



UL 2267

STANDARD FOR SAFETY

Fuel Cell Power Systems for Installation in
Industrial Electric Trucks

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UL Standard for Safety for Fuel Cell Power Systems for Installation in Industrial Electric Trucks, UL 2267

Second Edition, Dated March 27, 2013

Summary of Topics

The new edition dated March 27, 2013 was issued to reflect the current ANSI approval, incorporate minor editorial changes, some clarifications, organizational changes, renumbering changes, and revisions to harmonize with the criteria in the Standard for Electric-Battery-Powered Industrial Trucks, UL 583.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated January 25, 2013.

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MARCH 27, 2013



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UL 2267

**Standard for Fuel Cell Power Systems for Installation in Industrial Electric
Trucks**

First Edition – April, 2006

Second Edition

March 27, 2013

This ANSI/UL Standard for Safety consists of the Second Edition.

The most recent designation of ANSI/UL 2267 as an American National Standard (ANSI) occurred on March 27, 2013. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, or effective date information.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at <http://csds.ul.com>.

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APPENDIX B

INTRODUCTION

1 Scope

1.1 These requirements cover fuel cell power systems intended to be installed in Type E or Type CGH industrial trucks used in locations as defined in the Standard for Powered Industrial Trucks, Including Type Designations, Areas of Use, Conversions, Maintenance, and Operation, NFPA 505, the National Electrical Code, ANSI/NFPA 70, and the Standard for Electric-Battery-Powered Industrial Trucks, UL 583.

1.1 revised March 27, 2013

1.2 The fuel cell power systems covered by this standard are anticipated for use as described in the:

- Safety Standard for Low Lift and High Lift Trucks, ANSI/ITSDF B56.1;
- Safety Standard for Guided Industrial Vehicles and Automated Functions of Manned Industrial Vehicles, ANSI/ITSDF B56.5;
- Safety Standard for Rough Terrain Forklift Trucks, ANSI/ITSDF B56.6;
- Safety Standard for Industrial Crane Trucks, ANSI/ITSDF B56.7;
- Safety Standard for Personnel and Burden Carriers, ANSI/ITSDF B56.8;
- Safety Standard for Operator Controlled Industrial Tow Tractors, ANSI/ITSDF B56.9; and the
- Safety Standard for Manually Propelled High Lift Industrial Trucks, ANSI/ITSDF B56.10,

as applicable to the intended truck.

1.3 These requirements cover fuel cell power systems that incorporate a permanently mounted pressure vessel containing compressed hydrogen gas.

1.4 These requirements cover the use of designs that are fueled by hydrogen gas without the pressure vessel being removed from the industrial truck (onboard fueling).

1.5 These requirements cover only the fuel cell and fuel cell balance of plant components including the power and/or power conditioning electronics, regardless of packaging, as defined in 2.11 and Figure 2.1, as well as any components in classified zones.

2 Glossary

2.1 For the purpose of this standard, the following definitions apply.

2.2 **ABNORMAL OPERATION** – Operation of the fuel cell power system with any one electrical or control component malfunction or failure, in any failure mode regarded as reasonably probable in the FMEA; but excluding accidental rupture or breakdown of the containers of flammable liquids, vapors and/or gases.

2.3 **BONDING** – The permanent joining of metallic parts to form a positive electrically conductive path that provides electrical continuity between non-current carrying metal parts and is capable of conducting any fault current that may occur.

NOTE – This applies to bonding within the fuel cell system and between the fuel cell system and truck and does not refer to the means to ground the truck itself, such as with a grounding strap or with tires. Acceptable methods of bonding shall be by any positive means, such as by a clamp, rivet, bolt, screw, welded joint, soldered or brazed joint, or a bonding jumper with a closed loop connector secured by a screw.

2.4 **CHECK-VALVE** – Fluid control device that allows fluids to flow in only one direction.

2.5 **CIRCUIT, HIGH-VOLTAGE** – A circuit involving a potential greater than 42.4 V peak (30 Vrms) or 60 Vdc.

2.6 **CIRCUIT, LOW-VOLTAGE** – A circuit involving a peak open-circuit potential of not more than 42.4 V (30 Vrms) or 60 Vdc supplied by a battery, a fuel cell, a Class 2 transformer, or by a combination of a transformer and a fixed impedance that as a unit, complies with all performance requirements for a Class 2 transformer. A circuit derived by connecting a resistance in series with a voltage supply circuit as a means of limiting the voltage and current, is not considered to be a low-voltage circuit.

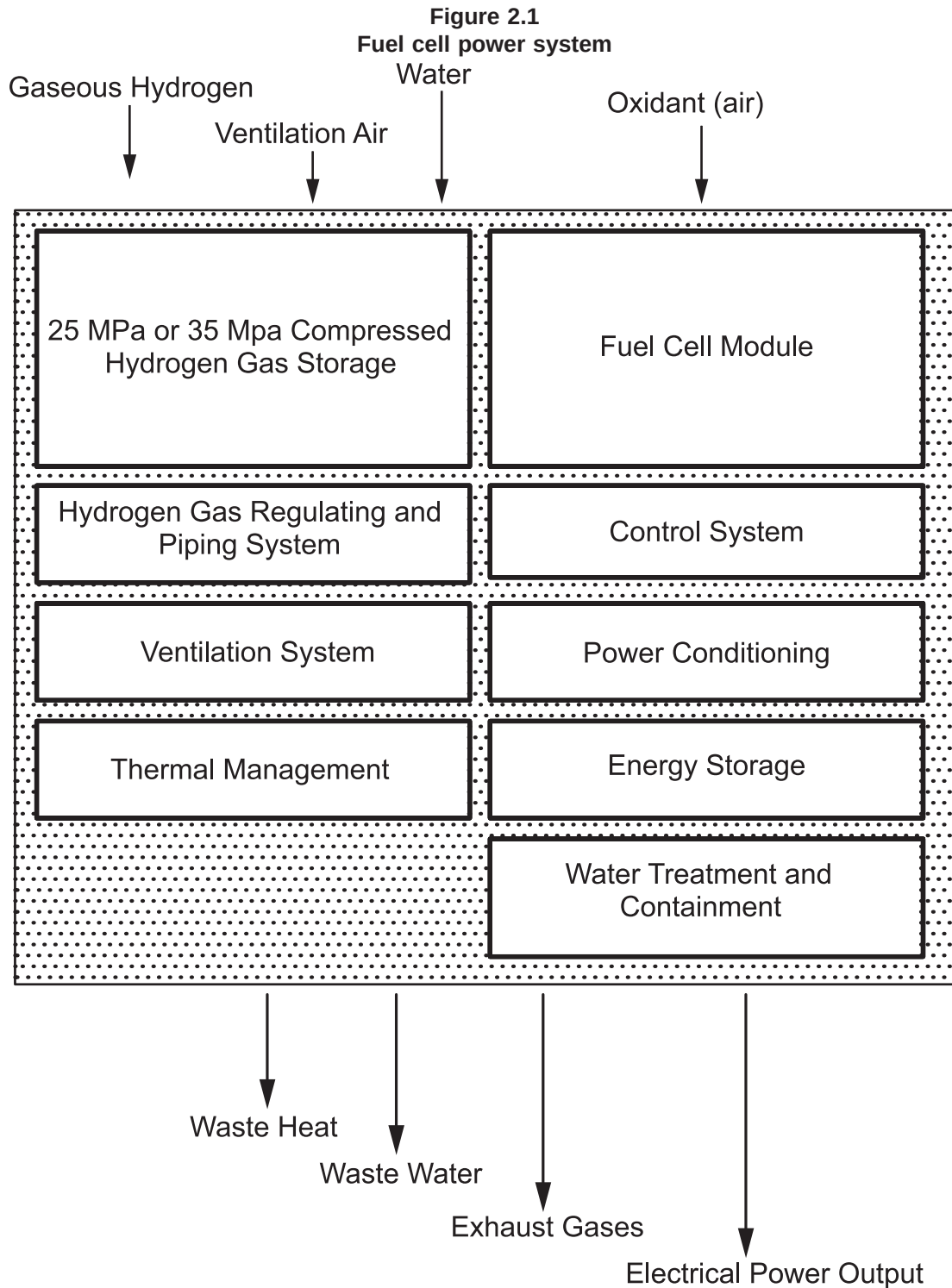
2.7 **DILUTION BOUNDARY** – The extent of a flammable area or zone created by a limited release of flammable gas or vapor, internal to the fuel cell power system or truck in which it is mounted, and controlled by mechanical ventilation or other effective means as outlined by Electrical Apparatus for Explosive Gas Atmospheres Part-10: Classification of Hazardous Areas, IEC 60079-10.

2.8 **ELECTROSTATIC DISCHARGE (ESD)** – Discharge created by static electricity.

2.9 **FUEL CELL POWER SYSTEM** – An assembly of components and parts that together electrochemically converts fuel and oxidant to electrical current. See Figure 2.1 for a block diagram of a fuel cell power system. A fuel cell power system may contain all or some of the components shown in Figure 2.1. The fuel cell power system for use with industrial trucks will be in one of the following forms:

SELF-CONTAINED SYSTEM – A complete system incorporated into its own housing that is intended to replace or combine with a battery system to power an industrial truck. Additional counterweighting may be located outside of the system's housing. Display and control functions may be located outside the system's housing in proximity to the operator's compartment.

INTEGRATED SYSTEM – A complete system of fuel cell components and parts that are incorporated into the industrial truck with the various parts of the system potentially distributed throughout the truck.



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Note: A fuel cell power system may contain all or some of the above components

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2.10 HAZARDOUS (CLASSIFIED) AREAS – Any work area or space where combustible dust, ignitable fibers, or flammable, volatile liquids gases, vapors or mixtures are or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures as defined by the National Electrical Code, ANSI/NFPA 70, or by Electrical Apparatus for Explosive Gas Atmospheres Part-10: Classification of Hazardous Areas, IEC 60079-10.

2.11 INTEGRAL – For the purposes of this standard, something that is either contained within the fuel cell power system or is external, but is a part of the fuel cell power system.

2.12 LIMITED POWER CIRCUIT – A circuit supplied from a source whose open circuit voltage is less than or equal to 60 Vdc and whose maximum current and power after 60 s of operation comply with the values outlined in Tables 30.1 and 30.2. Limited power circuits are considered equivalent to NEC Class 2 circuits as outlined in the National Electrical Code, ANSI/NFPA 70 and to low-voltage limited energy circuits as defined in Section 16 of the Standard for Electric-Battery-Powered Industrial Trucks, UL 583.

2.12 revised March 27, 2013

2.13 LOWER FLAMMABILITY LIMIT (LFL) – The lowest volume percentage of a gas in air that will ignite.

NOTE: The LFL for hydrogen is 4% by volume.

2.14 MAXIMUM ALLOWABLE WORKING PRESSURE (MAWP) – The maximum gauge pressure of the contained fluid for which each portion of the system is rated with consideration of an abnormal condition that initiates the operating of the safety pressure relief devices. See Appendix B for a comparison table of pressure terms.

2.15 MAXIMUM CONTINUOUS LOAD RATING – Maximum continuous power that can be sustained by the fuel cell system independent of any electrical energy storage device or storage component at 25°C (77°F) and 1 atm.

2.16 MAXIMUM OPERATING PRESSURE (MOP) – The highest gauge pressure of a component or the system that is expected during normal operation. See Appendix B for a comparison table of pressure terms.

NOTE – It is typically no more than 1.25 times the service pressure and a 10%-margin below the pressure relief device setting.

2.17 NORMAL RELEASE – Limited internal localized volumes of flammable vapor concentrations released during normal operation that may include fuel cell purge.

2.18 NORMAL OPERATION – All operating and non-operating modes encountered during product use that are not the result of a failure.

2.19 PRESSURE RELIEF DEVICE (PRD) – A pressure and/or temperature activated device used to prevent the pressure from rising above a predetermined maximum and thereby prevent failure of a pressurized part or system.

2.20 SAFETY CONTROL – Automatic controls and interlocks including relays, switches, sensors and other auxiliary equipment used in conjunction therewith to form a safety control system, which is intended to prevent unsafe operation of the controlled equipment.

2.21 SAFETY CRITICAL COMPONENT – A component, device, circuit, software, or similar part whose failure would affect the safety of the fuel cell power system as determined by Safety/Hazard Analysis, Section 18.

2.22 SERVICE PRESSURE – This term only relates to the hydrogen pressure vessel, and is the pressure, as specified by the manufacturer, at a uniform gas temperature of 15°C (59°F) and full gas content. Service pressure is equivalent to the term “nominal working pressure”. See Appendix B for a comparison table of pressure terms.

2.23 STACK PURGE – A controlled hydrogen release from the stack fuel circuit.

2.24 TOUCH CURRENT – Electric current through a human body or an animal body when it touches one or more accessible parts.

2.25 TYPE CGH INDUSTRIAL TRUCK – An electrically operated industrial truck that utilizes a compressed hydrogen powered unit utilizing a fuel cell for conversion of the hydrogen fuel gas to electricity that has minimum acceptable safeguards against inherent fire hazards. Type CGH Industrial Trucks can be operated in locations as outlined in the Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operation, NFPA 505.

2.25 added March 27, 2013

2.26 TYPE E INDUSTRIAL TRUCK – An electrically powered truck that has minimum acceptable safeguards against inherent fire and electrical shock hazards. Type E Industrial Trucks can be operated in locations as outlined in the Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operation, NFPA 505.

2.27 ZONE SYSTEM OF CLASSIFICATION – The means for classifying areas within the fuel cell power system in accordance with Article 505 of the National Electrical Code, ANSI/NFPA 70, and the methods outlined in Electrical Apparatus for Explosive Gas Atmospheres Part-10: Classification of Hazardous Areas, IEC 60079-10. The potential zones of this system are:

- Class I, Zone 0 – A location in which ignitable concentrations of flammable gases or vapors are present for long periods of time (e.g. inside the fuel cell stack or other hydrogen carrying components).
- Class I, Zone 1 – A location:
 - a) In which ignitable concentrations of flammable gases or vapors are likely to exist under normal operating conditions; or
 - b) In which ignitable concentrations of flammable gases or vapors may exist frequently because of repair or maintenance operations or because of leakage; or
 - c) In which equipment is operated or processes are carried on of such a nature that equipment breakdown or fault operations could result in the release of ignitable concentrations of flammable gases or vapors and also cause simultaneous failure of electrical equipment in a mode to cause the electrical equipment to become a source of ignition; or
 - d) That is adjacent to a Class I, Zone 0 location from which ignitable concentrations of vapors could be communicated, unless communication is prevented by adequate positive pressure ventilation from a source of clean air and effective safeguards against

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ventilation failure are provided (e.g. space in which purge gases are immediately released to be diluted or areas immediately adjacent to the fuel cell stack and hydrogen recirculation system).

- Class I, Zone 2 – A location:

- a) In which ignitable concentrations of flammable gases or vapors are not likely to occur in normal operation and if they do occur, will exist only for a short period; or
- b) In which volatile flammable liquids, flammable gases or flammable vapors are handled, processed, or used, but in which the liquids, gases or vapors normally are confined within closed containers or closed systems from which then can escape only as a result of accidental rupture or breakdown of the containers or system or as a result of abnormal operation of the equipment with which the liquids or gases are handled, processed, or used; or
- c) In which ignitable concentrations of flammable gases or vapors normally are prevented by positive mechanical ventilation, but which may become hazardous as result of failure or abnormal operation of the ventilation equipment; or
- d) That is adjacent to a Class I, Zone 1 location from which ignitable concentrations of flammable gases or vapors could be communicated, unless such communication is prevented by adequate positive-pressure ventilation from a source of clean air and effective safeguards against ventilation failure are provided (e.g. an area with a hydrogen fuel line and fittings at bulkhead locations but without components - a pass through).

- Unclassified Zone – A location:

- a) In an area where there is no risk of ignitable concentrations of flammable gases; or
- b) Where flammable gases are not present as part of the standard processes; or
- c) Where there are no fittings that may leak; or
- d) That is adjacent only to other unclassified zones or Zone 2 locations (e.g. a compartment with a fuel line passing through without bulkhead connections or other fittings adjacent only to zone 2 locations and areas outside of the systems).

3 Components

3.1 Except as indicated in 3.2, a component of a product covered by this standard shall comply with the requirements for that component. See Appendix A for a list of standards covering components used in the products covered by this standard.

3.2 A component is not required to comply with a specific requirement that:

- a) Involves a feature or characteristic not required in the application of the component in the product covered by this standard, or
- b) Is superseded by a requirement in this standard.

3.3 A component shall be used in accordance with its rating established for the intended conditions of use.

3.4 Specific components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits, and shall be used only under those specific conditions.

4 Units of Measurement

4.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

5 Undated References

5.1 Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

CONSTRUCTION

6 Hydrogen and Other Fluid Containing Parts

6.1 General

6.1.1 Pressure or fluid containing parts shall be resistant to the action of the fluid.

6.1.2 The refueling interface shall be in accordance with Compressed Hydrogen Surface Vehicle Refueling Connection Devices, SAE J2600.

6.1.3 Metallic parts containing hydrogen gas shall be resistant to hydrogen embrittlement as outlined in Basic Considerations for the Safety of Hydrogen Systems, ISO 15916. If employing a material other than as outlined in ISO 15916, an evaluation for susceptibility to hydrogen embrittlement will need to be conducted in accordance with the:

- a) Standard Test Method for Determination of Susceptibility of Metals to Embrittlement in Hydrogen Containing Environments at High Pressure, High Temperature, or Both, ASTM G 142, or the
- b) Standard Test Method for Determination of the Susceptibility of Metallic Materials to Gaseous Hydrogen Embrittlement, ASTM F 1459.

1) Results of testing done in accordance with ASTM G 142 shall be at least one. Ratios below one indicate a susceptibility to hydrogen embrittlement with the test method outlined in ASTM G 142.

2) Ratios above two indicate a susceptibility to hydrogen embrittlement with the test method outlined in ASTM F 1459.

6.1.4 When atmospheric corrosion of a part containing fluid interferes with its intended function or permits external leakage of a fluid creating a hazardous condition, the part shall be made of corrosion-resistant material or is to be provided with a corrosion-resistant protective coating.

6.1.5 An elastomeric part, relied upon for safety such as a seal for fluids other than hydrogen, which could create a hazard when leaked (for example, a gasket between electrical and wetted parts), shall be suitable for the application as determined by the Standard for Gaskets and Seals, UL 157.

6.1.6 An elastomeric part employed as a seal for hydrogen shall be suitable for use with hydrogen. The elastomeric materials outlined in Basic Considerations for the Safety of Hydrogen Systems, ISO 15916, shall be considered for reference and guidance. The material shall be evaluated for tensile strength and elongation as-received and after oven-aging (based on service temperatures) in accordance with Elastomeric Seals, Gaskets and Tubing, Section 37.

6.2 Piping, hoses, tubing and fittings

6.2.1 When conveying gases or vapors at pressures exceeding 15 psi gauge (103.4 kPa), or liquids at pressures exceeding 160 psi (1103 kPa), or temperatures exceeding 120°C (250°F), piping and associated component parts shall be fabricated and tested to conform to all applicable specifications of the Standard for Power Piping, ANSI/ASME B31.1, or the Standard for Process Piping, ANSI/ASME B31.3, as applicable.

Exception: Piping for hydrogen service shall comply with 6.2.5.

6.2.2 Piping utilized at levels below the pressures and/or temperatures noted in 6.2.1 and nonmetallic piping shall be evaluated to the requirements of this standard with consideration given to materials and fluids contained and service conditions, including pressures and temperatures. Nonmetallic piping containing gaseous hydrogen fuel shall be evaluated to the additional requirements of 6.2.7.

6.2.3 Nonmetallic hoses used for gaseous hydrogen located external to the fuel cell power system and subject to physical stress shall meet the applicable requirements of Hoses for Natural Gas Vehicles and Dispensing Systems, ANSI/IAS NGV 4.2. Materials shall be suitable for service with hydrogen fuel, or the fluid contained, in accordance with General, Section 6.1. Flexible hose longer than 60 in (1.5 m) shall have a stainless steel wire braid reinforcement.

6.2.4 Flexible metal connectors and associated fittings, when used for conveying gaseous hydrogen, shall comply with Connectors for Gas Appliances, ANSI Z21.24/CSA/CGA 6.10, or the Standard for Flexible Metallic Hose, UL 536, as applicable.

NOTE – ANSI Z21.24/CSA/CGA 6.10 is limited to pressures less than 1/2 psi (3.4 kPa).

6.2.5 All piping systems in hydrogen service shall be designed and constructed in accordance with Hydrogen Piping and Pipelines, Part IP, ANSI/ASME B31.12.

6.2.6 A hydrogen fuel line shall be supported to minimize chafing and to maintain at least a 2-in (50.8-mm) clearance from exhaust- and electrical-system parts.

Exception No. 1: Electrical equipment and sensors in limited power circuits that do not have enough electrical energy to damage a fuel line are not required to comply with this requirement.

Exception No. 2: If it can be demonstrated that the fuel lines and wiring are sufficiently supported to prevent the clearance from being reduced to less than 1/2 in (12.7 mm), the clearance between fuel lines and electrical-system parts may be reduced.

6.2.7 Nonmetallic hydrogen fuel lines shall:

- a) Be protected within ventilated enclosures where they will be subject to a minimum of mechanical or physical stresses,
- b) Be either conductive to avoid static discharge with a maximum resistance of 1 MΩ per meter as outlined in Hoses for Natural Gas Vehicles and Dispensing Systems, ANSI/IAS NGV 4.2, the Continuity Test, Section 27, or comply with the Test for Accumulation of Static Electricity as outlined in the Exception to 27.3,
- c) Employ materials that have been evaluated and found suitable for fluids they contain with consideration given to temperatures they are exposed to during service. Compliance shall be determined by Elastomeric Seals, Gaskets and Tubing, Section 37, and Permeation of Nonmetallic Tubing and Piping, Section 38, as applicable, and
- d) Comply with the ESD requirements for 100R14 Type B hose as defined in Hydraulic Hose, SAE J517, when connected between the fuel system and the stack.

6.2.8 Pipe, tubing, fittings, and other piping components shall be capable of withstanding a minimum hydrostatic test of 1.5 times the rated service pressure without structural failure.

Exception: High-pressure pipe, tubing, fittings, and other piping components shall have a safety margin equivalent to the storage cylinder in use. See 6.3.