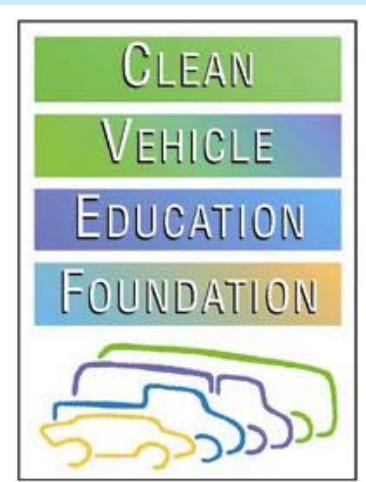


# Some Things to be Learned from the “Other” Compressed Gas Fuel System

Lessons from NGVs to the Hydrogen Vehicle Industry

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March 11, 2008

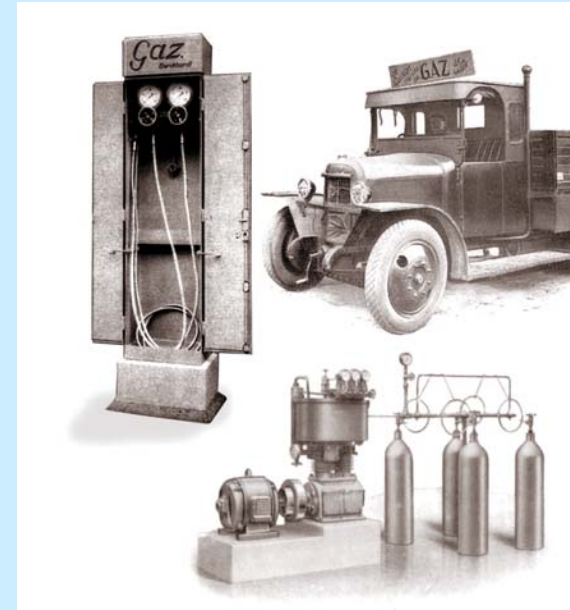
# What is the *Clean Vehicle Education Foundation*?

In 2004 the U.S. Natural Gas Vehicle Coalition split into:

- **NGVAmerica** – the lobbying and communications arm of the US NGV Industry
- **Clean Vehicle Education Foundation** – the technical arm of the US NGV Industry

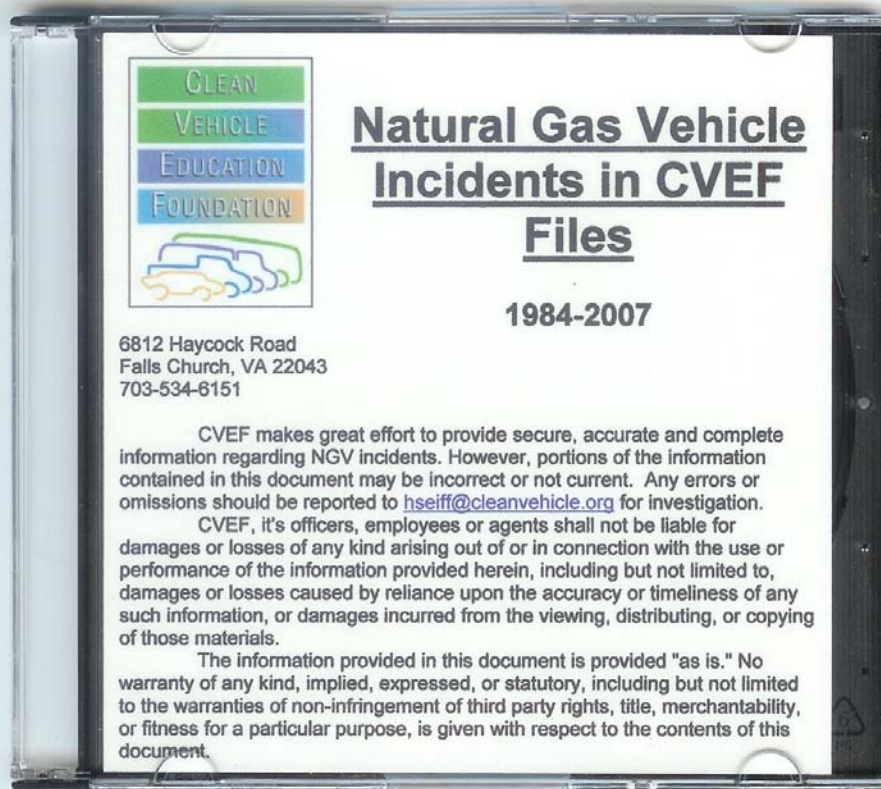


Compressed natural gas vehicles were commercialized after World War II in Italy. There are now seven million CNG vehicles on the road worldwide.



“Those who cannot learn from history are doomed to repeat it.” This presentation discusses a few of the things learned from CNG vehicles that can help assure the safety of compressed hydrogen tanks and fuel systems.

The Clean Vehicle Education Foundation runs a voluntary incident reporting program in order to learn from incidents involving NGVs.



We have details of 77 incidents since 1984, primarily in the US, plus a number of overseas incidents. We use this information to improve NGV codes and standards to assure higher levels of vehicle safety.

# Some Things the NGV Industry has Learned about cylinders which apply to Hydrogen Vehicles:



# 1. Vehicle Cylinders can be Over Pressurized and Rupture

- In the US, Cylinder PRDs are only required to protect against fires, not over pressure
- Dispensers have two separate pressure relief valves to protect the cylinder against over pressurization

In 2000 a Type 1 cylinder failed, probably from over pressurization. It is suspected that multiple failures of



pressure regulating and relief systems allowed dispensing of 400 bar gas, failing a cylinder during fueling.

Also in 2000, the over pressure sensing system on a VRA clogged, allowing over pressurization of a CNG cylinder on a delivery truck being fueled in Montreal. One of four Type 1 cylinders ruptured.

# Lesson for Compressed Hydrogen Vehicles:

Consider whether vehicle tanks should also provide protection against over pressurization.

## 2. Physical or Chemical Abuse can Damage Cylinders

- Required Chemical and physical abuse tests have strengthened over the years
- Old cylinders are still in use
- New problems constantly occur and old problems constantly recur

The first fatal accident in the US attributed to the CNG fueling system took place last year, when an older add-on Type 3 tank on a shuttle van ruptured during fueling. The failure was due to acid exposure during a previous accident.



In 1996 a Los Angeles transit bus cylinder ruptured due to physical damage. “Since the rupture all of the buses have been equipped with shields to protect the cylinders....”

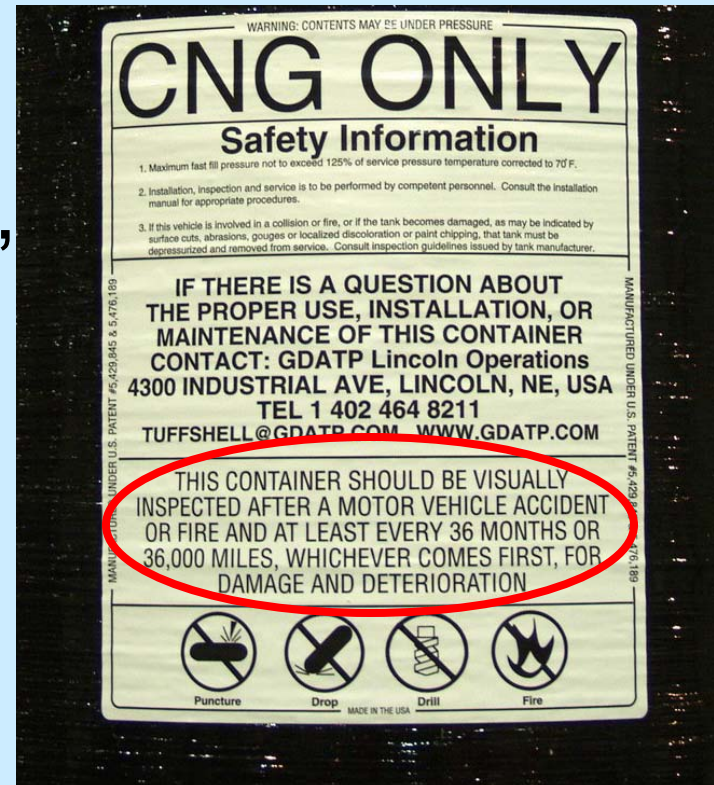
# Lesson for Compressed Hydrogen Vehicles:

Cylinders must be designed to protect against corrosive agents, road debris, and other types of foreseeable damage.

Alternatively cylinders must be mounted in the vehicle to avoid these types of damage.

# 3. Cylinders/Fuel Systems Need Inspection

- In the US the cylinder label says they **should** be inspected every three years or 36,000 mi (57,600 km), but:
- There are no laws actually **requiring** that inspection!



In September 2003 in a suburb of Toronto, a cylinder ruptured during fueling of a van which was converted to CNG in 1994. “Apparently the cylinder failed during fueling at substantially under its rated 200 bar....It was reported that there was massive external corrosion on the tank and there was no evidence of it having been inspected.”



# Lesson for Compressed Hydrogen Vehicles:

Periodic fuel system safety  
inspections help ensure safe vehicle  
operation

## 4. Pressure Relief Devices (PRDs) Sometimes Leak

- Type 1 failure – PRD fails to properly vent during a fire
- Type 2 failure – unintended venting of PRD during normal vehicle operation

Although a Type 1 PRD failure is usually more dangerous, in an Akron, Ohio bus garage in 1999 a leaking PRD led to a serious fire. In this case there were two preceding leaks, one two-weeks before and one seven-hours before the leak which led to the fire. In some cases of Type 2 failure, moisture gets into the PRD vent tube, freezes and, as it expands, damages the PRD.



# Lesson for Compressed Hydrogen Vehicles:

Type 2 failures, where PRDs vent unintentionally, must be eliminated or at least minimized.

## 5. PRDs Don't Always Protect Against Fires, Especially Localized Fires

The US PRD Standard (ANSI/CSA PRD1) contains a warning that the PRDs may not provide protection under all conditions of fire exposure, such as localized and intensive fires or fires remote from the PRD.

In September 2002 a cylinder on a Ford Crown Victoria police car “exploded during a fire” in a holding lot. A direct flame (from the interior of the vehicle) onto the cylinder mounted in the trunk caused the rupture before the PRD sensed the high temperature.

In March 2007 an arsonist torched 12 vehicles in a Seattle, WA city government holding lot. The tank in a Honda GX failed from a fire moving from the back seat area onto the center of the cylinder, while the PRD was located on one end .



Honda GX

# Lesson for Compressed Hydrogen Vehicles:

There are cases where today's PRDs may not protect the cylinders from localized fires. New designs or systems may be needed.

## 6. Fiber-Wrapped Cylinders are Expensive

Composite cylinders are used in most NGVs in the US because of their relatively low weight. They seem to be the only type of cylinder being considered for hydrogen vehicles.

A “ball park” estimate of the cost of various types of eight GGE (30 GLE), 250 bar CNG cylinders is:

Type 1 - \$375 (€253)

Type 2 - \$580 (€391)

Type 3 - \$1022 (€689)

Type 4 - \$1022 (€689)

For compressed hydrogen far higher pressures and/or larger cylinders would be needed to hold an equal amount of fuel energy, although fuel cell vehicles should have much higher efficiency.

# Lesson for Compressed Hydrogen Vehicles:

Lower cost manufacturing processes and materials must be found to substantially lower the cost of cylinders if hydrogen vehicles are to be competitive in the marketplace.

## 7. High-Pressure Cylinders have a Limited Life and Need Periodic Safety Inspection

In the US, NGV cylinders (even Type 1 cylinders, similar to industrial gas cylinders ) have been limited to 15-20 year lives, with recommended three-year safety inspections. In other countries Type 1 cylinders may have unlimited life with periodic hydro testing. But hydrogen vehicles seem to require limited-life composite cylinders for light weight.

There is no Federal vehicle safety inspection in the US and only 20 states require vehicle inspection. Both natural gas and hydrogen vehicle manufacturers strongly oppose allowing components from one vehicle to be moved to another vehicle. How can we:

1. Assure that “expired” cylinders are removed from service and replaced?
2. Assure that components from scrapped vehicles are not used on other vehicles?



“Do not use after” and “Inspection” Warnings on CNG tank label

# Lesson for Compressed Hydrogen Vehicles:

At least in the US, a way must be found to either make CH<sub>2</sub> cylinders and fuel systems safe for the life of the vehicle, or to ensure they are inspected periodically to ensure improper components are not “transplanted” and that systems remain safe.



**Questions?**