Overview of NGV Fuel Tank Testing Requirements

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Transportation Fuels

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Presentation Overview

Introduction
Fuel Tank Technologies
Service Conditions
Design Considerations
Testing of NGV Tanks
Overview of CSA Group

- Consumer Product Evaluation
- Standards
- Product Certification & Testing
A Trusted Advisor

- Established in 1919 (94 years)
- Private not-for-profit
- 1,650 employees
- 35 offices in 14 countries
- 88,000 customers globally
- CSA mark appears on billions of products worldwide
- 8,500 engaged and committed Members
- 1,300 standards development Technical Committees
- 3,000+ standards in 54 technologies and services
Craig Webster (30 years exp.) and Livio Gambone (23 years exp.), formerly of Powertech Labs Inc., joined CSA Group in Oct. 2013

Founded and led Powertech’s high pressure alternative fuels testing facility since 1983

The focus is to establish high pressure test facilities in the global marketplace

- Pre-normative research
- Testing and certification
- Production inspection
- Quality auditing
- Training in the handling, installation, and servicing/safety inspection of high pressure components, vehicle fuel systems, and fueling stations.
NGV Fuel Tank Technologies

Four basic types of NGV fuel tank designs

Which design to use depends on need to reduce weight, fuel storage requirements and cost

All designs have equivalent level of safety, since all meet the requirements of the same standards

Design type can also determine how a tank may be handled and how it may be filled
NGV Fuel Tank Technologies

Type 1 – All metal (aluminum or steel)

- Inexpensive but heavy

Source: CNG Cylinders International
Type 2 – Metal liner reinforced with composite hoop wrap

• Liner takes 50% and composite takes 50% of the stress caused by internal pressurization

• Less heavy but more costly than Type 1
NGV Fuel Tank Technologies

Type 3 – Metal liner reinforced with composite full wrap

• Liner takes small amount of stress
• Light weight but more cost than Types 1/2

Source: Structural Composites Industries

Source: Luxfer Gas Cylinders
Type 4 – Plastic gas-tight liner reinforced with composite full wrap

- Composite reinforcement takes entire stress
- Light weight but more cost than Types 1/2

Source: Quantum Technologies
Source: Hexagon Lincoln
NGV Service Conditions

Road conditions are a very severe environment for pressure vessels

- Pressure extremes (300 psi – 4,500 psi)
- Multiple fills (11,250 cycles for 15 year life)
- Temperature extremes (-40°F – 185°F)
- Road environment and cargo spillage
- Vibration
- Vehicle fire
- Collision

Standards require tests or specify installation requirements to address these service conditions
NGV Fuel Tank Design Considerations

Limited to the life of the vehicle (10 – 25 years)
  • Alternative is to overdesign so it lasts indefinitely

Leak-before-break requirement
  • If a fuel tank stays in service beyond its design life, and experiences excessive fill cycles, it will only fail by leakage

Fire protection is provided by a thermally activated pressure relief device (PRD) on every fuel tank
NGV Fuel Tank Regulations/Standards

All NGV fuel tanks MUST meet the federal government’s FMVSS 304 (49 CFR 571.304), Compressed Natural Gas Fuel Container Integrity

All NGV fuel tanks SHOULD meet ANSI/CSA NGV 2, American National Standard for Natural Gas Vehicle Containers

- CSA B51 – Part 2 for Canada
- ECE R110 for Europe
- ISO 11439 for most other countries
Performance Testing

Qualification tests (performance-based) are required by standards to ensure tanks and components will perform safely when subject to automotive service conditions.

Automotive OEMs will perform additional tests to ensure the durability of the fuel storage system:

- Vibration (shock, random vibration, with temperature extremes)
- Severe corrosion
- Fast filling/defueling
Testing of NGV Fuel Tanks

Comparison: FMVSS 304 v. ANSI/CSA NGV 2

FMVSS 304 Requirements

- Ambient pressure cycling (10% – 100% SP for 13,000 cycles, 10 – 125% SP for 5,000 cycles)
- Burst (Min. 2.25x SP)
- Bonfire (100% SP, 25% SP, 20 min. or less)
- Labelling
Testing of NGV Fuel Tanks

ANSI/CSA NGV 2 Requirements

• Ambient pressure cycling (10% – 125% SP for 750 x no. years)

• Environmental
  • Pendulum impact
  • Exposure to sulfuric acid, sodium hydroxide, methanol/gasoline, ammonium nitrate, windshield washer fluid
  • Pressure cycle (10% - 125% SP for 3,000 cycles)
  • Burst (Min. 1.8x SP)

Source: CVEF
Testing of NGV Fuel Tanks

ANSI/CSA NGV 2 Requirements Cont’d

• Extreme temperature pressure cycling (10% – 125% SP for 4,000 cycles at 185°F, 10% – 80% SP for 4,000 cycles at -40°F)

• Burst (Min. 2.25x SP or meet stress ratio requirements)

<table>
<thead>
<tr>
<th>Material</th>
<th>Type 2</th>
<th>Type 3</th>
<th>Type 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-glass</td>
<td>2.65</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>S-glass</td>
<td>2.65</td>
<td>3.5</td>
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</tr>
<tr>
<td>Aramid</td>
<td>2.25</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Carbon</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
</tr>
</tbody>
</table>

• Composite flaw tolerance
  • Flaw cuts (1” x 0.050”, 8” x 0.030”)
  • Ambient pressure cycle (10% - 125% SP for 3,000 cycles)
Testing of NGV Fuel Tanks

ANSI/CSA NGV 2 Requirements Cont’d

• Drop (Impact)
  • Horizontal orientation (72”)
  • Vertical both ends (72”)
  • 45 degree angle (72” to CG)
  • Ambient pressure cycle (10% - 125% SP for 3,000 cycles)

Source: CVEF
Testing of NGV Fuel Tanks

ANSI/CSA NGV 2 Requirements Cont’d

• Bonfire (100% SP, 25% SP if pressure activated PRD used)

Source: CHA 2003
Testing of NGV Fuel Tanks

ANSI/CSA NGV 2 Requirements Cont’d

• Penetration (30 cal. AP at 45 degree angle)

Source: CVEF
Testing of NGV Fuel Tanks

ANSI/CSA NGV 2 Requirements Cont’d

- Accelerated stress rupture (125% SP for 1,000 hr at 149°F)
- Permeation (Type 4 only)
  - Boss 2x installation torque
  - Hold at 100% SP with CNG for 500 hr
  - Steady state permeation < 0.25 cc/hr/L
- Natural Gas Cycling (Type 4 only)
  - 10% - 100% SP with CNG for 1,000 cycles
  - Leak test
  - Sectioning to confirm no liner deterioration

Source: CVEF
Testing of NGV Fuel Tanks

ANSI/CSA NGV 2 Requirements Cont’d

- Leak-before break (Type 1/2 only) (10% – 150% SP for 2,250 x no. years)
- NDE defect size determination (Type 1/2/3 only)
  - Engineering critical assessment, or
  - Flawed container cycling
- Materials tests
  - Impact (steel/plastic)
  - Sulfide stress cracking (steel)
  - Tensile (steel/aluminum/plastic)
  - Sustained load cracking / corrosion (aluminum)
  - Softening/melting (plastic)
Testing of NGV Fuel Tanks

Changes to Standards to Accommodate New Fuel Tank Designs

Define a new Type 5, 6, etc.

- Linerless
- Internal structural members
- Intestine shape

Address orientation issues for drop, bonfire and penetration tests

Define production inspection requirements for new joining techniques/joints

Define materials tests for joints
Testing of NGV Fuel Tanks

Changes to Accommodate Conformable Fuel Tanks

New fiber type may require stress ratio value to mitigate stress rupture

New resin/liner type may require additional materials tests