SAE International™

# SURFACE VEHICLE INFORMATION REPORT

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Pressure Terminology Used In Fuel Cells and
Other Hydrogen Vehicle Applications

RATIONALE

Not applicable.

## 1. SCOPE

SAE J2579 is being developed by the SAE Fuel Cell Vehicle (FCV) Standards Committee to provide recommended practices for Fuel Systems in Fuel Cell and Other Hydrogen Vehicles. As part of this work, definitions for pressurized systems and containers were developed. The purpose of this document is to disseminate these definitions prior to the release of SAE J2579 such that other technical groups are aware of the information.



## 2. REFERENCES

### 2.1 Applicable Publications

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest version of SAE publications shall apply.

#### 2.1.1 SAE Publications

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J2578 Recommended Practice for General Fuel Cell Vehicle Safety

SAE J2600 Compressed Hydrogen Surface Vehicle Refuelling Connection Devices

### 2.2 Related Publications

The following publications are provided for information purposes and are not a required part of this document. They should be consulted for additional information.

#### 2.2.1 ASME Publication

Available from the ASME, 22 Law Drive, PO Box 2900, Fairfield, NJ 07007-2900, Tel: 973-882-1170, www.asme.org.

ASME B&PVC Section VIII Part UG Section 125



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2.2.2 CSA America Publications

Available from CSA America, 8501 East Pleasant Valley Road, Cleveland, OH 44131-5575, Tel: 216-524-4990, www.csa-america.org.

CSA America HGV 2 Compressed Hydrogen Vehicle Fuel Containers

CSA America HPRD-1 Pressure Relief Devices for Hydrogen Vehicle Fuel Containers

CSA America HGV 3.1 Fuel System Components for Hydrogen Gas Powered Vehicles

CSA America HGV 4.1 Hydrogen Gas Vehicle (HGV) Dispensing Systems

CSA America HGV 4.2 Hoses for Compressed Hydrogen Vehicles and Dispensing Systems

CSA America HGV 4.3 Temperature Compensation Devices for Gaseous Hydrogen Vehicle Fuelling Stations

CSA America HGV 4.4 Breakaway Devices for Hoses Used in Hydrogen Vehicle Fuelling Stations

CSA America HGV 4.5 Priority and Sequencing for Hydrogen Vehicle Fuelling

CSA America HGV 4.6 Manually Operated Valves Used In Gaseous Hydrogen Vehicle Fuelling Stations

CSA America HGV 4.7 Automatic Pressure Valves for Use In Gaseous Hydrogen Vehicle Fuelling Stations

CSA America HGV 4.8 Hydrogen Gas Vehicle Fuelling Station Compressor

## 3. DEFINITIONS

### 3.1 Chemical Hydride System

A system that stores materials with chemically bonded hydrogen, releases hydrogen through chemical reactions, and stores reaction byproducts for later removal.

### 3.2 Flammability Limits

The limits of sufficient concentrations of fuel and oxidant to propagate combustion from an ignition source.

NOTE: See SAE J2578 for a complete discussion.

#### 3.2.1 Upper Flammability Limit (UFL)

Highest concentration of fuel at which there is sufficient oxidant in the gas mixture for the mixture to be flammable.

NOTE: The UFL of hydrogen is 74% in air and 95% in pure oxygen as in each case 5% oxygen is required in the mixture. See SAE J2578 for a complete discussion.

#### 3.2.2 Lower Flammability Limit (LFL)

Lowest concentration of fuel at which a gas mixture is flammable.

NOTE: National and international standard bodies (such as NFPA and IEC) recognize 4% hydrogen in air as the LFL. See SAE J2578 for a complete discussion as this criterium is appropriate for some circumstances and inappropriate for other situations.

3.2.3 Non-Flammable

Fluid that cannot propagate or sustain combustion at its point of release or as it disperses in the surrounding atmosphere (or fluid).

NOTE: See SAE J2578 for a complete discussion.

3.3 Hazardous Fluids

Gases or liquids that pose potential dangers. Hazards present with fluids in fuel systems are as follows:

a. Flammability—Sufficient quantities of fuel/air mixtures at or above the lower flammability limit (LFL) are by definition dangerous. Fuel/air mixtures below 25% LFL are considered non-hazardous.

b. Toxicity—Point sources greater than the IDLH (Immediately Dangerous to Life and Health) as defined and stipulated by NIOSH (National Institute of Occupational Safety and Health) and accessible areas greater than Occupational Safety and Health Administration (OSHA) TWA (Time Weighted Average) should be considered hazardous.

c. High Pressure—High-pressure fluids in fuel supply subsystems, fuel processors, fuel cells, and/or thermal management subsystems that can transfer kinetic energy causing personal injury.

d. Extreme Temperature—Very high or low temperature fluids or materials that are capable of causing personal injury such as burns or frostbite.

e. Reactive—Materials that can react with other common materials and can directly or indirectly pose hazards to humans. Fluids with extreme pH are examples.



3.4 Hazardous Materials

Hazardous fluids or solids that pose potential dangers.

3.5 Hydrogen Handling System

The system that processes, conditions, and/or conveys hydrogen (or hydrogen rich gas) to the fuel cell or engine.

3.6 Hydrogen Storage System

System of assembled components that include the containment vessel(s), shut-off valves, interconnecting fuel piping/lines, shields, and other system elements (as identified by the manufacturer) required to contain and isolate the stored hydrogen.

3.7 Maximum Allowable Working Pressure (MAWP)

The MAWP is the maximum gauge pressure of the working fluid (gas or liquid) to which process equipment or system is rated with consideration for initiating fault management above normal operation.

NOTE: See Appendix A for an illustration and discussion of the relationship between various pressure vessel and container terms.

3.8 Maximum Developed Pressure (MDP)

The MDP is the highest gauge pressure that occurs during failure management.

NOTE: See Appendix A for an illustration and discussion of the relationship between various pressure vessel and container terms.

3.9 Maximum Fill Pressure

The maximum fill pressure is the highest gauge pressure, as specified by the manufacturer, that is normally encountered during a fueling process.

NOTE: See Appendix A for an illustration and discussion of the relationship between various pressure vessel and container terms.

3.10 Maximum Operating Pressure (MOP)

The MOP is the highest gauge pressure of a component or system that is expected during normal operation including starts, stops, and transients.

NOTE: See Appendix A for an illustration and discussion of the relationship between various pressure vessel and container terms.

3.11 Nominal Working Pressure (NWP)

The NWP is the gauge pressure that characterizes typical operation of a pressure vessel, container, or system. For compressed hydrogen gas containers, NWP is the container pressure, as specified by the manufacturer, at a uniform gas temperature of 15 °C (59 °F) and full gas content.

NOTE: NWP is also called Service Pressure. See Appendix A for an illustration of the relationship between various pressure vessel and container terms.

3.12 Normal Operation

Normal operation includes all operating and non-operation modes encountered during product use that are not the result of a failure.

3.13 Pressure Relief Devices (PRD)

A pressure and/or temperature activated device used to prevent rupture or burst of a pressurized part or system.

3.13.1 Primary Pressure Relief Device

A PRD that provides protection from process faults.

3.13.2 Secondary Pressure Relief Device

A PRD that provides redundancy and/or protection from externalities.

3.14 Reversible Metal Hydride

A metal-hydrogen compound for which there exists an equilibrium condition where the metal alloy, hydrogen gas and the metal-hydrogen compound co-exist. Changes in pressure, temperature or electrical potential will shift the equilibrium favoring the formation or decomposition of the metal-hydrogen compound with respect to the metal alloy and hydrogen gas.

3.15 Rupture

A structural failure resulting in the sudden release of stored energy or contents in such a manner that it poses a safety hazard to people or property.

## 4. GENERAL REQUIREMENTS

There are two sets of pressure terminology commonly used and the differences between these terminology sets are rooted in their distinct applications; the Pressure Vessel Terminology is used in processes and flowing systems and the Container Technology is used for gas storage. Each of these applications are discussed in Sections A.1 and A.2.

Additionally, as part of developing a unified approach for developing pressurized systems for vehicles, a set of terminology was developed to “bridge the gap” between these two sets of terminologies. This “bridging” terminology as used throughout this document is discussed in Section A.3.

When the vehicle is connected to the dispenser for fueling, the vehicle is then dependent on the dispenser and fuel station to perform various filling and protective functions. While the specific functions are noted (or implied) in SAE J2578, SAE J2600, and other documents being developed by SAE, a listing of these functions is provided in Appendix B to provide a comprehensive overview points where common terminology and requirements needs to be defined and communicated between various standards-writing organizations.

PREPARED BY THE SAE FUEL CELL SAFETY WORKGROUP
OF THE SAE FUEL CELL STANDARDS COMMITTEE

# APPENDIX A - PRESSURE VESSEL TERMINOLOGY

***The purpose of this appendix is to compare the two terminologies and show equivalencies. In order to accomplish this goal, simplifications and generalizations are made to facilitate comparison. The information in this appendix should not be used to demonstrate compliance with any particular standard; the actual standards should be consulted for this purpose.***

## A.1 PRESSURE VESSEL TERMINOLOGY

Pressure vessel terminology is commonly used in the design of processes and flowing systems. This terminology is used for the design of process equipment in oil refineries and steam generation plants based on the ASME Boiler and Pressure Vessel Codes, for example.

The terminology is based on determining normal operating limits for the particular processes being designed. The Maximum Operating Pressure (MOP) is the highest gauge pressure expected during normal steady-state and transient operating modes including starts, stops, and control over-shoots that do not involve failures. The possibility of trapping gas between shutoff valves on shutdowns should be addressed. For example, the European Integrated Hydrogen Project (EIHP) suggests that the MOP be at least 1.3 times higher than the Nominal Working Pressure.

Margin is usually provided by the system designer between the MOP and set-points for Pressure Relief Devices, if used, to avoid inadvertent operation. Relief valves typically require about 10% margin, other devices may require more margin.

In general, a combination of primary and secondary Pressure Relief Devices (PRDs) are used to protect the pressurized system from damage. Primary PRDs, when required, are set to actuate at or below the Maximum Allowable Working Pressure (MAWP) of the equipment being protected against faults in order to account for pressure drops between the equipment being protected and the PRD as well as provide design margin. The primary PRD should limit any over-pressure event to no more than 110% of the MAWP. Secondary PRDs are used, when appropriate, to provide redundancy or protection from externalities. The secondary PRD are usually designed so that they do not interfere with the operation of the primary PRDs. While the specific margins and setpoint requirements vary between different codes and standards groups, the combination of primary and secondary PRDs generally limit pressure during any over-pressure event to no more than 150% of the MAWP.

Maximum Allowable Working Pressures (MAWP) for equipment represents the highest gauge pressure that the equipment may encounter during normal operation. Stresses at the MAWP are typically designed to not exceed 2/3 of yield and 1/3 of ultimate strength of pressure-containing parts over the projected life such that failure management can be accomplished without damage. The proof test (and burst test, when used) is used to demonstrate structural integrity.



## A.2 CONTAINER TERMINOLOGY

The container terminology is based on tanks or vessels that have been charged with a fixed amount (mass) of gas. The Service Pressure (or preferably Nominal Working Pressure per discussion in Appendix A.3) represents the settled pressure of a full tank on a 15 °C (59 °F) day for compressed hydrogen.

NOTE: The definition of service pressure for compressed natural gas is not the same as hydrogen and is based on 21 °C (70 °F).

In this system, pressure variations are predictable through thermodynamic relationships, primarily due to temperature. Pressure excursions are, therefore, predictable based on variations in ambient temperature and compression heating during the charging (fueling) of containers. The Maximum Fill Pressure is expected to not exceed 1.25 times the Nominal Working Pressure (NWP).

In order to prevent human errors and control faults causing an inadvertent over-fill of the tank, it is assumed that a PRD on the filling station will provide fault protection. Following the guidance in Section A.1, the PRD will be set up to 1.38 times the NWP, and the pressure could reach approximately 1.50 times the NWP during fault management.

## A.3 TERMINOLOGY USED IN THIS DOCUMENT TO "BRIDGE THE GAP"

Vehicles are faced with the likelihood that equipment designed (and labeled) to both systems will be present and actually interconnected. For example,

a. the fueling station will probably be designed to the Pressure Vessel Terminology as this terminology system is typically used in stationary equipment,

b. the high pressure compressed hydrogen container and associated equipment will be designed and labeled to the Container Terminology, and

c. the process equipment in the low pressure fuel cell system will likely be designed (and labeled) to the Pressure Vessel Terminology as this terminology is very common in process equipment.

The use of both terminology systems within a single application can be confusing and could lead to errors. Since both systems exist and are established within the industry, the SAE Fuel Cell Standards Committee has established terminology which attempts to avoid confusion. Additionally, an illustration has been constructed (see Figure A) to show the correspondence of the two terminologies for a situation common to fuel cell vehicles. The key points that can be derived from the illustration are as follows:

a. The Nominal Working Pressure (NWP) as defined in Section 3.10 is generally applicable. In the case of flowing process systems (using Pressure Vessel Terminology) it represents a typical, characterizing process condition. In the case of Container Terminology, it is characterized as a full tank after settling to 15 °C (59 °F). The use of the term NWP is preferable to Service Pressure as it "warns" the user that it is a nominal condition and not the maximum.

b. The Maximum Operating Pressure of the Pressure Vessel Terminology is equivalent to the Maximum Fill Pressure of the Container Terminology.

c. The Primary Relief Setting of the Container Terminology is similar to that used in Pressure Vessel Terminology. With the relief valve set to 1.38 (1.25 X1.10) times the Nominal Working Pressure of the Container, the 10% margin typically selected by process engineers using the Pressure Vessel Terminology is provided to prevent inadvertent operation of the PRD.

d. Since the PRD in the fill station is located at the pressure source, no margin is necessary for protecting the vehicle fuel system. The MAWP as used in the Pressure Vessel Terminology corresponds to 1.38 times the NWP for this case.

e. The Maximum Developed Pressure (MDP) is equivalent to 1.5 times the MAWP and matches the yield pressure in pressure vessel terminology. For the case of fault management during filling of high pressure compressed hydrogen, the MDP corresponds 1.5 times the NWP.