106	48.1	7525	123.3	1291	36.6	10.4	39.4	9.3	35.2
15.7 x 62	399 x 1575	119	54.0	8620	141.3	1479	41.9	11.9	45.1	10.6	40.3
*15.7 x 71	399 x 1803	147	66.7	10030	164.4	1721	48.7	13.9	52.5	12.4	46.9
*15.7 x 120	399 x 3048	235	106.6	17620	290.0	3023	86.0	24.4	92.3	21.7	82.3
*16.1 x 71	409 x 1803	139	63.0	10883	178.3	1867	52.9	15.1	57.0	13.4	50.8
*16.1 x 120	409 x 3048	232	105.3	19222	315.0	3298	93.4	26.6	100.7	23.7	89.8
*18.4 x 49	467 x 1245	157	71.2	9128	149.6	1566	44.3	12.6	47.8	11.3	42.6
*18.4 x 78	467 x 1981	235	106.6	15230	249.6	2613	74.0	21.1	79.8	18.8	71.2
*18.4 x 100	467 x 2540	303	137.4	19695	322.7	3379	96.0	27.2	103.2	24.3	92.0
*18.4 x 120	467 x 3048	350	158.8	23944	392.4	4108	116.3	33.1	125.4	29.6	111.9
*21.1 x 80	536 x 2032	258	117.0	21153	346.6	3629	102.8	29.3	110.8	26.1	98.8
*21.1 x 120	536 x 3048	380	172.4	32937	539.7	5651	160.0	45.6	172.5	40.7	153.9

* Available with 2" Port Standard port sizes on all other tanks: 1 1/16"-12 UNF and 1 1/8"-12 UNF

** Standard Cubic Feet. Natural gas capacity is based on a tank at service pressure filled with gas at a specific gravity of 0.60 and a temperature of 70°F.

Tanks are available in boss mount configurations.
Contact us for custom sizes and service pressures.
General Dynamics offers valves, end plugs, pressure relief devices, bracket kits and tank packs.

ISO 9001
ANSI-RAB QMS ACCREDITED
Registered Company
TUV Rheinland of North America, Inc.

GENERAL DYNAMICS
Armament and Technical Products

Lincoln Operations · www.gdatp.com
4300 Industrial Avenue, Lincoln, NE 68504
Tel 1-800-279-TANK or 402-464-8211 · Fax 402-464-6777
E-mail tuffshell@gdatp.com

NGV Container Inspection Record

Inspector Name	
Inspection Date	
Serial No.	
Model No.	
Expiration Date	
Mounting Location	
Vehicle Identification Number (VIN)	
Vehicle Mileage	

Examination Features	**Accept**	**Reject**	**Comments (include damage level if applicable)**
Tank and brackets clean prior to inspection			
Tank Installation			
1/2" of clearance around tank when mounted			
Bracket Condition			
Mounting pads in good condition			
Labels in Place			
Tank has not exceeded service life			
Tank service pressure meets or exceeds vehicle service pressure			
Valve Condition			
PRD Condition			
Plug Condition			
Fuel supply lines mounted securely			
Vent lines mounted securely			
Vent lines free of debris			
Interfaces free of leaks			
Container (cylinder) condition			
Container (dome with valve) condition			
Container (dome opposite of valve) condition			

Notes:

Notes:

Proof and leak tests are performed on all TUFFSHELL™ fuel containers

Hydrostatic testing, at 1.5 X operating pressure, is performed on all containers to ensure structural integrity. This testing also provides volume and weight data for each container.

Mass spectrometer leak inspection is performed with helium as a trace gas, to screen all containers for leakage. The leak detection system continuously monitors the test enclosure for leakage with a maximum sensitivity of 1 X 10-7 cubic centimeters per second.

TUFFSHELL

GENERAL DYNAMICS
Armament and Technical Products