Reliable Temperature Compensation is Critical to CNG Vehicle Safety

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This Technical Bulletin addresses the potential hazards created by failure of compressed natural gas (CNG) dispensers that do not accurately compensate for the temperature of the natural gas in vehicle storage containers as they are filled and the history of serious incidents as a result.

Accurate temperature compensation is essential to safety whenever a CNG vehicle is fueled, regardless of the type of station. Serious incidents have resulted from the overfilling of CNG containers at fast-fill as well as time-fill fueling locations. NFPA dispenser requirements and the recommendations that follow apply to both fast-fill and time-fill dispensers, including home refueling appliances.

Furthermore, the Clean Vehicle Education Foundation (CVEF) continues to receive anecdotal reports of CNG dispensers that have been intentionally tampered with to get "a better fill." This is always unsafe and violates the basic principle of safe high-pressure system design: know the safe maximum design pressure and control the actual operating pressure accordingly.

Recommendations:

1. Station operators should contact their fast- and time-fill dispenser suppliers to make sure they have—and are using—the latest set of written instructions and maintenance schedules as required in NFPA 52-2013. The instructions for pressure and temperature calibrations and functional checks are likely unique to each smart-fill dispenser design and may require special technical assistance.

2. Station operators should schedule annual temperature and pressure calibrations and function checks in early fall to allow time for any needed corrective action before winter temperatures. The mass flow meter should also be calibrated since it may be used in the temperature compensation system. Mass flow meters at private stations, which are not checked regularly by weights and measures officials, should still be checked for safety reasons.

3. Station operators should also ask their dispenser suppliers whether existing dispensers comply with the requirements of NFPA 52-2013 edition. If the dispensers do not comply, the operator should seriously consider upgrading the equipment to provide the enhanced level of safety provided by these requirements when filling vehicles.

Rationale/Supporting Arguments for Recommendations

Why Compensate for Temperature?

The underlying safety rationale for limiting the maximum pressure in CNG containers and equipment may seem obvious. However, limiting the maximum pressure in the cylinder is not as simple as limiting the pressure dispensed to the vehicle. This is because the temperature of the gas in the container may increase *after fueling* if the temperature of the environment increases before fuel from the container is used and pressure is reduced, which may occur with warming outdoor temperatures or when parking indoors. The following recent serious incident illustrates this point. A vehicle was time-filled outdoors on an unusually cold winter night and without accurate temperature compensation; the approximate station pressure setting was 3,600 psi. In the morning, the vehicle was then moved to a heated service garage where temperatures were much warmer. The result was the pressure in the container increased to over 5,000 psi, causing a pressure relief device (PRD) to quickly vent the entire fuel load. The released fuel was ignited and the garage and vehicles burned. There have also been other serious incidents in which the container PRD was not activated by the excess pressure and the container ruptured.

Accurate temperature compensation allows dispensers to place a full fuel load on the vehicle during all weather conditions. Anytime the temperature of the gas in a cylinder is higher than 70° F, the full cylinder pressure will be greater than the commonly rated 3,600 psi service pressure at 70° F. This is allowable as long as the pressure in the cylinder does not exceed 4,500 psi during the fueling process, nor afterward, and the "settled" pressure at 70° F does not exceed 3,600 psi. While temperature compensation is a critical function for CNG vehicles that regularly operate in hot climates, it is also still important in moderate and cold weather to prevent over pressurization if the gas in the container becomes hotter than the surrounding environment was during fueling.

The safety rationale for accurate temperature compensation is especially strong in many areas of the U.S. where wide temperature swings throughout the day and throughout the year are common.

Why Does Pressure Increase with Temperature?

Thermal expansion is the natural tendency of matter to change in volume in response to change in temperature. A clear example of this physical law is what happens to a car tire with changes in temperature. When winter comes and the air in the tire becomes cold, the pressure drops and your tire pressure monitoring system may tell you to add air. The opposite may happen in summer, and if you check the pressure before and after a fast drive on a hot summer day you will find your tire pressure has increased. The same thing happens to a greater extent in a CNG container. A full container, defined as one in which the gas pressure is 3,600 psi at 70° F, will have a pressure of only 1,753 psi at -40° F and a pressure of 4,272 psi at 110° F. The following extreme case further illustrates this point. If a CNG cylinder was filled without temperature compensation to 3,600 psi at -40° F and parked until summer or otherwise exposed to a temperature of 110° F, the cylinder pressure would theoretically rise to 8,775 psi, a completely unsafe level well in excess of the applicable NGV2 CNG cylinder 8100psi burst pressure requirement.

Why Is It More Important Now?

1. Accurate and reliable temperature compensation is more critical today because many newer vehicles, especially light-duty trucks and cars, are being equipped with rupture disc PRDs. Rupture discs can provide an added level of protection for Type 1 (all metal) cylinders in a fire as over-pressurization could occur before tripping a temperature PRD (TPRD). Some manufacturers choose to install them as an added safeguard against improper temperature compensation at some existing CNG stations. CVEF believes that the combination of rupture discs and potential overfilling due to non-existent or faulty temperature compensation at the filling station may present a new hazard in indoor parking and vehicle maintenance facilities, especially in cases like the one described above. Further exacerbating this potential hazard, few states or local authorities currently inspect station dispensing systems for proper temperature compensation calibration and operation. As more of these vehicles come into service, there's potential for more frequent rupture disc-initiated cylinder vent downs inside garages as a result of faulty dispensing temperature compensation, and this presents an unacceptable hazard.

2. The second, subtler change has been the widespread adoption of individual container solenoid valves for multi-cylinder fuel systems. A major selling point of these valves is to stop large gas releases in buildings if a leak develops in a vehicle fuel line while parked or if a fuel line ruptures in a crash. However, an unanticipated threat of these valves is if they do not open properly while the vehicle is running and do not discharge fuel. This would result in gradual over-pressurization of the container by repetitive vehicle fills, which will shorten the container life and make a major reduction in its tolerance of in-service damage. If the station also fails to temperature compensate a container with a stuck solenoid valve, the pressure built on a particularly warm day could cause the rupture of an undamaged container. The 2013 change to NFPA 52 requires vehicles to have solenoid failure detection systems, but virtually no older vehicles are equipped with detection systems.

NFPA 52 Requirements for Station Operators:

NFPA 52-2013 fueling requirements are stated in language that may be difficult to understand so some explanation is added below.

<u>7.14 System Operation:</u>

7.14.1: A container shall not be charged in excess of the design pressure at the normal temperature for that container.

Explanation: The quantity of the gas in the filled vehicle containers shall not produce a pressure greater than 3,600 psi at a uniform temperature of 70° F. However, the actual gas is almost never at a uniform 70° F. This safety requirement ensures that the filled pressure is compensated for temperatures above and below 70° F.

7.14.1.1: DOT, TC, and ANSI/IAS NGV2 containers shall be charged in accordance with

DOT, TC, and ANSI/IAS NGV2 regulations.

7.14.1.2: DOT, TC, and ANSI/IAS NGV2 containers shall not be subjected to pressure in excess of 125 percent of the marked service pressure even if, on cooling, the pressure settles to the marked service pressure.

Explanation: The maximum container pressure at any point during the filling process shall not exceed 4,500 psi for a 3,600psi service pressure rated cylinder (3,600 x 1.25 = 4,500 psi).

7.14.2: A fuel supply container shall not have a settled pressure above the service pressure that is stamped on the container and displayed on a label near the filling connection, corrected for the ambient temperature at the time of filling.

Explanation: When the gas in the container reaches equilibrium at a uniform temperature, the container pressure shall not exceed the pressure that would be produced at that temperature by the gas quantity in 7.14.1

7.14.3: CNG dispensing systems shall be equipped to stop fuel flow automatically when a fuel supply container reaches the temperature-corrected fill pressure *(see 7.6.3).*

Explanation: An automatic control system independent of the dispenser operator shall be provided to shutoff the dispenser when the maximum fill, as defined in either 7.14.1 or 7.14.1.2, is reached. Manual adjustments and shutoffs do not meet this requirement.

7.14.4: The dispenser shall be designed to detect any malfunction that fills the vehicle fuel container in excess of the limits specified, or causes the relief valve required in 7.6.3 to open.

Explanation: "Any malfunction" is intended to be a very broad criteria, and much more than a simple pressure relief valve is required. An excessive fill can occur at pressures below 4,500 psi or even 3,600 psi if the temperature is low.

7.14.4.1: After any such malfunction, the dispenser shall be repaired and calibrated in accordance with Section 7.16 before continued operation.

7.14.4.1.1: The excess fuel shall be removed from the vehicle.

7.14.4.2: If the vehicle fuel system has been pressurized in excess of 1.25 times the service pressure of the fueling connection, the dispenser shall be shut down until repaired and calibrated, and the vehicle operator shall be notified to contact the container manufacturer for approval before continued operation.

Explanation: Overfilling the container so that the pressure exceeds 4,500 psi or may rise to more than 4,500 psi as a result of later warming may require that the container be replaced, which exposes stations to possible liability.

<u>7.16 Station Systems Maintenance and Verification Requirements:</u>

7.16.2: Written instructions shall be provided for CNG dispensing systems to include the following:

(1) Operating instructions (2) Emergency shutdown instructions (3) Maintenance and repair instructions (4) Instructions for pressure and temperature calibrations and functional checks to assure that the dispenser continues to satisfy the requirements of Section 7.14.

7.16.3: Dispensing systems shall be maintained in accordance with the instructions required in 7.16.2 to verify pressure control and pressure relief valves.

7.16.3.1: A written record of maintenance shall be provided.

Note: NFPA 52 should probably have included the mass flow meter in the calibration requirements since some dispensers use mass measurements to determine when to stop fueling. The accuracy of the mass flow meter on a retail station is typically tested annually but many dispensers are installed in private, non-retail stations.

What Pressure in the Container Is Acceptable?

The following table is presented to give a better idea of how significantly the pressure in a CNG container changes with changes in the temperature of the gas in the container. If the vehicle is parked for several hours after fueling, the gas in the container will settle to a temperature close to the ambient temperature reading on an outdoor thermometer and the actual pressure should not exceed the values in the table. This table cannot be used immediately after fueling because CNG gets hotter as it is forced into the container. This effect is referred to as compression heating and is independent of the heating that occurs in the actual CNG station compressor. It occurs whenever the pressure in the container is increased by adding fuel and can be many tens of degrees F.

Temperature Compensated Cylinder Pressure	
3,600 psi service pressure calculated from the standard gas composition used to create the gasoline gallon equivalent	
Gas Temperature, Degrees F	Pressure in Full 3,600 psi CNG Container, psig
123.6	4,500
120.0	4,455
110.0	4,272
100.0	4,105
90.0	3,936
80.0	3,768
70.0	3,600
60.0	3,432
50.0	3,263
40.0	3,094
30.0	2,926
20.0	2,757
10.0	2,589
0.0	2,421
-10.0	2,253
-20.0	2,086
-30.0	1,919
-40.0	1,753

For any questions about this bulletin, please contact John Dimmick at 262-549-1894 or JDimmick@cleanvehicle.org

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