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INSPECTION GUIDELINES - Type 3 NGV Fuel Cylinders

Certified to: DOT FMVSS 304 & ANSI/AGA NGV2

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1.0 SCOPE

This guideline is intended to provide sufficient data and details to an experienced cylinder retester to assist them in effectively carrying out the following on Type 3 Cylinders manufactured by Structural Composites Industries (SCI):

- Examination
- Assessment
- Determination of "Safe For" continued service

The guideline will also identify minor repair procedures, which may prolong the useful life of cylinders that have received MINOR Surface Damage. This guideline should be used in conjunction with other applicable standards and specifications.

Please read and understand ALL ASPECTS of this guideline before attempting to perform any inspection or repair of a Cylinder manufactured by SCI. In the event these instructions are unclear or clarification is required, please forward your questions to:

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2.0 INTRODUCTION

The technology for Composite Cylinders was first developed, by SCI, in the 1960's for use by the Aerospace Industry in rocket motors and other pressure related vessels. Gas Cylinders (NGV) for commercial use were first introduced in the USA in the mid-70's. Since that time SCI has manufactured more than 1,300,000 composite pressure cylinders, which are in-service around the world.

SCI's Quality Assurance procedures together with their knowledge in cylinder design ensure each cylinder manufactured is of the "Highest" Quality. Subsequently, the maintenance of the integrity of the cylinder becomes the responsibility of the user, filler and retest organizations.

3.0 APPLICABLE SPECIFICATIONS

CGA C-2	Recommendation for the Disposition of Unserviceable Cylinders
CGA C-6.4	Methods for Visual Inspection of Natural Gas Vehicle (NGV) Fuel Containers and Their Installations.
ANSI/NFPA 52	Compressed Natural Gas (CNG) Vehicular Fuel Systems.
ANSI/AGA NGV2	Basic Requirements for Compressed Natural Gas Vehicle (NGV).
CSA B51 Part 2	High Pressure Cylinders for the On-Board Storage of Natural Gas as a Fuel for Automotive Vehicles.
DOT FMVSS 304	Federal Motor Vehicle Safety Standards: Compressed Natural Gas Containers.

4.0 DESCRIPTION OF TERMS

ABRASION	Damage caused by wearing, grinding or rubbing away of material by friction.
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BLUNT IMPACT	Damage caused by a forceful blow, which does not cut, gouge or significantly indent the cylinder surface.
NOTE:	This type of damage is not readily apparent by visual inspection. Therefore, CAUTION should be used when inspecting cylinders.
CRAZING	Hairline cracking of the Resin material. Giving it the appearance of being opaque "frosty" or stringy "spider-web".
CUT DAMAGE	Caused by contact to the composite surface from a sharp "Knife-like" object
DELAMINATION	Damage in which a separation develops between the layers of composite material.
IMPACT	Damage caused by dropping of the cylinder or a blow received by another object.
CONDEMNED CYLINDER	Cylinders, which are Damaged Beyond Repair, Fail Retest or have reached their "End of Service Life" MUST be removed from service.
COMPOSITE MATERIAL or REINFORCED FIBER	Continuous fibrous stands used in the Filament Winding or overwrapping process of the cylinder. Typically consisting of three types: <ul style="list-style-type: none"> • Carbon • Fiberglass • Hybrid (i.e. Aramaic, Kevlar)
FILAMENT WINDING or OVERWRAPPING	Process used for Composite Material orientation on to the cylinder liner.
LINER	The metallic, cylindrical shaped, portion of the Cylinder which the composite material is wrapped over.
DOMES	The curved end portion forming the closure in the Cylinder and/or Liner.
RESIN	A liquefied plastic solution applied in connection with fiber that when cured forms a bonding matrix.
PORT or PORT END	The opening on the Dome end(s) of the cylinder, which are threaded for the installation of a valve, Pressure Relief Device (PRD) or blank plug.
SERVICE PRESSURE	The settled pressure at a uniform 70°F gas temperature at which the cylinder, under normal conditions is considered full.

5.0 DESCRIPTION OF LEVEL DAMAGE

- LEVEL 1 - Damage (Acceptable)
Is minor, and would be considered normal "Wear-N-Tear". Such damage should have no adverse effects of the safety of the cylinder and it's continual use.
- LEVEL 2 - Damage (Rejectable - Additional inspection or rework required)
May be cuts or gouges which, are deeper or longer than those of Level 1 or may include a group of severed fibers.

LEVEL 3 - Damage (Condemned - Not Reworkable)

Is such that the cylinder has been rendered unfit for continued service and cannot be reworked. The owners of cylinders with such damage shall be notified in writing by the Inspection Agency, including notation of the cylinder serial number.

6.0 INSPECTION PROCEDURE

6.1 PREPARATION FOR INSPECTION

6.1.1 The surface (External & Internal) should be clean and free of Dirt, Debris or other Contamination, which would, obstruct the inspector's ability to clearly determine the condition of the cylinder. Shields or any covering should be removed (carefully to prevent additional damage) to expose maximum cylinder surface.

IMPORTANT

Cylinders received with a Valve, PRD or plug will be considered pressurized and handled accordingly. Before inspection can take place the cylinder should be depressurized. The depressurization process should ONLY be performed by qualified personnel and after ALL safety precautions are in place.

DO NOT VENT THE CYLINDER IN AN AREA WHERE FLAMMABLE GAS CAN ACCUMULATE AND IGNITE.

6.1.2 Cylinder owners should be questioned regarding any known conditions or incidents where damage was made to the cylinder. They would include, but not limited to:

- Dropping of the Cylinder
- Impacts made to the Cylinder
- Exposure to Excessive Heat or Fire
- Vehicle Accident
- Exposure to Harsh Chemicals

The Cylinder owner should also be questioned regarding any of the following:

- Unusual observations or usage
- Service History
- Repairs made since the Last Inspection

6.2 TOOLING LIST

The following tools should be available to perform a comprehensive inspection:

- Torque Wrench
- Socket Drive - with 3/4" Socket
- Measuring Device - i.e. 6" Scale or Depth Gage
- Liquid Leak Detector
- 3/4" Crows Foot
- 3/4" "Open-end" Wrench
- Coin - i.e. Quarter or Half-dollar
- Grounding Strap or Cable
- Drill Motor - with 1/2" drill bit
- Cloth Rags
- Flashlight or Droplight

6.3 COMPOSITE CYLINDER INSPECTION

The cylinder integrity can potentially be compromised without showing significant damage on the surface. Therefore, any inspection should be performed as carefully as possible. Visual

Inspection is the primarily observation for making any determinations, the surface (both Internal and External) should be clean and well illuminated. However, Paint removal for inspection is not permitted.

6.3.1 Primary Inspection Elements

6.3.1.1 Cylinder Service History

Inspectors should review Inspection/Service History before performing inspection of the cylinder. This review may provide the inspector with an insight of the cylinder and aid them in the Inspection Process

6.3.1.2 Visual Inspection

This is the primary means of detecting damage to the cylinder. Potential damage detected may include, but not limited to:

- Cuts
- Fractures
- Material Removal
- Discoloration of the Surface (Internal and/or External)
- Deterioration of the Surface (Internal and/or External)
- Heat or Fire Damage
- Delaminating
- Dents

NOTE: Verify manufacturers expiration Date on label

6.3.1.3 Coin Tap Examination

Potential defects may be detected by a variation in the sound (From a "Solid" to a "Hollow" or "Dead" sound) emitted by tapping the surface with a coin. This variation in the sound may indicate the presence of a delamination within the composite material. This test is primarily useful in the sidewall area of the cylinder and should be viewed as a "Quick" indication method for detecting delamination. Areas, which have indications of impact damage, should be subjected to further detailed inspection.

6.3.1.4 Manufacturer Inspection

Cylinders that "Have Been" or "Suspected to Having Been" subjected to a damaging incident or if they Exhibit evidence of damage NOT SPECIFICALLY identified as acceptable by this Guideline, MUST be removed from service.

These cylinders may be sent to SCI for a more extensive evaluation. Contact the SCI Sales and Service Department for making arrangements to return a cylinder.

The CGA pamphlet CGA C-6.4 should be used as a supplement to the Inspection Criteria referenced in this guideline.

6.4 INSPECTION CRITERIA

6.4.1 Cuts, Scratches and Abrasions

Cylinders with Cuts, Scratches or Abrasions shall be evaluated per Table 1. Abrasions may be the results of another object, repeatedly, lightly against the surface of the cylinder.

Light Load Abrasions - Tend to be smooth and polished in appearance

Heavy Load Abrasions - Appear as a group of or a single line of parallel gouges or cuts. Heavy Load Abrasion should be examined as if the surface had been subject to an impact.

TABLE 1 - Damage Levels

Damage Level (Rework Type)	Scratch/Gouge Depth in Inches	Abrasion Depth in Inches	Rework Required
Level 1	$0 \leq .010$	$0 \leq .010$	None
Level 2 (Customer Rework)	$.011 \leq .028$	$.011 \leq .028$	I
Level 2 MFG Inspection	$.028 \leq .036$	$.028 \leq .028$	II
Level 3	$> .036$	$> .036$	III
<p>NOTE: Damage is limited to the Glass Overwrap ONLY</p> <p>Rework Types:</p> <p>I) Apply any commercial Room Temperature curing two-component epoxy resin system. Loose fibers may be removed and edges of a cut or gouge may be tapered by hand filling or sanding prior to application of epoxy. Do not abrade the surface more than .010" from the composite surface when filling or sanding.</p> <p>II) Remove Cylinder from service and contact SCI Customer Service for Manufacturer Inspection. Cylinders will be evaluated for possible rework procedures.</p> <p>III) Cylinder is to be removed from service and CONDEMNED.</p>			

6.4.2 Impact Damage

Cylinders damaged from an impact may incur severe structural damage and pose a safety hazard. Impact Damage may occur during Shipping, Handling and/or in-service use. The impact may be the result of dropping the cylinder prior to or during installation, or due to in-service conditions such as a vehicle accident.

Impact damage differs from other forms of damage in the fact that the cylinder wall may suffer serve damage within the wall rather than on the surface. This is particularly true if the surface of the impacting object is blunt and relatively smooth. The surface of a composite cylinder tends to return to its original shape after an impact.

Impact Damage may cause delaminations and fractures of the composite layers. Therefore, careful examination of the surface damage from an impact may include, but not limited to:

- Cutting
- Gouging
- Scraping
- Scuffing
- Chipping
- Punctures
- Fiber Breakage
- Loose Fibers
- Resin Cracking
- Change in coloration or appearance

Known areas should be marked to aid the inspection process. They must be inspected for evidence of damage within the wall which, may include:

- Permanent Deformation or Dent - Level 3 Damage
- Softness in the Cylinder Wall - Level 3 Damage
- Port Damage
- Local Surface Cracking - Exhibited by circular, oval or linear zones of crazing

NOTE: Small random hairline cracks in the resin surface, parallel to the reinforced fibers are common in composite wrapped cylinders and are not cause for alarm.

- "Coin Tap" Sound Variation

NOTE: Difference in sound is evidence of damage within the composite wall. Cylinders should be removed from service and subjected to further examination by SCI, or be condemned and destroyed.

6.4.3 Fire and Excessive Heat Damage

With a maximum service temperature of 180°F, NGV cylinders may experience excessive heating if located too close to an exhaust system, or is involved in a fire. The following can be evidence of heat damage:

- Darkening of the Surface
- Charring
- Sooting
- Severe exposure - Resin removal and/or loose fibers

Cylinders experiencing excessive heat or fire exposure are defined as a Level 3 damage and are to be condemned and destroyed.

6.4.4 Gas Leakage

Cylinders suspected of or exhibiting gas leakage must be removed from service IMMEDIATELY. Contact SCI to report the condition and for requesting information for any additional testing and disposition.

NOTE: Air Bubbles are typically observed on the composite surface, hours after pressurization, particularly after the initial pressurization. Trapped air between the aluminum liner and the composite over wrap is forced outward when the cylinders is pressurized. The bubbles should subside after a few hours.

6.4.5 Chemical Damage

Materials used to make the cylinder are resistant to chemical agents encountered during normal usage. However, cylinders should be maintained in a clean state and not experience prolonged exposure to the following:

- Moisture
- Automotive Fluids
- Corrosive Agents

Chemical damage will appear as an alteration to the composite surface. This includes but not limited to the following:

- Discoloration
- Etching
- Blistering
- Swelling
- Softening of the Composite Material
- Resin removal

Extreme Cases;

- Surface Fractures of Composite Material
- Broken or Loose Fibers

6.4.5.1 Level 1 Damage:

- Minor Paint Damage
- Minor Discoloration
- Minor Etching

Is acceptable, provided the chemical is removed and the cylinder cleaned.

6.4.5.2 Level 2 Damage

- Cuts in coating and/or glass overwrap

6.4.5.3 Level 3 Damage:

- Blistering
- Swelling
- Softening
- Resin Removal
- Fractures

Cylinder must be removed from service, condemned and destroyed

6.4.6 Weathering

Cylinders may exhibit degradation of the external coating after prolonged exposure to sunlight and/or weather. Discoloration and/or flaking of the coating may result; this is considered Level 1 Damage. The affected surface may be reworked by applying a coat of paint, ONLY after a complete Inspection process has been performed.

7.0 **NON-STRUCTURAL ANOMALIES**

Cylinder, at times, may exhibit anomalies that will have no affect on its structural integrity. Non-Structural Anomalies include but limited to the following:

- Fiber Gaps on the Dome Surface
- Resin and/or Paint Runs
- Excessive Resin on the Surface

8.0 CYLINDER DISPOSITION

After inspection a cylinder may be disposition in One of Three ways:

1. Level 1 or NO Damage - Acceptable, remain in service
2. Level 2 Damage - May be Reworked in field, or by manufacturer, and return to service
3. Level 3 Damage - CONDEMN & DESTROY

9.0 CYLINDER DESTRUCTION

Cylinders, which have been CONDEMNED, shall be processed in the following manner:

1. Clearly Marked as "CONDEMNED" at the time of inspection
2. Affix marking to the manufacturer's label(s)
3. Drill two or more ½" (or greater) holes, completely through the cylinder wall
4. Dispose of cylinder, within accepted Environmental, Safety & Health Guidelines.

CAUTION: Cylinders WILL contain residual gas fumes after depressurization. Safety precautions should be used to ensure the fumes would not ignite during the Drilling and/or Disposal process.