Safety Alert

Improper Use of Underrated European CNG Valves and Rupture Disc PRDs[1] on US Vehicles

The Clean Vehicle Education Foundation (CVEF) www.cleanvehicle.org has received reports of the unintended activation of rupture disc[i] style pressure relief devices (PRDs) on cylinder valves marked in accordance with the European requirements for vehicles with 200 bar service pressure (3,000 psi). These occurrences are alarming because unintended activations had not been reported since the adoption of ANSI PRD1 in [1998]. An unintended activation releases the entire contents of a CNG cylinder within a minute or two with far more severe potential consequences than a smaller leak. Had these vehicles been inside a building at the time of the unintended release, a large cloud of natural gas would have formed with high risk of a serious fire. It is very important to **not** use European or global CNG components that are not designed and marked for the higher service pressure of 3,600 psi used in the US. CVEF has reports that some distributors in the US have sold - and are still selling - these underrated components.

While underrated components were identified as the cause of the recent rupture disc activations, other failures are possible when components are used at pressures higher than their certification pressure.[ii] The appropriate markings for US cylinder valves are:

Newly Produced Cylinder Valve Marking in Accordance with ANSI NGV3.1-2012:

- Manufacturer's Identification
- Part Number
- P36 (Signifies a CNG valve designed for 3,600 psi service pressure)
- Serial number or date code
- Identification of certifying agency (CSA as one example)

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Older Cylinder Valve Marking in accordance with AGA NGV3.1-1995:

AGA NGV3.1-95
Manufacturer's Identification
Part Number
Working Pressure (Must be no less than 4,500 psi)
CNG
Identification of certifying agency (CSA as one example)
Serial number or date code

Some valves are marked and certified for both the US and Europe.

IMPORTANT! The new NGV3.1 standard has been harmonized with the NGV2 and FMVSS 304 cylinder standards. The old 1995 version of NGV3.1 required marking the working pressure instead of the service pressure as is now specified in the 2012 edition of ANSI NGV3.1. Working pressure is the maximum pressure that may occur in normal operation. This working pressure is 4,500 psi for a cylinder with a service pressure of 3,600 psi.[iii] Many valves intended for use on lower pressure European vehicles are marked with a working pressure of 260 bar or 26 MPa (3,770 psi). While this is greater than the US 3,600 psi service pressure, it is well below the required 4,500 psi working pressure.

It appears that all rupture disc PRDs currently supplied are integrated into the container valve. If a rupture disc is installed as a stand-alone device it should be marked in accordance with ANSI PRD1-2013.

PRD1-13
CNG
Service pressure P36 or 3,600 psi
Manufacturer's identification
Part number
Traceability code

Unrelated to the recently discovered use of underrated CNG valves and PRDs, CVEF also has received reports of rupture disc activation and resultant venting of fuel for discs that were designed and marked for use with 3,600 psi vehicles. With the exception of rupture disc failures in 2010 that were determined to be the result of high-sulfur CNG attacking the discs, the root causes of these rupture disc activations have not been determined. It is possible that dispenser malfunctions resulted in excessive pressure or that some failure mechanism resulted in activation at normal operating pressures. CVEF has reviewed the requirements for rupture discs in ANSI NGV2 and has determined that the reliability requirements should be strengthened. If a rupture disc activates, whether due to a filling error or due to some other unintended failure mode, the entire contents of the cylinder or vehicle will be released in a minute or two. Past experience with unreliable new PRD designs more than 15 years ago included full release of cylinder contents, and a few serious fires resulted. Experience with the use of rupture discs in our high-pressure fast fill environment indicates that traditional international rupture disc designs cannot be assumed to be reliable.

Recommendations:

1. CNG vehicle operators who have had systems installed in the last five years should verify that the container valves, PRDs, regulators and other system components that are exposed to the 3,600 psi cylinder service pressure are rated for 3,600 psi service pressure/4,500 psi working pressure. If the installer cannot provide that assurance, these components should be visually inspected. Any components that are found to be certified only for lower European and global pressures should be replaced.

2. When taking delivery of a newly installed CNG system, assure that components are all rated and marked for the 3,600 psi service pressure US operating environment.

3. Converters, alterers and equipment distributors should verify that their stocks include only components rated for our 3,600 psi service pressure/4,500 psi working pressure and dispose of any underrated components.

4. Cylinders must be equipped with PRDs that are specified by the cylinder manufacturers. Cylinder manufacturers should verify that any specified PRD, **especially rupture disc PRDs**, will have high reliability for the required 15-25 year life. ANSI PRD1 requires that all PRD manufacturers prepare Failure Mode and Effects Analyses (FMEA) that assure the necessary reliability has been achieved. <u>CVEF recommends against specifying PRDs with un-backed rupture discs unless there is assurance of reliability against unintended activation.</u>

5. PRD manufacturers should evaluate their rupture disc designs for high reliability in the normal US fill cycle that will exert pressures up to 4,500 psi at each fill under some ambient conditions.

6. Due to recent occurrences of rupture disc venting, their use should not be seen as a default requirement. Their sudden release of CNG without a preexisting fire calls into question the indoor parking and maintenance of CNG vehicles. CVEF suggests considering alternative solutions to protect against over-pressurization.[iv]

7. Dispenser designers and station operators should be aware that there are now many vehicles equipped with rupture disc PRDs. Unlike traditional temperature activated PRDs, rupture disc PRDs may vent the contents of the container either during filling or later if dispensers are not accurately calibrated and maintained. NFPA 52-2013 contains new requirements for maintenance procedures, records and verification of dispensers. It is recommended that all station operators adopt these new practices.

[i] Several different types of PRDs are available. The most common are temperature-activated devices, which open and vent gas from cylinders when the temperature exceeds their design activation temperature, which typically is slightly above the boiling point of water. The primary function of these devices is to prevent rupture of a cylinder weakened by exposure to fire. These devices are not sensitive to pressure. A less common type of PRD uses a rupture disc device that is a thin metal diaphragm designed to rupture if the pressure exceeds a certain value. Conventional rupture disc designs will vent at about 1.5 to 1.7 times the service pressure of 3,600 psi. Being highly stressed metal components, rupture discs can also fail due to fatigue from pressure cycling or environmental exposure. These devices are intended primarily to protect against over-pressurization of cylinders due to CNG dispenser errors. They may also activate in a fire and provide some protection to Type 1 or 2 containers but the insulation value of composites makes them ineffective for Type 3 and 4 cylinder fire protection. An even less-common design incorporates a spring-loaded relief valve that provides some protection against dispenser errors.

Since rupture discs and spring loaded relief valves do not offer protection against rupture in a fire, they are almost always combined with a temperature-activated device.

[ii] The ANSI PRD1 and ANSI NGV3.1 standards require many tests for qualification of a new design and additional in-process tests to assure that production PRDs and valves will also meet those same requirements. Many of the tests, such as pressure fatigue cycling, burst tests, environmental and operational tests, are conducted at pressures proportional to the marked service pressure. Designs tested successfully for the lower service pressure of 3,000 psi may fail prematurely and unsafely if used at a higher pressure such as our 3,600 psi service pressure. Some of these failures include inability to operate a valve or rupture of the component due to pressure cycling or environmental exposure.

[iii] US CNG cylinders are designed and tested for a maximum safe peak operating pressure of 4,500 psi. This pressure should only be reached if a vehicle with full cylinders is parked outside on a very hot day or if a smart fill dispenser has delivered a temperature compensated pressure to the cylinder in order to maximize range on a warm or hot day. For nearly a century, US practice for filling gas cylinders has been to fill them so that the gas pressure at a uniform temperature of 70 F does not exceed the marked service pressure. A full CNG cylinder will have a pressure of 3,600 psi at 70F and, since gas expands or contracts with temperature changes, the pressure in a full cylinder will be greater or less at any other temperature.

Full cylinder gas pressures at other temperatures are estimated as follows:

1,887 psi at -40F
2,070 psi at -25F
1,887 psi at -40F
2,070 psi at -25F
2,433 psi at 0F
2,909 psi at 30F

3,600 psi at 70 F
4,134 psi at 100F
4,474 psi at 120F

While one function of temperature compensation is to allow a cylinder to be filled on a hot day, the primary reason is safety. The major threat from failure to accurately temperature compensate fill pressure is the potential to fill a cylinder to too high a pressure in cold conditions and subsequently expose the full cylinder to fire or to hot operating conditions. This is why it is unsafe to just fill the cylinder to 3,600 psi regardless of temperature. An extreme, but feasible, case would be to fill the cylinder to 3,600 psi on the coldest day of the year in Minneapolis and use no gas until the hottest day in the summer. The estimated pressures of this scenario are:

3,600 psi at -40F
9,500 psi at 100F

The minimum design burst pressure for a new 3,600 psi CNG cylinder is 8,100 psi so we should expect a CNG cylinder to rupture at less than 9,500 psi. This scenario is entirely credible if two conditions were to exist simultaneously.

1. The CNG dispenser did not compensate for ambient temperature and thus allowed for a 3600 psi fill at -40F, and

2. The vehicle sat dormant from when it was filled during the cold weather or, more likely - in the case of a multi-cylinder fuel system, due to a defective/inoperable cylinder solenoid valve preventing gas flow from one cylinder during normal operations, thus allowing the gas in that cylinder to continue to expand as the weather warmed. .

In assisting with the investigation of cylinder ruptures, CVEF has identified dispensers operating without temperature compensated fill pressure.

[iv] Some potential alternative ways that a vehicle could be equipped to prevent over-pressurization due to a CNG dispenser error are:

1. Installation of a spring-loaded reclosing pressure relief valve. This has the advantage of only releasing enough gas to correct over-pressurization and not the whole cylinder contents. Models have shown that normal building ventilation rates are adequate to prevent serious consequences with a limited release of CNG.

2. Installation of a pressure-actuated shutoff valve in the fill line. This would shut off the gas flow into the vehicle at the maximum working pressure but would not protect against temperature compensation errors by the dispenser that would result in a delayed pressure increase.

3. Installation of a limiting orifice in a rupture disc PRD. Since the rupture disc is not required to vent gas quickly in the event of a fire, a relatively low gas flow rate can be adequate to prevent serious over-pressurization

of the cylinder. A slow rate of gas release would allow normal ventilation to prevent a large cloud of combustible gas from forming.