CLEAN VEHICLE FUEL STORAGE & TRANSPORTATION FROM WORTHINGTON

Featuring the TYPE III CNG TANK

The Worthington Type III CNG Tank delivers more usable gas storage and features ultra-lightweight composite reinforced technology for extreme durability.

Worthington is the leading global supplier of pressure cylinders, offering the broadest line of alternative fuel cylinders for storage of CNG, LPG and Hydrogen.

www.worthingtonindustries.com
**Fiberglass Usage**

- **Fiberglass Composite Can Be Used As A Sacrificial Component But Should Not Be A Structural Element**
  - Static Failure Mode (Static Vessel Rupture)
  - Greater Susceptibility to Stress Corrosion Damage
  - Greater Susceptibility to Ultra Violet (UV) Damage
  - If fiberglass composite is included in the cylinder structure, the cylinder should be first certified without the fiberglass so it will truly be a sacrificial element

**Advantages Of Type III Cylinders**

- **Seamless Aluminum Liner**
  - Gas Tight Construction, Zero Permeation
  - No Welds, Joints, or Connections

- **Superior Impact Tolerance**
  - The rigid metal liner supports the composite and prevents or minimizes composite flexing and breakage during an impact event

- **Superior Heat Tolerance**
  - The liner conducts heat to the pressure relief devices (PRD’s)
  - The liner does not readily breakdown in heat
  - The liner holds composite fibers in place as the resin burns away

- **No Filling Restrictions in Hot or Cold Weather**
- **Superior Fast Filling Efficiency**
- **Inherent Leak Before Burst Fatigue Failure Mode**

**Aviation Grade Quality Standards**

-CNG vehicle owners and passengers deserve the same cylinder safety protections as on watercraft, railcars, and aircraft*** - Kenneth O. Miller, Director of Composite Technology.

<table>
<thead>
<tr>
<th>Minimum Burst Safety Factor (Burst Pressure ÷ Rated Service Pressure)</th>
<th>Aircraft, Railcar, and Watercraft Standards</th>
<th>ECE R110 CNG Vehicle Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td><strong>Yes</strong></td>
<td><strong>No</strong></td>
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***All Worthington CNG Type III cylinders are built with a burst safety factor of at least 3.0, and with design verification impact testing about the full cylinder periphery including the critical sidewall region.

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Fast Fill Efficiency of Type III Vessels

The aluminum liner of a Type III vessel conducts heat away from the interior storage space as the heat of compression begins to dominate the fast fill process.

Fast Fill Efficiency of Type III Vessels

- The actual lack of driving range for CNG vehicles is not due to poor CNG fuel mileage but rather in most cases is a miscalculation of fuel capacity of a CNG cylinder in fast fill operations.

- Where driving range and weight of the vehicle are critical limitations, Type III cylinders provide a significant improvement in tank weight. Selection of Type III cylinders will provide a twenty to twenty-eight percent increase in driving range over type IV composite, the lightest tanks previously available, without increasing vehicle gross weight. Comparing Type I steel cylinders to Type III aluminum liner cylinder, the Type III provides a sixty-six percent weight savings or approximately three times the driving range at the same tank weight.

- Driving range is determined by the mass of natural gas stored on the vehicle. If two cylinders of the same storage (water) volume are filled to the same pressure, but the gas inside one cylinder is colder when filling is completed, the gas in the colder cylinder is more dense. As such, the cylinder with cold gas is storing a larger mass of gas and will provide greater driving range than the cylinder with hotter gas inside. Interestingly, cylinders that get very warm on their exterior during fill are actually dissipating the internal heat of compression to the environment and will therefore have a lower internal gas temperature as compared to when this heat is locked up inside like a thermos bottle.

- CNG cylinders constructed primarily from steel (Type I) provide the most cost effective gas storage.

- CNG cylinders constructed from thin wall aluminum with full composites over-wrap (Type III) provide the most weight efficient gas storage.

Composite Stresses and Sidewall Impact Testing

- Commercial Aviation Standards Specifically Require Initial Impact Upon the Vessel Sidewall Region During the Horizontal Drop Test.

- Vessel Mishandling and Sidewall Impact Events Can and Do Occur During Manufacture, Shipping, Installation, and While In Service.

- A Rigid Internal Liner Supports the Composite Above It During an Impact Event and Eliminates or Minimizes Composite Flexing and Undetected Internal Damage to the Innermost Composite Fiber Layers During an Impact Event.
Providing superior customer service is our goal. For assistance, please contact your regional sales managers.

**General Manager, Alternative Fuels and Composite Technology**
Wayne Powers
+1 (614) 840 4746
Wayne.Powers@worthingtonindustries.com

**Western US**
John Coursesn
+1 (909) 444 2503
John.Coursesn@worthingtonindustries.com

**Eastern US**
Christopher Hanners
+1 (614) 840 4197
Christopher.Hanners@worthingtonindustries.com

**Director of Alternative Fuels and Composite Technology**
Kenneth Miller
+1 (909) 444 2533
Kenneth.Miller@worthingtonindustries.com

**Europe & Middle East**
Radisa Nunic
+3 (748) 560 6204
Radisa.Nunic@wthg.at

**Asia**
Bill Clinkscales
+1 (909) 444 2500
William.Clinkscales@worthingtonindustries.com

**Director of Sales, Fuel Systems**
Kyle Takavitz
+1 (614) 840 4737
Kyle.Takavitz@worthingtonindustries.com

**National Account Manager, Fuel Systems**
Mike Sullivan
+1 (832) 279 8692
Michael.Sullivan@worthingtonindustries.com

**National Account Manager, Fuel Systems**
Doug Peterson
+1 (321) 663 3267
Michael.Sullivan@worthingtonindustries.com

**Customer Service**
+1 (877) 860 0534
AlternativeFuel@worthingtonindustries.com