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Gaseous hydrogen – Fueling stations – Dispensers

Contents

Introduction

This international standard, which deals with the safety requirements and safety tests of hydrogen dispensers, has been developed mainly by reference to ANSI/CSA HGV 4.1-2012, *Standard for Hydrogen Dispensing Systems,* and partially by reference to ANSI/CSA HGV 4.4-2013, *Standard for Breakaway Devices for Compressed Hydrogen Dispensing Hoses and Systems* (hose breakaway test). This standard is intended to be used for certification purposes for dispensers.

1. Scope

This standard provides the requirements and test methods on the safety of complete hydrogen dispensers with the normal working pressure of 35 MPa and/or 70 MPa for gaseous hydrogen fueling stations.

This standard does not provide:

- the safety of individual components composing the hydrogen dispenser;
- fueling protocols for vehicle hydrogen tanks or vehicle filling tests for hydrogen fueling stations;
- the accuracy verification of fill content for vehicle hydrogen tanks.

This standard covers the components within the boundary of a dispenser, an example of which is shown in Figure 1.

NOTE Component presence and location may differ from what is shown.

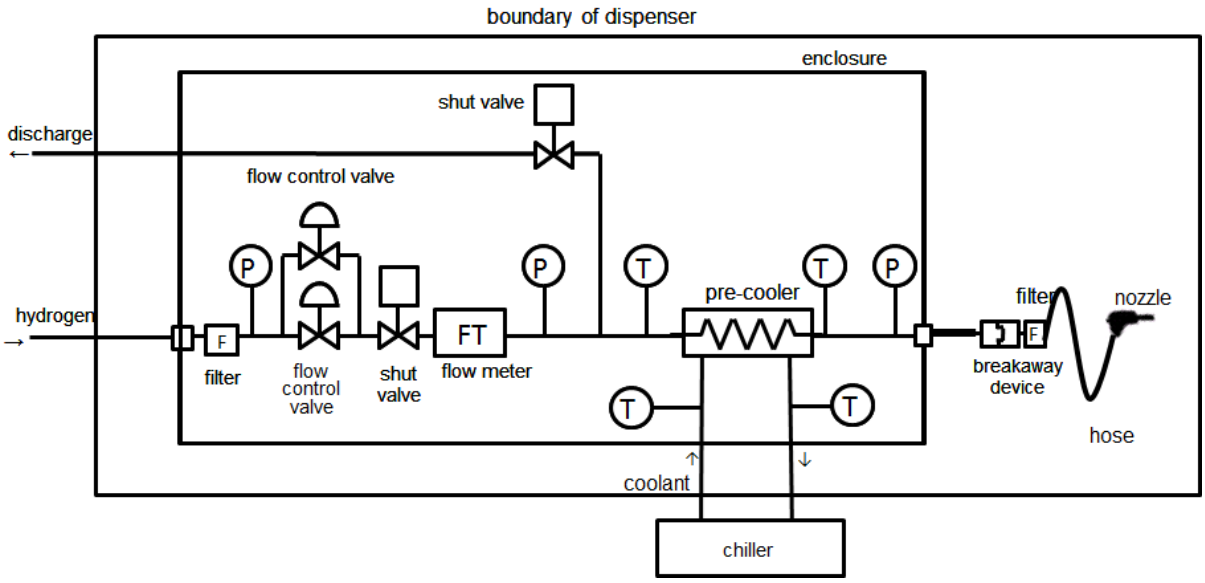


Figure 1 Example of the boundary of a dispenser

When components that are considered critical for the safe operation of a hydrogen fuel dispenser are provided separately to the dispenser, such external components are considered to be outside the scope of this standard. Such components shall not be assessed as part of the dispenser; however, an

equivalent level of safety and performance to those components included in this standard should be achieved when the dispenser is integrated into a hydrogen fuelling station.

2. Normative references

ANSI/CSA HGV 4.1-2012, *Standard for hydrogen dispensing systems*

ANSI/CSA HGV 4.4-2013, *Breakaway device for compressed hydrogen dispensing hoses*

API RP 2003, *Protection against ignitions arising out of static, lightning, and stray currents*

ANSI/ASME B31.3, *Process piping.*

NFPA 68*, Standard on Explosion Protection by Deflagration Venting,*

ANSI/NFPA 2, *Hydrogen Technologies Code*

ANSI/NFPA 496*, Purged and Pressurized Enclosures for Electrical Equipment*

ANSI/UL 404*, Gauges, Indicating Pressure for Compressed Gas Service*

IEC 60364, *Electrical installations for buildings*

IEC 60079, *Explosive atmospheres*

ISO 3601-1: 2012, *Fluid power systems -- O-rings -- Part 1: Inside diameters, cross-sections, tolerances and designation codes*

ISO 3601-2:2008, *Fluid power systems -- O-rings -- Part 2: Housing dimensions for general applications*

ISO 3601-3:2005, *Fluid power systems -- O-rings -- Part 3: Quality acceptance criteria*

ISO 11114-4, *Transportable gas cylinders -- Compatibility of cylinder and valve materials with gas contents -- Part 4: Test methods for selecting metallic materials resistant to hydrogen embrittlement*

ISO 15649, *Petroleum and natural gas industries – Piping*

ISO14687-2, *Hydrogen fuel — Product specification — Part 2: Proton exchange membrane (PEM) fuel cell applications for road vehicles*

ISO 17268:2012, *Gaseus hydrogen land vehicle refuelling connection devices*

ISO 13849-2:2012, *Safety of machinery -- Safety-related parts of control systems -- Part 2: Validation*

SAE J2600, *Compressed Hydrogen Surface Vehicle Refueling Connection Devices*

SAE J2601*, Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles*

UL 1998, *Standard for Software in Programmable Components*

CSA HGV 4.10*, Specifications for Fittings for Compressed Hydrogen Gas and Hydrogen Rich Gas Mixtures*

CSA HGV 4.2, *Hose and Hose Assemblies for Compressed Hydrogen Dispensing Systems*

CSA HGV 4.3*, Test Methods for Hydrogen Fueling Parameter Evaluation*

3. Terms and definitions

3.1
authority having justification (AHJ)
organization, office or individual responsible for approving a facility along with equipment, an installation or a procedure

3.2
certified
(with respect to any accessory, component, equipment, or manufacturer's installation instructions) investigated and identified by a nationally recognized testing agency as conforming to recognized standards or requirements or accepted test reports

3.3
cylinder
(with respect to compressed hydrogen gas ground storage) a container which complies with the requirements of national regulations for storage and transportation of compressed hydrogen gas

3.4
dispenser
part of the pressurized-gas fuelling station via which the pressurized gas is dispensed to vehicles

Note 1 to entry: As an example, the dispenser may include a dispenser cabinet, gas flow meter, a fuelling hose and fuelling nozzle attachments.

3.5
breakaway device
component installed immediately upstream of the nozzle to shut off gas flow in the event of vehicle driving away while still connected to the dispenser

3.6
ESS
emergency shutdown device or electronic shut-down system such as E-Stop that cuts off the flow of hydrogen gas to the dispenser and vehicle

3.7
enclosure
structure that protects equipment from the environment, provides noise attenuation, or provides safety to the areas surrounding the equipment

3.8
fill pressure
pressure attained at the actual time of filling

Note 1 to entry: Fill pressure varies according to the gas temperature in the container which is dependent on the changing parameters and the ambient conditions.

3.9
fitting
connector used in joining a piping, tubing, or hose system

3.10
fueling station
facility for the dispensing of compressed hydrogen, which includes all stationary equipment that supplies, compresses, stores, and dispenses gaseous hydrogen to fuel a land vehicle

3.11
hose
flexible conduit

3.12
housing
section of the system that encloses, and is intended to protect, operating parts, control mechanisms, or other components, that need not be accessible during normal operation

3.13
hydrogen gas
gas whose composition complies with ISO14687-2 or ISO 14687-2

3.14
listed
equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction (AHJ) and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states, either that the equipment or materials, meet appropriate standards or have been tested and found suitable for use in a specified manner

3.15
manufacturer
person or organization responsible for the design and fabrication of the equipment and components

3.16
maximum allowable working pressure (MAWP)
maximum pressure to which a component is designed to be subjected when handling the specified fluid at the maximum specified temperature

3.17
nominal working pressure (NWP)
gauge pressure that characterizes typical operation of a container, system or dispenser normal working pressure, e.g H35 or H70. For compressed hydrogen gas containers, NWP is the container pressure, as specified by the manufacturer, at a uniform gas temperature of 15°C and full gas content

3.18

pressure
expressed as psi or Pa

3.19
test pressure
pressure to which a component or equipment is taken during testing

3.20
pressure relief valve
device which prevents a pre-determined upstream pressure from being exceeded

3.21
valve
device by which the flow of a fluid may be started, stopped, or regulated by a movable part which opens or obstructs passage

3.22
automatic valve
self-actuated or remotely actuated device consisting essentially of a valve and operator

4. Safety Requirements

4.1. General material requirements

Generally, materials shall comply with the following:

a) Materials used shall be rated for the temperature and pressure to which they will be exposed.

b) Use materials or coated materials that are sufficiently resistant to corrosion under the service condition.

c) For non-metal materials such as rubber or plastic, select those that are appropriate for the service condition so that no short-term deterioration will occur.

d) For metals to be used in a highly humid environment, select those that are resistant to corrosion such as stainless steel, or coat the metals to make them highly resistant to corrosion.

e) For electrical insulation materials, use those that are sufficiently resistant to the temperature of the system parts they contact or are adjacent to and have low moisture absorbance.

f) For the exterior enclosure of an outdoor dispenser, use materials with high weather ability such as metal with anticorrosion treatment or synthetic resin. Exterior materials, including synthetic resin, shall not blister, crack, or fracture under working conditions.

g) Materials used for system parts shall not contain polychlorinated biphenyl.

h) Materials used for system parts shall not include asbestos or materials containing asbestos.

i) Particular attention should be given to hydrogen embrittlement, permeability and hydrogen accelerated fatigue. Materials normally in contact with hydrogen shall be demonstrated to be acceptable in hydrogen and deionized water service. The material compatibility shall be

documented by the component manufacturer or an independent third party.

NOTE Material performance data in hydrogen environments may be found in ISO/TR 15916.

4.2. Construction requirements

4.2.1. General Construction and Assembly

a) All components used in compressed hydrogen gas dispensing equipment shall either be listed by a nationally recognized certification agency as complying with an applicable standard, or shall be evaluated by the certification agency for the intended application as part of the dispensing equipment.

b) The construction of all parts of a compressed hydrogen gas dispenser, whether specifically covered in this standard or not, shall be in accordance with industry recognized concepts of safety, durability, and maintainability.

c) All components used in compressed hydrogen gas dispensing equipment shall either be:

i) listed by a nationally recognized certification agency as complying with an applicable standard,

ii) evaluated by the certification agency for the intended application as part of the dispensing equipment, or

iii) evaluated by the manufacturer and approved by the local AHJ for the intended application as part of the dispensing equipment.

d) All components in a housing used in a dispenser shall be assembled in such a manner so as to be secure against distortion, warping, or other damage, and shall be supported to maintain a fixed relationship with each other.

e) All parts which may come into contact, during normal servicing and operation, shall be free from sharp projections or edges and projecting screw ends.

f) All components that are routinely serviced shall be accessible for servicing and functional adjustment in position, and shall be replaceable during servicing.

g) A dispenser shall have provisions for operation in conjunction with an Emergency Shut-down System (ESS). Activation of the ESS shall cause the dispenser to disable the flow of gas to the vehicle, and shall shut off the electrical supply to the dispenser. (See 5.4 Dispenser shut-down test).

h) In the event of a loss of electrical power, the compressed hydrogen gas dispenser shall shut down in a safe manner. The current fueling event, if one is in progress, shall be terminated and the flow of gas to the fueling nozzle shut off automatically. Once power is restored, the dispenser may resume operations; however, a new fueling event must be initiated using standard procedures.

i) Dispensers for outdoor installation shall be compatible with climatic conditions, or equipped with a means to protect all operating controls and electrical wiring from climatic conditions. (See Clause 5.10, Rain test).

j) Each dispenser shall be provided with a mounting means to provide sufficient support in accordance with the requirements of the local jurisdiction.

k) Dispensers shall be equipped with a means to secure and protect the fueling nozzle when not in

use.

l) The dispenser shall be protected against overpressure to prevent any internal inlet piping or components in contact with hydrogen gas from being exposed to pressures exceeding the maximum allowable working pressure.

If such overpressure protection device is not a part of a dispenser, instruction shall be given to the installer of the dispenser on the requirement of such device upstream of the dispenser connection.

The over-pressure protection shall prevent the vehicle fuel system from being exposed to pressures exceeding 1.38 x NWP in the event of a fault in the dispenser system.

m) Any component covered under this standard shall be capable of operating in the temperature and pressure range specified by the manufacture.

n) A compressed hydrogen gas line inlet or outlet for field connection shall be plugged, capped or otherwise sealed by the manufacturer prior to shipment to prevent entrance of foreign materials.

o) A dispensing system shall be designed to provide electrical grounding from the point the nozzle contacts the vehicle to the station ground, when attached to the vehicle. (See 5.7 Vehicle dispenser Interface test).

NOTE: Also see ANSI/NFPA 2 and API RP 2003.

p) Manual block and bleed valves to purge the dispenser shall be provided. The block valve may be accessible to the public. The bleed valve shall be inaccessible to the public, and shall be provided with a locking mechanism, or housed in a permanent enclosure with a lockable access to prevent accidental operation of the valve. The bleed valve shall allow the hydrogen piping and components in the dispenser to be depressurized for service.

q) The dispensing system shall incorporate immediate shutdown protection in the event of a rupture or rapid depressurization of the fuel delivery system during active fueling. (See 5.5 Hose rupture test).

r) Nozzles shall be positioned such that removal from their mounting is required before the dispenser can be activated. A dispenser shall require a minimum of two operations to initiate gas flow to the vehicle. One operation shall ensure the nozzle is properly connected to the vehicle to enable fuel flow. The second operation shall be to authorize the fueling.

s) The controls for manual start-up of the dispenser shall be located or orientated so there is no possibility of accidental actuation. Switches, valves, etc., that can be activated with the power off and that can cause the system to function as soon as the power is restored shall not be used.

t) A dispenser shall be protected against lightning strikes in accordance with API RP 2003.

u) The dispenser shall be constructed so the enclosure, frame and similar non-current carrying metal parts are electrically continuous to the point of connection of the equipment grounding means. (See 5.8 Dispenser ground continuity test).

v) The assembled system shall be cleaned in accordance with recognized industry practice so as not to affect fuel quality as established in ISO14687-2.

w) While inactive, a dispenser hose shall be pressurized to a pressure greater than atmospheric

pressure.

4.2.2. Housing

a) Housings shall be made of suitable materials and finished with appropriated coatings. Housing will be durable, and facilitate normal operation of the device. A recess or depression in the housing that may collect water shall incorporate a means to drain the water to a safe location.

b) The construction of housings not specifically covered by this requirement shall be in accordance with industry recognized concepts of safety, substantiality, and durability.

c) The housing shall accommodate field connections of gas piping and electrical equipment. Openings shall be provided to accommodate field connections, inspection, and adjustments. Where required for safety reasons or protection against accidental equipment contact or vandalism, openings will have removable covers which will require a key or tool to open or remove them.

d) To prevent the accumulation of hydrogen, the enclosure which houses gas carrying components shall incorporate vent opening(s) near the top and bottom. These openings shall be of such size and arrangement as to prevent the accumulation of hydrogen within the enclosure.

e) A plastic panel used as part of the housing shall remain intact when subjected to room temperature and cold impact tests as described in clause 5.3, Impact test. Except as otherwise stated, testing at room temperature will be conducted between 15°C minimum and 30°C maximum.

f) Plastic parts shall be resistant to deterioration from conditions imposed on them in service.

g) Each dispenser shall be equipped with means to indicate the reason for any shutdown.

h) The protective housing of the dispenser shall be made from non-combustible and anti-static materials

4.2.3. Overpressure protection devices

a) Each dispenser shall be equipped with an overpressure control system that includes a mechanical pressure safety valve or control device that will protect both vehicle and the components of the dispenser from overpressure in the event of extreme controller malfunction. Each dispenser nozzle shall be protected.

b) The set point of the mechanical pressure safety valve in the dispenser overpressure control system shall be set at no greater than 1.38 x the dispenser nozzle service pressure to provide adequate protection for vehicle fuel systems.

c) The set point of the mechanical pressure safety valve in the dispenser overpressure control system shall be set at no greater than MAWP of the lowest pressure rated component in the dispensing system.

d) Pressure relief valves when used to protect the dispenser shall be designed and installed in accordance with ISO 4126 or applicable local codes.

e) The discharge opening of all pressure relief valves shall be vented to a safe location, as specified in applicable local codes such as CGA G-5.5.

4.2.4. Filters

a) Means shall be provided to protect both the vehicle and the dispenser from gas, liquid and solid contaminants. The dispenser shall be designed to deliver fuel with gas composition specified by ISO14687-2.

Gas line filters shall be included as part of the dispenser to protect both the dispenser and the vehicle.

Filters shall be of adequate size and construction for the applications. Particulate concentration shall be minimized to avoid contamination, clogging, and erosion of fuel system components. The fuel delivered to the vehicle shall be processed with a filter rated at no greater than 10 μm (micron) nominal (i.e. 98% efficiency) particle size and is recommended to be installed upstream of the hose breakaway device.

b) Filters shall be installed in such a manner so that the force required to install or open the filter will not permanently distort the piping or other components of the dispenser.

Filters shall be able to be isolated and vented and shall be accessible for inspection, cleaning and replacement, without disturbing any part of the dispensing device assembly other than the minimum number of components necessary for inspection, cleaning, and replacement of filters. The dispenser operator shall have a maintenance and inspection plan for the filters and follow this plan.

4.2.5. Valves

All valves used in the high pressure parts shall be certified, listed or accepted under the national standards. Valves used in piping systems for gaseous hydrogen shall be designed in accordance with ISO 15649. Valve materials shall comply with ISO 11114-4.

4.2.6. Venting

a) A dispenser shall be equipped with means for venting the release of hydrogen gas by carrying it to a safe location or captive system. Hydrogen vent systems discharging to the atmosphere shall be in accordance with CGA G-5.5.

b) A dispenser shall be equipped with a means to depressurize the fuel hose when fueling is interrupted through activation of the ESS so as to enable disconnection of the fuel hose from the vehicle.

4.2.7. Piping and fittings

a) Piping, tubing, fittings, and piping components shall be suitable for use with compressed hydrogen gas, and shall be rated over the dispenser temperature and pressure range.

b) Piping and tubing design, fabrication, testing, and welded joints shall be done in accordance with an applicable local piping code such as ANSI/ASME B31.3.

c) Where used, tube fittings shall be chemically compatible with associated components, and shall be designed to resist electrolytic action.

d) Ends of piping and tubing shall be carefully machined to remove defects that could cause

particulate contamination.

e) An elastomeric part, not already evaluated as part of an approved component or assembly, when used in contact with compressed hydrogen gas shall have the following properties when tested as specified in ISO 3601-1, 3601-2, and 3601-3.

- Those properties relating to minimum tensile strength and elongation after oven aging, all as specified in ISO 3601-1, 3601-2 and 3601-3. The maximum service temperature used to determine the conditioning time and temperature for oven aging is considered to be 75°C unless the product is designated for use at a higher temperature or tests show that it will be exposed to a higher temperature.

- Volume change and extraction as specified in ISO 3601-3 except that the conditioning shall be for 96 hours at 20.7 MPa at a temperature of 65°C for compressed hydrogen gas, and for 70 hours immersion in IRM903 oil and methanol. Volume change limits shall be - 1 to + 25%. Maximum extraction shall be +10%.

ISO 3601-3 provides for the testing of either finished elastomeric parts or sheet or slab material. Sheet or slab material is to be tested when the parts are O-rings having diameters of less than 25 mm. The material tested is to be the same as that used in the device, regardless of whether finished elastomeric parts or sheet or slab material is tested.

f) Formed supply piping and tubing shall have all bends made in accordance with applicable local codes such as *ANSI/ASME B31.3.*

g) The use of tapered threaded components shall be minimized as much as possible. Close pipe nipples shall not be used. Cone and thread fittings are preferred for 70 MPa dispenser systems.

h) All fittings and end connections shall be proven suitable for use with compressed hydrogen gas by complying with the applicable tests specified by applicable local codes such as *CSA HGV 4.10.* Testing specified to establish the suitability for use may be waived by the testing agency when acceptable evidence in the form of a declaration, supplied by the manufacturer, to substantiate it's suitability for use in the expected environment, is submitted by the applicant.

4.2.8. Fueling hose assemblies and nozzles

a) A dispenser shall be equipped with a nozzle and fueling hose assembly that shall be supported so that the hose does not touch the ground under normal operations.

b) The nozzle shall match the pressure class of the dispenser and shall prevent fueling of vehicles with a lower pressure class.

c) Fueling hoses shall be designed for hydrogen service and the environmental conditions at the site of use. Hydrogen leakage by permeability shall not exceed 1×10^{-2} Pa/m^3s. Construction and materials shall be such as to prevent the trapping of hydogen within or between the materials at a pressure that could damage the hose when the internal pressure is relieved. Metal mesh enforcement shall not be susceptible to corrosion from penetration of humidity, if such penetration is reasonably foreseeable during expected lifetime. The fuelling hose shall be strong enough to withstand without damage the expected loads (tensile and torsion) exerted by the user.

d) Nozzles shall be listed by a nationally recognized agency as complying with SAE J2600.

e) A breakaway device certified, listed, or accepted by a nationally recognized agency as complying with *HGV 4.4* shall be provided in the hose assembly between the dispenser frame and the fueling nozzle.

f) Where hoses are attached to a hose retrieving mechanism, the breakaway device shall be installed between the point of attachment of the hose retrieving mechanism to the hose and the nozzle, unless the retrieving mechanism separates from the hose at a force less than that of the breakaway device, does not affect operation of the hose breakaway feature and does not result in damage to the dispenser frame.

4.2.9. Pressure indicating devices

a) The dispenser shall be equipped with a device to indicate the delivery (hose) pressure.

b) All pressure gauges exposed to compressed hydrogen gas shall be suitable for use with it at the operating pressure and temperature range. The gauge shall read at least 1.2 times the maximum allowable working pressure of the system for which it is used, and shall have a dial face at least 63 mm in diameter and an orifice no greater than 1.4 mm in diameter.

c) Pressure gauges in a dispenser shall be of a safe construction in the case with a relief function.

4.2.10. Fueling protocol

a) Each dispenser shall be equipped with a control system that utilizes a fueling protocol to control the fueling speed and target pressure for each fueling event such that the vehicle tank is not overfilled or overheated. Each dispenser shall meet the process requirements in SAE J2601 or equivalent.

b) The performance of the dispenser and its ability to perform the fueling protocol in compliance with the performance requirements of the fueling protocols such as SAE J2601 shall be field or type tested by a hydrogen dispenser test apparatus as defined by Annex B of ISO DTR 19880-1.

c) If the dispenser offers fast filling:

(i) the fueling protocol shall use the fuel temperature, ambient temperature, and vehicle start pressure data to calculate the vehicle tank system volume, an acceptable hydrogen flow rate (or pressure rise ramp rate) and final pressure to achieve full fills (>90% state of charge) so as not to overfill or over heat the vehicle tank system.

(ii) The dispenser control system and fueling protocol shall comply with clause 7.2 in ISO/TR 19880-1.

d) If the dispenser offers slow speed fueling below 5 g/s, the dispenser shall not fuel the vehicle to pressures exceeding the NWP. If the ambient temperature is below 15°C, the dispenser shall compensate for low temperatures and fill the vehicle tank to less than the NWP and stop the fueling so the tank contents are no greater than 98% state of charge and less than service pressure if the tank system were to be equilibrated at 15°C.

e) If the dispenser uses an IRDA communication method to gather information, the data language shall use a format such as what is described in SAE J-2719, and shall:

(i) Terminate fueling events if an ABORT signal is seen as “sent from the vehicle” and,

(ii) Evaluate that the tank temperature data is valid before taking credit for the tank temperature in calculation of the final target pressure.

f) The dispenser shall not top–off vehicles that present to the dispenser with greater than 94% state of charge.

g) The dispenser shall not fill vehicle tank systems that present to the dispenser with less than 50 bar internal pressure.

4.2.11. Electrical equipment and wiring

a) Electrical components of the dispensing devices shall comply with the applicable provisions of IEC 60364 and IEC 60079.

b) Electrical classifications for dispensers shall be defined as Zone 2 in IEC methodology or in accordance with the manufacture's risk assessment. Protection techniques identified in IEC 60079-10-1 are acceptable for electrical and electronic equipment in hazardous locations.

4.2.12. Emergency Shutdown Systems

4.2.12.1. General

Each dispenser shall be equipped with an Emergency Shutdown System (ESS) that complies with all of the following:

(a) The ESS and its entire components shall fail in a safe manner;

(b) No single point failure shall result in a hazardous event;

(c) It shall promptly and automatically shut down the dispenser in the event of a hazardous condition occurring or in response to a manual E-Stop command; and

(d) In the event of a power failure, the ESS shall act to shut down all hydrogen supplies in a safe manner.

4.2.12.2. Hazardous Identification with FMEA and mitigation

a) The manufacturer of the dispenser shall conduct a Failure Modes and Effects Analysis (FMEA) or equivalent hazard analysis intended to identify failures which have significant consequences affecting the dispenser safety.

b) For each critical failure mode identified in the FMEA, the dispenser manufacturer shall demonstrate the cascading affect of individual component(s) powering down leading to the dispenser shutting down in a fail-safe manner.

c) Compliance with this sub-clause shall be established for each critical failure mode using a simulated test procedure or supportive evidence from the dispenser manufacturer, either of which verifies that the required action will occur.

4.2.12.3. Software

a) Software used to control the dispenser's emergency shutdown system shall be evaluated in accordance with UL 1998 Standard for Software in Programmable Components.

b) The investigation of the software shall include an integral evaluation of the controlling hardware in

accordance with ISO 13849-2:2012 to perform its specified safety-related protective function in accordance with this standard.

4.2.12.4. Control circuits

a) Control circuits shall be arranged such that when an ESS switch is activated, the electrical power and fuel supply to the dispenser is automatically cut off. Systems that shut down shall remain shut down until they are manually reset by an authorized, trained operator after it has been verified that a safe situation has been restored.

b) Electronic control circuits relied upon for fueling station safety shall be evaluated to UL 991.

4.2.13. Purging systems

A purging system, if used, shall be approved by a third party agency as complying with the applicable local codes such as ANSI/NFPA 496. Failure of the system shall disable the flow of gas to the vehicle.

4.2.14. Marking

a) Marking material shall be identified by class number and meet the following specifications. All metal marking materials shall be rustproof and shall be reasonably compatible with events and substances normally encountered in the fueling environment (e.g. fuels, lubricants, sunlight, air, etc.). All markings shall be suitable for application to surfaces upon which applied and shall demonstrate suitable legibility as specified under Section 2.13 Marking Material Adhesion and Legibility, CSA HGV4.1:2013 Standard for Hydrogen Dispensing Systems. The designation of any class of marking shall not preclude the use of marking of a lower number class.

Class I. Integral Marking.

Marking that is embossed, cast, stamped or formed in the part. This includes markings baked into an enameled surface.

Class II A1. Permanent plate.

Shall be made of metal having a minimum thickness of 0.30 mm, shall be securely attached by mechanical means and shall comply with said Section 2.13 Marking Material Adhesion and Legibility.

Class II A2. Permanent plate.

Shall be made of metal having a thickness of 0.15 mm to 0.30 mm, shall have mechanical attachment means at all corners with a maximum spacing of 150 mm between mechanical fasteners and shall comply with said Section 2.13 Marking Material Adhesion and Legibility.

Class II A3. Permanent plate.

Shall be made of metal having a thickness less than 0.15 mm. Such plates shall be attached by means of non-water soluble adhesive which will comply with said Section 2.13 Marking Material

Adhesion and Legibility. These materials shall not be located on surfaces having temperatures exceeding 150°C.

Class II A4. Permanent plate.

Shall be made of pressure sensitive metal foil requiring no solvent or activator, provided such plates comply with said Section 2.13, Marking Material Adhesion and Legibility. These materials shall not be located on surfaces having temperatures exceeding 150°C.

Class III A1. Permanent label.

Shall be made of material not adversely affected by water, shall be attached by means of non-water soluble adhesive and shall comply with said Section 2.13, Marking Material Adhesion and Legibility. These materials shall not be located on surfaces having temperatures exceeding 150°.

Class III A2. Permanent label.

Shall be made of material not adversely affected by water, shall be attached by means of non-watersoluble adhesive and shall comply with said Section 2.13, Marking Material Adhesion and Legibility. These materials shall not be located on surfaces having temperatures exceeding 80°C.

Class III B. Waterproof Marking.

Shall be printed directly on the part with waterproof marking not adversely affected by a temperature of 80°C and shall comply with said Section 2.13, Marking Material Adhesion and Legibility. This marking shall not be used on surfaces having temperatures exceeding 80°C.

Class IIIC. Waterproof label.

Shall be made of material not soluble in water, and may use water-soluble adhesive for attachment means.

Class IV. Non-waterproof label.

Shall be made of material which may be soluble in water, and may use water-soluble adhesive for attachment means.

Class V. Printed Marking.

Marking shall be clear and prominent and may be applied directly by any printing means.

b) The area adjacent to the filter shall be provided with a label or tag containing the following or equivalent “WARNING - Disconnect electrical power and purge gas per manufacturer’s instructions before servicing filter.”

c) Each dispenser assembly shall bear a plate or a combination of adjacent plates of Class IIIA marking material located so as to be easily legible when the dispenser is in a normally installed position. This plate shall include, at minimum, the following information:

i) Manufacturer's name, trade name or other identification with address

ii) Date of manufacture

iii) Model name

iv) Manufacturing or serial number

v) Operating service temperature

Other markings as may be required by the authorities having jurisdiction.

d) Dispensers intended for self-serve operation shall bear, on a Class III marking, operation instructions. These instructions shall be easily read when the dispenser is in a normally installed position.

5. Safety tests

5.1. General

a) These are qualification tests to evaluate a design. Changes to the initial design require requalification and testing as deemed necessary.

b) The performance of a compressed hydrogen gas dispensing system shall meet the applicable requirements when tested as described herein. During these tests the dispensing system shall be operated according to the manufacturer's instructions. If any indications are observed during the tests that the equipment will not continue to meet the requirements in normal service conditions so as to assure continued safe performance, such supplementary tests shall be conducted as deemed necessary to assure safe service.

c) Representative samples of a dispensing system and its component parts are to be subjected to the tests described in these requirements.

d) Test gas as specified in these requirements shall be:

- Hydrogen, for leak tests;
- Hydrogen for permeation;
- Liquids (e.g., water or oil) or gases for strength tests;
- Hydrogen, helium, nitrogen, or dry air for all other tests.

e) All tests shall be conducted with the inlet pressure maintained at the manufacturer's specified maximum allowable working pressure, unless otherwise specified.

f) Tests required are to be conducted at room temperature. Unless otherwise stated, testing at room temperature will be conducted between 15°C minimum and 30°C maximum.

5.2. Leakage test

5.2.1. Acceptance criteria

Excluding leakage to a safe vent during the disconnection of a nozzle, all dispenser parts, including joints and connections that contain hydrogen, shall not leak more than 10% of the test pressure over a 24 hour period.

5.2.2. Test method

This test shall be conducted using fuel cell grade hydrogen (ISO14687-2) at normal dispenser operating conditions specified by the manufacturer.

5.2.3. All manual and automatic process valves shall be held in the open position. In the case of a 70 MPa dispenser, the vented (to atmosphere) dispenser hose, nozzle and breakaway device must be tested **separately**.

The dispenser including any fuel temperature cooling system associated with the dispenser shall be tested at the MAWP or no less than 90 percent of the set point of the pressure relieve device protecting the dispenser components and vehicle tank.

The leakage rate from a 35 MPa dispenser with fully charged dispenser hose shall not exceed a rate that allows the test pressure to fall more than 20% over a 24 hour period (10% over 12 hours, 1% over 1.2 hours).

70 MPa dispensers: The leakage rate from a 70 MPa dispenser with vented dispenser hose shall not exceed a rate that allows the test pressure to fall more than 10% over a 24 hour period (5% over 12 hours, 1% over 24 hours). The dispenser hose, nozzle and breakaway device must be tested separately from the rest of the dispenser and the leakage rate (including the hose diffusion) shall not exceed a rate that allows the test pressure to fall more than 20% over a 24 hour period (10% over 12 hours, 1% over 1.2 hours).

5.3. Impact test

5.3.1. Acceptance criteria

A plastic panel used as part of the housing shall withstand a single impact of 6.7 J without developing cracks or other openings that expose bare live parts or gas confining parts when subjected to room temperature and cold temperature impacts as described in the following method of test.

5.3.2. Test method

This test shall be conducted at room temperature and minimum temperature specified by the manufacture.

The panel should be in place on the housing. It shall be struck with an impact produced by a pendulum consisting of a 50 mm diameter steel ball weighing approximately 0.5 kg suspended by a cable that provides a minimum of 1.3 m between the center of the ball and the hinge point at the other end of the cable.

The ball shall have an at-rest position not more than 25 mm clear of the panel without any object interfering with the cable. The point of impact shall be determined as the point most likely to result in a failure when hit. The pendulum shall be raised along its arc until the ball is 1.3 m vertically above its at-rest position, and then released.

For the cold impact test samples shall be conditioned at minimum ambient temperature specified by the manufacturer for at least 24 hours.

The conditioning samples shall be removed from the conditioning environment, quickly clamped into place on the housing, and impacted as previously described.

5.4. Dispenser shutdown test

5.4.1. Acceptance criteria

A dispenser shall disable the flow of gas to the vehicle when the ESS is activated. (See 4.2.1 f)

5.4.2. Method of test

The dispenser nozzle shall be attached to an appropriate storage container. A device simulating an ESD shall be provided on the dispenser in accordance with the dispenser manufacturer's instructions. The gas supply pressure to the dispenser shall be maintained at the dispenser manufacturer's maximum allowable working pressure.

The dispenser shall be operated to allow gas to flow into the storage container. While gas is flowing, the ESS shall be activated. The dispenser shall cause gas flow to stop within three seconds of the activation of the ESS.

This test shall be conducted 5 times.

5.5. Hose rupture test

5.5.1. Acceptance criteria

Dispenser controls shall incorporate shutdown protection in the event of a rupture or rapid depressurization of the fuel delivery hose during active refueling.

5.5.2. Test method

A tee fitting shall be installed at the end of the dispenser fueling hose, and upstream of the nozzle. The hose shall be attached to one of the "through" ports of the tee fitting. A fast opening valve shall be installed on the other "through" port. The nozzle shall be attached to the "stub" port of the tee. The test set-up is shown in Figure 2. The tee fitting and valve shall have a combined Cv as close as practical to that of the hose. A valve permanently mounted inside the dispenser with a Cv less than the hose may be used in place of the temporary test set up. For safety reasons, the valve shall be secured so as not to move when the valve is opened to allow full flow. The nozzle shall be attached to an appropriate storage container.

The gas supply pressure to the dispenser shall be maintained at least 90% of the NWP. With the valve closed, the dispenser shall be operated to cause gas to flow into the storage container. After the fueling hose pressure reaches 80% of the NWP, the test valve shall be opened. The dispenser shall cause the flow of gas to stop within three seconds of the opening of the fast-opening valve.

This test shall be conducted 5 times.

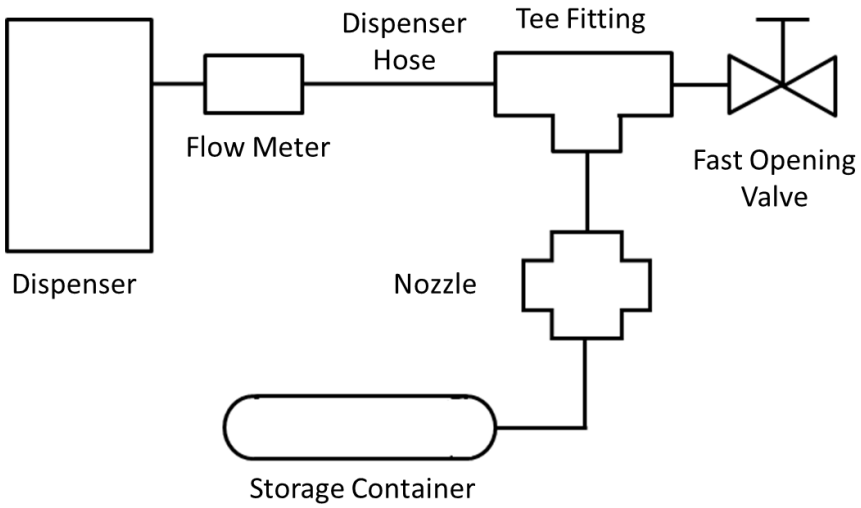


Figure 2. Test setup for hose rupture

5.6. Hose breakaway test

5.6.1. Acceptance criteria

When tested in accordance with the following method of test; the device shall separate upon application of a maximum pull force of 667 N but not less than 222 N when the device is installed as specified by the manufacturer. Upon separation under the pressurized condition, the flow of gas from the inlet component shall cease, and the flow of gas from the outlet component shall either (1) cease within one second or (2) bleed down the attached hose through a maximum 1.5 mm orifice.

5.6.2. Test method

The device being tested shall be installed as specified by the manufacturer in a simulated dispenser/hose assembly.

The test shall be conducted at four different temperature and pressure combinations as shown in Table 1.

Table 1. Separation test

	Temperature	Internal pressure	Number of times to test the reusable sample	Number of “one time use” samples to test
1	Min. ambient temp.	Atmospheric	5	2
2	Max. ambient temp.	Atmospheric	5	2
3	Min. ambient temp.	MAWP	5	2
4	Max. ambient temp.	MAWP	5	
			(NOTE one sample, tested 20 times)	(NOTE 8 total samples, each tested once)

For reusable devices, one sample shall be provided. The sample shall be tested a total of 20 times, 5 times at each of the listed temperature/pressure combinations. For ″one time use″ devices, 8 samples shall be provided. Two ″one time use″ samples shall be tested at each of the listed temperature/pressure combinations.

The device being tested shall be maintained at the required test temperature for at least two hours per 25.4 mm of maximum diameter of the breakaway device prior to the test and shall remain conditioned throughout the test.

The device being tested shall be maintained at the required test temperature for at least two hours per 25.4 mm of maximum diameter of the breakaway device prior to the test and shall remain conditioned throughout the test.

A direct tensile force shall be applied beginning at a force less than 222 N and increasing until the device separates. The device shall separate and, if pressurized, the flow of gas from the inlet half shall cease and shall not continue to leak in accordance with ANSI/CSA HGV 4.4-2013, Section 2.2 Leakage. The flow of gas from the outlet half shall either (1) cease and shall not continue to leak in accordance with ANSI/CSA 4.4, Section 2.2 Leakage, or (2) control the depressurization of the hose.

A reusable device sample shall then be reassembled for subsequent testing.

Upon completion of the testing specified above, each ″one time use″ sample shall comply with said Section 2.2, Leakage in the separated configuration. The reusable sample shall comply with ANSI/CSA 4.4, Section 2.2 Leakage in both the separated configuration and when reassembled.

If the device is intended for connection directly to a rigid assembly such as the dispenser, the above tests shall be repeated on new samples with the pull force directed at angles deemed most critical by the testing agency.

5.7. Vehicle-dispenser interface test

5.7.1. Acceptance criteria

The dispenser nozzle and fueling hose shall be electronically continuous with (see clause 4.2.1 o) the dispenser electrical grounding means. This provision shall be deemed met when the electrical resistance between the nozzle and the dispenser grounding connection does not exceed 1 MΩ.

5.7.2. Test method

An electrical potential ranging from 0 to 1000 volts dc shall be applied between the outlet of the dispenser nozzle and the point on the dispenser intended for attachment of the electrical grounding means. The current between these two points shall be measured. The electrical resistance shall be calculated using the following equation:

$R = V / I$

where:

R = resistance (ohms)

V = applied potential (volts dc)

I = measured current (amperes)

5.8. Dispenser ground continuity test

5.8.1. Acceptance criteria

A dispenser shall be constructed so the enclosure, frame, and similar non-current carrying metal parts are electrically continuous to the means provided for equipment grounding. This provision shall be deemed met when the electrical resistance between the point of connection of the equipment grounding means and any non-current carrying metal part is not more than one ohm, unless not in compliance with applicable electrical codes (nonconductive finishes may be scraped from the test points).

5.8.2. Test method

The electrical resistance between the point of connection of the equipment grounding means and each non-current carrying metal part shall be determined by measuring the potential drop between the two points when an alternating current of 20 amperes, derived from a power supply of not more than 12 volts, is passed between the two points, dividing the measured potential drop by the current.

5.9. Dielectric voltage-withstand test

5.9.1. Acceptance criteria

Adequate dielectric shall be interposed between ungrounded current-carrying parts and those external surfaces which can be contacted.

5.9.2. Test method

When connected in the manner intended to a supply circuit of rated voltage and frequency, the appliance shall be operated to equilibrium temperature. At the conclusion of the operating period specified, the applicable dielectric withstand test(s) specified below shall be conducted.

During conduct of the dielectric withstand tests, a 500 volt-ampere or larger transformer, having an essentially sinusoidal output voltage which can be varied, shall be used. The applied potential shall be increased gradually from zero until the required test voltage is reached and shall be held at that value for 1 minute. The use of a 500 volt-ampere or larger transformer is not necessary if the high potential testing equipment used maintains the specified high potential voltage at the equipment during the test.

a) An appliance shall be capable of withstanding, for 1 min without breakdown, the application of a rated frequency potential between high voltage live parts and dead metal parts, and between live parts of high and low voltage circuits. The test potential shall be:

1,000 volts plus twice rated voltage; except

1,000 volts for motors rated at not more than 1/2 hp (373 W) and not more than 250 volts.

When higher than rated voltage is developed in a motor circuit through the use of capacitors, the rated voltage of the appliance shall be employed to determine the dielectric withstand test potential, unless the developed steady state capacitor voltage exceeds 500 volts, in which case the test potential for the parts affected shall be 1,000 volts plus twice the developed voltage.

b) A low voltage circuit shall be capable of withstanding, for 1 minute without breakdown, a 60 hertz potential of 500 volts applied between low-voltage live parts of opposite polarity and between low voltage live parts and dead metal parts.

The dielectric withstand test between low voltage parts of opposite polarity need not be conducted

on the complete assembly if the components have been separately subjected to this test condition.

The arrangement of the test circuit shall be such that if the dielectric material breaks down, a positive signal will be obtained, rather than depending upon a visual inspection of the material.

The above test shall be conducted at the conclusion of the operating period specified in Clause 5.10, Rain test.

5.10. Rain test

5.10.1. Acceptance criteria

A dispenser for outdoor installation shall be constructed so it will function normally when subjected to a simulated rainstorm. (See 4.2.1 h))

5.10.2. Test method

This test shall be conducted in accordance with either IPX2 or IPX3 under IEC60529 as follows:

a) The dispenser shall be placed on the test platform of the rain test apparatus shown in Figures 3 and 4 in the position with respect to the spray heads deemed most critical by the certification agency. The dispenser shall be placed in operation.

b) The rain test apparatus shall then be placed in operation and each spray head adjusted by means of the control valve to operate at 34.5 kPa. The spray head unit shall be adjusted to varying elevations and horizontal distances from the test platform to determine the most critical location. The exposure at the position deemed most critical by the certification agency shall be maintained throughout the test.

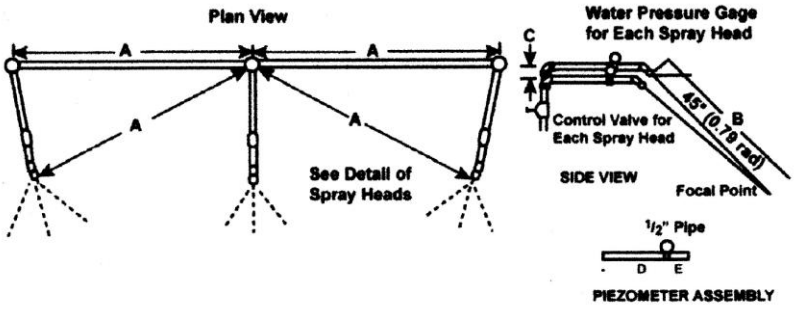
c) After adjustment of the spray head unit, the rain test apparatus shall be operated for a period of 15 minutes. The dispenser shall then be used to fill a vehicle fuel storage container.

d) The above test procedure shall be repeated with the dispenser rotated to any other position(s) with respect to the spray heads deemed necessary by the certification agency.

e) The dispenser shall function normally during exposure to the simulated rainstorm. Upon completion of exposure to the simulated rainstorm, there shall be no evidence of damage or malfunctioning of any part of the dispenser, nor detrimental accumulation of water in any part of the dispenser. The test is not to result in the entrance of water into an electric enclosure above the lowest live part or in wetting live parts.

f) If the dispenser uses a purged and pressurized enclosure system, this test shall be conducted with and without the system in operation.

g) At the conclusion of this test, the dispenser shall comply with the dielectric strength test specified in 5.9, Dielectric Voltage-Withstand Test.



Item	Inch	(mm)
A	28	(711)
B	55	(1397)
C	2 1/4	(57)
D	9	(229)
E	3	(76)

Figure 3. Arrangement of spray heads and associated piping for simulated rainstorm test

Item	Inch	(mm)	Item	Inch	(mm)
A	1 7/32	(30.96)	N	1/32	(0.79)
B	7/16	(11.11)	P	0.575	(14.60)
C	9/16	(14.29)		0.576	(14.63)
D	0.578	(14.68)	Q	0.543	(11.51)
	0.580	(14.73)		0.454	(11.53)
E	1/64	(0.40)	R	1/4	(6.35)
F	c	c	S	1/32	(0.7)
G	0.06	(1.52)	T	(No. 35)[b]	(2.79)
H	(No. 9)[b]	(5.00)	U	(No. 40)[b]	(2.49)
J	23/32	(18.26)	V	5/8	(15.88)
K	5/32	(3.97)	W	0.06	(1.52)
L	1/4	(6.35)			
M	3/32	(2.38)			

[a] - Molded nylon rain-test spray heads are available from Underwriters Laboritories Inc.
[b] - ANSI/ASME B94.11 drill size.
[c] - Optional - To serve as wrench grip.

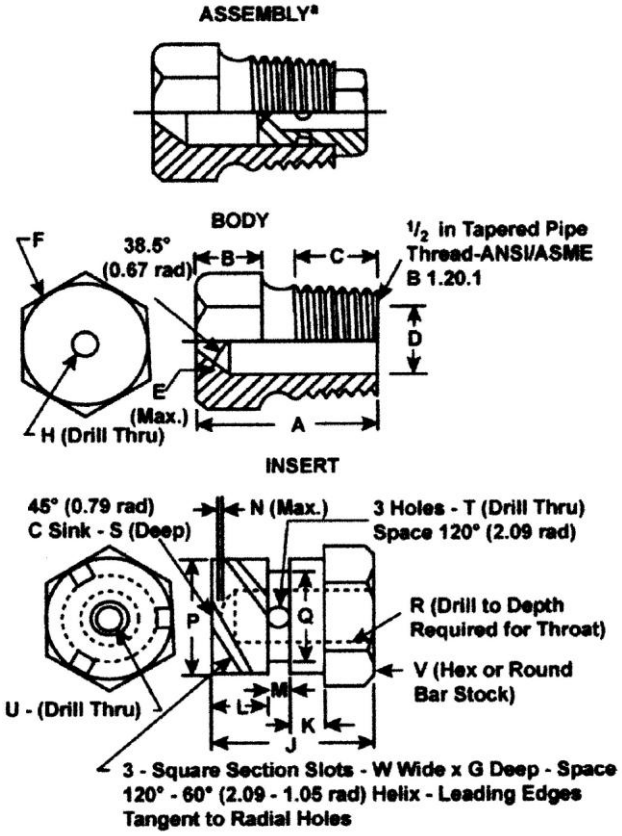


Figure 4. Spray head assembly and detail of construction

5.11. Marking material adhesion and legibility test

5.11.1. Acceptance criteria

The adhesive quality and the legibility of marking materials shall not be adversely affected when the

marking materials are exposed to heat and moisture as specified in the following method of test.

5.11.2. Test method

a) Adhesive type marking materials shall be applied to the particular type of finish used on the appliance in production. A sample metal panel of this finish shall be cleaned with a solvent and dried. Half of the panel shall be wiped with a clean cloth lightly oiled with SAE-30 medium machine oil. Two samples of marking material shall be applied to the panel, one on the dry area and one on the oiled area. Test samples shall be applied with firm pressure, unless the manufacturer's application instructions specify otherwise. Each sample shall be allowed to set for 24 hours at room temperature.

Each sample of marking material shall exhibit:

i) Good adhesion and no curling at edges,

ii) No illegible or defaced printing when rubbed with thumb or finger pressure, and,

iii) Good adhesion when a dull metal blade (as the back of a pocketknife blade) is held at 90 degrees (1.57 rad) to the applied marking and scraped across the edges of the marking.

b) Non adhesive type marking material shall exhibit no illegible or defaced printing when rubbed with thumb or finger pressure. Two samples of marking material shall be tested.

c) Samples of both adhesive and non-adhesive type marking materials shall then be placed in an oven for a period of 2 weeks with the oven temperature maintained at:

i) 175°C (350°F) for Class IIA-1, IIA-2, IIA-3, IIA-4 and IIIA-1 marking materials, or

ii) 120°C (250°F) for Class IIIA-2 and IIIB marking materials.

Following the oven test, adhesion and legibility of the samples shall be checked again as specified in "a" and "b" above.

Samples shall then be immersed in water for a period of 24 hours, after which adhesion and legibility shall be rechecked as specified in "a" and "b" above.

Good adhesion and legibility qualities shall be obtained for all samples under the above specified test conditions.

Final acceptance of marking materials shall be based on the suitability of the application of the marking material to the appliance.

6. Routine tests

6.1. Leakage test

Each dispensing device shall satisfy the acceptance criteria specified in 5.2.1 when tested according to the test method described in 5.2.2, as a routine production line-test.

6.2. Dielectric voltage-withstand test

Each dispensing device shall satisfy the acceptance criteria specified in 5.9.1 when tested according to the test method described in 5.9.2, as a routine production line-test.

7. Installation, service, maintenance and operating instructions

a) The manufacturer shall provide maintenance instructions for the dispenser, which may include instructions from respective component manufacturers (e.g. filters and seals).

b) For the purposes of review by the certification agency or the AHJ, the dispensing system shall be accompanied by concise and thorough installation, service, maintenance and operating instructions.

c) Manufacturer's instructions shall be reviewed by the certification agency for accuracy and compatibility with the results of tests deemed most critical for certification, listing or acceptance from a technical standpoint.

d) The instructions shall state at a minimum the following:

i) The user, installation, service and technical manuals, as applicable, shall be left with the appropriate persons;

ii) The installation shall be in accordance with the requirements of the AHJ. In the absence of local codes, the installation shall be in accordance with the following:

i *ANSI/NFPA 2*;

ii *ANSI/NFPA 70* as applicable.

iii) The dispenser system is intended for use with fuel cell grade hydrogen as defined in ISO 14687-2, unless additional precautions are taken;

iv) The dispensing device shall be installed as recommended by the manufacturer; and

v) The maximum allowable working pressure of the inlet of the dispenser and the discharge of the hoses.

vi) The proper method of mounting and the type of structure(s) that each device is intended to be mounted on: In all cases, adequate support shall be provided for each unit of the dispensing system, independent of piping, tubing or conduit that may be connected thereto; and

vii) Clear and concise printed instructions and diagrams in a form that can be easily understood and adequate for:

a. Proper field assembly,

b. Installation,

c. Maintenance,

d. Replacement of components as appropriate,

e. For safe operation by all users,

f. Suitability and use; and

g. Storage and handling.

Bibliography