Heavy-Duty Gaseous Fuel Applications

Instructor's Manual

National Alternative Fuels Training Consortium

A Program of
West Virginia University

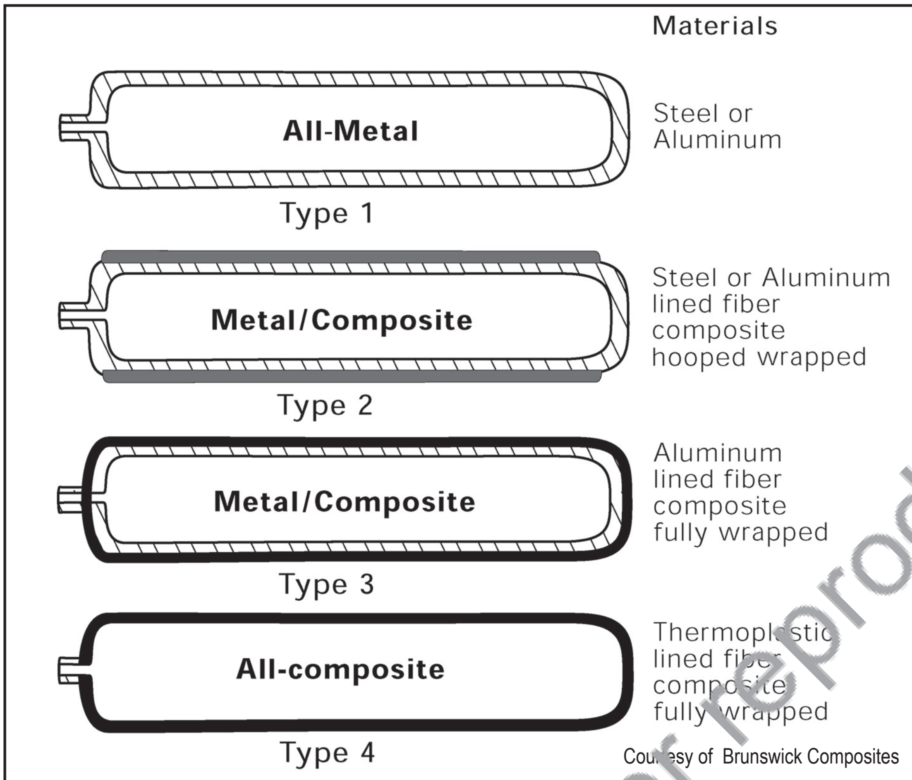

Figure 6-4: Examples of the four different types of CNG cylinders.

A typical medium- or heavy-duty bus requires four to twelve CNG cylinders, each containing approximately 1200 standard cubic feet (scf) of NG weighing from 115 to 250 pounds, depending on the material used. As shown in Figures 6-4 and 6-5, Type 1 cylinders are the heaviest, and Type 4 are the lightest in terms of weight for volume of CNG stored; Type 2 and 3 cylinders fall in between.

All-Steel or Steel Composites—Types 1 and 2

The first NG fuel containers were made entirely of steel and had a standard pressure rating of 2400 psig. Today, however, all-steel cylinders are seldom used in the US for CNG storage. All metal cylinders are classified as Type-1 cylinders. The test date was traditionally stamped on the top of the steel cylinders; however, today it is located on the label on the side wall of the cylinder.

The steel typically used in CNG cylinders is 4130x or equivalent. To achieve higher pressures, the steel or aluminum cylinders are wrapped in a composite material—commonly fiberglass or carbon fiber. Steel and composite-wrapped cylinders are classified as Type 2 (hoop-wrapped). These wrapped or composite materials can accommodate a greater range of pressures, with the typical range being 3000 to 3600 psig.

All-Aluminum or Aluminum Composites—Types 1, 2, 3

Currently, no Type 1 all-aluminum cylinders are used in motor vehicles. In order to obtain a working pressure equivalent to that of an all-steel cylinder, an all-aluminum cylinder must have thicker walls. For the same NG storage capacity, there is little weight difference between all-steel and all-aluminum NGV2 cylinders.

In contrast, however, aluminum composite cylinders are much lighter (about 25% to 50% less weight for an equal volume), compared to an all-metal cylinder. Composite cylinders are

Notes.

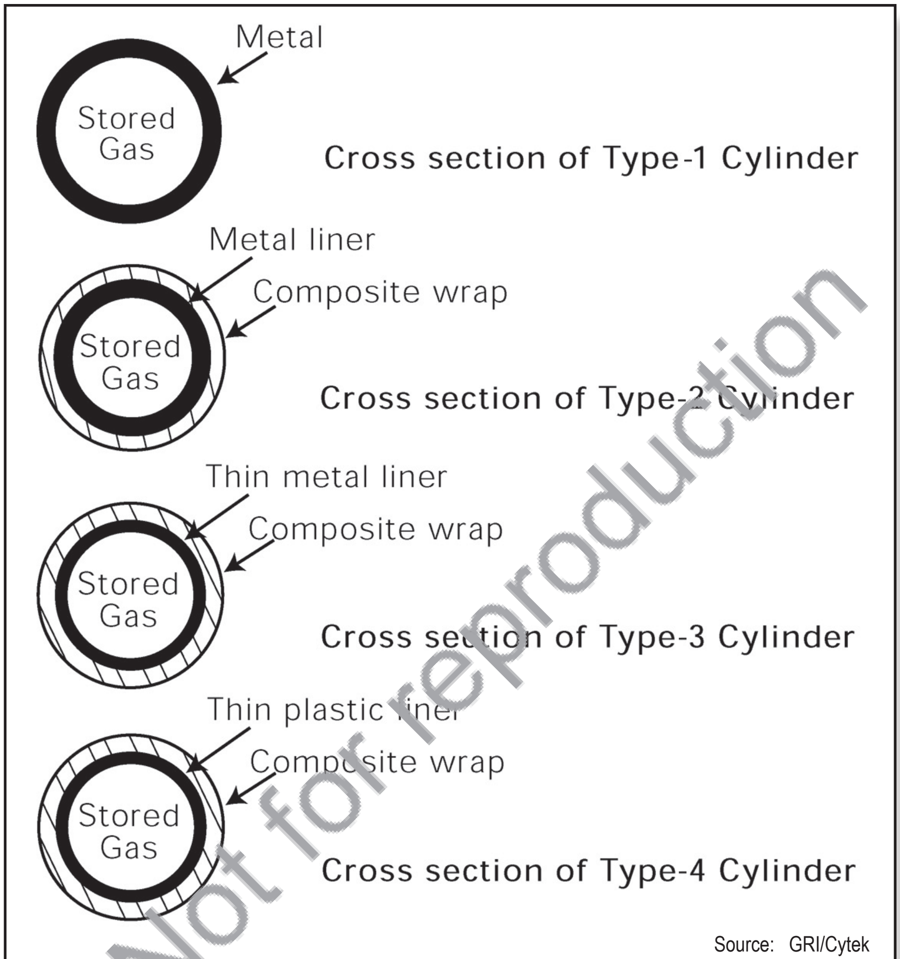

Figure 6-5: Cross sections of the four types of CNG cylinders.

classified as Type 2 (hoop-wrapped) or Type 3 (fully wrapped). The aluminum typically used in CNG cylinders is AA6010 or AA6061.

Looking at Figure 6-5, you can see that the **outside diameter** of the Type 1 and 2 cylinders is the same. However, because the Type 2's metal liner is inside the composite material, the **interior diameter (**the space available to contain the gas) is reduced. Also note the thickness of the dome in Figure 6-8 (a few pages ahead). A Type-2 cylinder has no wrap on the dome, so the metal must be thicker. The dome of the cylinder is the strongest part.

Type-2 composite cylinders are typically wrapped in S- or E-glass (fiberglass) and resin composite. The wrap is often painted for protection from caustic liquids and sunlight.

> ***Note:*** *Composite materials typically used in CNG cylinders are E-glass, S-glass, aramid, or carbon fiber. The resins used to bind and harden the composite wrap are epoxy, polyester, vinyl ester, or thermoplastic.*

Full-Composite—Type 4

Type 4 full-composite cylinders are the lightest cylinders. Type 4 cylinders are constructed from a combination of layered materials. The outer overwrap is usually a carbon fiber, covered with an epoxy resin. Typically, the inner liner is made of thermoplastic. These materials provide for a thinner wall, which results in more storage volume for the outer diameter of the cylinder, while maintaining the strength necessary to meet impact requirements (ANSI/NGV-2)

Notes.

Heat from ceiling-mounted heaters or other controllable sources can trigger a TAPRD. Take precautions with overhead heat sources and building structures when operating and servicing roof-mounted CNG cylinder vehicles.

School buses and many transit buses have under-floor-mounted cylinders with PRDs–vented or unvented. If vented, steel pipe or copper tubing is typically used.

The schematic shown in Figure 6-11B shows six CNG cylinders connected in a manifold that vents out the back and roof of the bus. State and local regulations may also impose additional requirements regarding external venting. In all circumstances, ensure that technicians are properly trained and certified before servicing or repairing high-pressure CNG systems.

High-pressure CNG Stainless-Steel Fittings and Supply Lines

All NG fuel lines between cylinders and the pressure regulator must be made from high-pressure, annealed, seamless stainless steel. The steel line must be able to withstand a hydrostatic test of **four times the working pressure** (12,000 to 14,400 psig).

In addition, the fuel lines must be resistant to corrosion and vibration. Figure 6-12 and Table 6-2 show burst pressure and the result of bursting.

Stainless steel tubing is marked with manufacturer's information and tubing specifications, including tubing diameter and wall thickness.

Keep flexible hoses from rubbing against other components and vehicle structures. Inspect frequently for leakage and signs of abrasion.

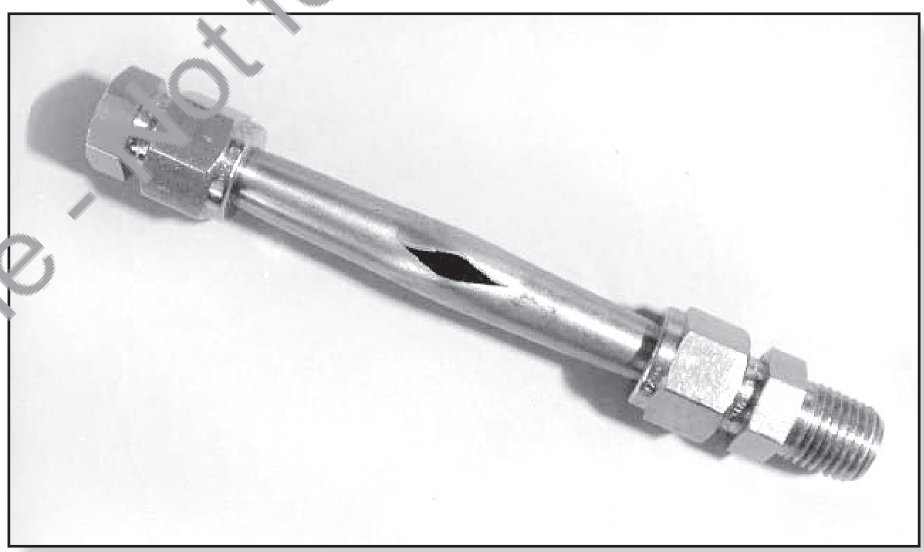

Figure 6-12: Burst sample of outer diameter (O.D.) 3/8 (0.375") x 0.0375" wall thickness tubing with a working pressure of 3,300 psig, actual test burst pressure was 17,200 psig.

Tube bending and fitting require skill and practice. Bends and loops are put in tubing to allow ease of installation and to absorb vibration. Tubing angles and lengths are calculated in various ways, using simple measurements and "eyeballing" as well as using geometric and trigonometric functions. These methods are taught in fittings seminars and vocational education programs.

> ***Note:*** *To avoid weakening tubing, do not bend tubing beyond 90°. In order to avoid surface damage, do not crimp, scratch, or clamp tubing .*

Fittings

STAINLESS STEEL ANNEALED SEAMLESS TUBING
ASTM A-213 OR EQUIVALENT
MAXIMUM AND BURST PRESSURES

Tube O.D. (in.)	Wall Thickness (in.)					
	.035		.049		.065	
	Max Press	**Burst Press**	**Max Press**	**Burst Press**	**Max Press**	**Burst Press**
1/8	12,641	50,700				
1/4	5,891	23,625	8,602	34,495	11,688	46,870
3/8	3,777	15,108	5,460	21,895	7,517	30,145
1/2	2,768	11,100	3,976	15,945	5,423	21,745
5/8	2,188	8,775	3,123	12,525	4,245	17,020
3/4	1,814	7,275	2,581	10,345	3,478	13,945

Table 6-2: Maximum and burst pressures of various thickness of steel tubing.

The swage fittings used to connect the high-pressure fuel storage and supply components must be made of stainless steel and are generally of the ferrule-compression (swage) type. The simple principle behind this high-quality fitting is that the ferrule grips the steel line as the nut compresses it against the fitting while being tightened.

Training by specific fitting and valve manufacturers (such as Swagelok) is generally available free of charge. It is highly recommended that every technician receive this training. See Figures 6-13A through F.

Each manufacturer of ferrule fittings has unique but similar design features. Read the brand name stamped on the fitting and, if possible, the pressure rating of the fitting.

> ***Note:*** *Manufacturers' guidelines must be followed very carefully before installing and assembling high-pressure fittings. Never interchange of components made by different manufacturers.*