## UN-GTR PART A INSERTION

### A.7.1.2.1 Rationale for HPRD Qualification Requirements

The qualification requirements verify that the design shall be such that, once activated, the device will fully vent the contents of the fuel container even at the end of the service life when the device has been exposed to fueling/de-fueling pressure and temperature changes and environmental exposures. The adequacy of flow rate for a given application is verified by the hydrogen storage system fire test requirements (B.5.1.4).

### A.7.1.2.2 Rationale for Check Valve Qualification Requirements

These requirements are not intended to prevent the design and construction of components (e.g. components having multiple functions) that are not specifically prescribed in this standard, provided that such alternatives have been considered in testing the components. In considering alternative designs or construction, the materials or methods used shall be evaluated by the testing facility to ensure equivalent performance and reasonable concepts of safety to that prescribed by this standard. In that case, the number of samples and order of applicable tests shall be mutually agreed upon by the manufacturer and the testing agency. Unless otherwise specified, all tests shall be conducted using hydrogen gas that complies with SAE J2719 (Information Report on the Development of a Hydrogen Quality Guideline for Fuel Cell Vehicles), or ISO 14687-2 (Hydrogen Fuel-Product Specification). The total number of operational cycles shall be 11,000 (fueling cycles) for the check valve and 50,000 (duty cycles) for the automatic shut-off valve.

Fuel flow shut-off by an automatic shut-off valve mounted on a compressed hydrogen storage vessel shall be fail safe. The term “fail safe” shall refer to a device’s ability to revert to a safe mode or a safe complete shutdown for all reasonable failure modes.

The electrical tests for the automatic shut-off valve mounted on the compressed hydrogen storage vessels (that B.7.1.2.2.1.g) provide assurance of performance with: (1) over temperature caused by an overvoltage condition, and (2) potential failure of the insulation between the component’s power conductor and the component casing. The purpose of the Pre-Cooled Hydrogen Exposure Test (B.7.1.2.2.1.k) is to verify that all components in the flow path from the receptacle to the container that are exposed to precooled hydrogen during fuelling can continue to operate safely.

**UN-GTR PART B INSERTION**

### B.7.1.2.1 HPRD Qualification Requirements

Design qualification testing shall be conducted on finished pressure relief devices which are representative of normal production. The HPRD shall meet the following performance qualification requirements:

- Pressure Cycling Test (B.8.1.1 test procedure)
- Accelerated Life Test (B.8.1.2 test procedure)
- Temperature Cycling Test (B.8.1.3 test procedure)
- Salt Corrosion Resistance Test (B.8.1.4 test procedure)
- Stress Corrosion Test (B.8.1.5 test procedure)
- Drop and Vibration Test (B.8.1.6 test procedure)
- Leak Test (B.8.1.7 test procedure)
- Bench Top Activation Test (B.8.1.8 test procedure)
- Flow Rate Test (B.8.1.9 test procedure )

### B.7.1.2.2 Check Valve and Automatic Shut-Off Valve Qualification Requirements

Design qualification testing shall be conducted on finished pressure relief devices which are representative of normal production. The valve units shall meet the following performance qualification requirements:

- Hydrostatic Strength Test (B.8.2.1)
- Leak Test (B.8.2.2)
- Extreme Temperature Pressure Cycling Test (B.8.2.3)
- Salt Corrosion Test (B.8.2.4)
- Vehicle Environment Test (B.8.2.5)
- Atmospheric Exposure Test (B.8.2.6)
- Electrical Tests (B.8.2.7**)**
- Vibration Test (B.8.2.8)
- Stress Corrosion Test (B.8.2.9)
- Pre-Cooled Hydrogen Exposure Test (B.8.2.10)

### B.8.1 TYPE APPROVAL HPRD Qualification Performance Tests

Testing shall be performed with hydrogen gas having gas quality compliant with ISO 14687-2/SAE J2719. All tests shall be performed at ambient temperature 20($\pm$5)$^{o}$C unless otherwise specified. The HPRD qualification performance tests are specified as follows:

B.8.1.1 Pressure Cycling Test

Five HPRD units shall undergo 11,000 internal pressure cycles with hydrogen gas having gas quality compliant with ISO 14687-2/SAE J2719. The first five pressure cycles shall be between < 2MPa and 150% NWP; the remaining cycles shall be between 2($\pm$1)MPa and 125% NWP($\pm$1MPa). The first 1500 pressure cycles shall be conducted at a HPRD temperature of +85($\pm$5)°C. The remaining cycles shall be conducted at a HPRD temperature of +55($\pm$5)°C. The maximum pressure cycling rate is ten cycles per minute. Following this test, the pressure relief device shall meet the requirements of the Leak Test (B.8.1.7) and the Bench Top Activation Test (B.8.1.8).

B.8.1.2 Accelerated Life Test

Eight HPRD units shall undergo testing; three at the manufacturer's specified activation temperature, $T_{act}$, and five at an accelerated life temperature, $T_{life} = 9.1 \times T_{act}^{0.503}$. The HPRD shall be placed in an oven or liquid bath with the temperature held constant (±1°C). The hydrogen gas pressure on the HPRD inlet shall be 125% NWP ($\pm$1MPa). The pressure supply may be located outside the controlled temperature oven or bath. Each device may be pressured individually or through a manifold system. If a manifold system is used, each pressure connection should include a check valve to prevent pressure depletion of the system when one specimen fails. The three HPRDs tested at $T_{act}$ shall activate in less than ten hours. The five HPRDs tested at $T_{life}$ shall not activate in less than 500 hours.

B.8.1.3 Temperature Cycling Test

(1) Place an unpressurized HPRD in a liquid bath maintained at -35($\pm$5)°C at least two hours. Transfer the HPRD to a liquid bath maintained at +85($\pm$5)°C within five minutes, and maintain that temperature at least two hours. Transfer the HPRD to a liquid bath maintained at -35($\pm$5)°C within five minutes.

(2) Repeat step (a) until 15 thermal cycles have been achieved.

(3) With the HPRD conditioned for a minimum of two hours in the -35°C liquid bath, cycle the internal pressure of the HPRD with hydrogen gas between < 2MPa and 100%NWP for 100 cycles while maintaining the liquid bath at -35($\pm$5)°C.

(4) Following the thermal and pressure cycling, the HPRD shall meet the requirements of the Leak Test (B.8.1.7), except that the test shall be conducted at -35($\pm$5)°C, and the Bench Top Activation Test (B.8.1.8).

B.8.1.4 Salt Corrosion Resistance Test

Two HPRD units shall be tested. Any non-permanent outlet caps shall be removed. Each HPRD unit shall be installed in a test fixture in accordance with the manufacturer's recommended procedure so that external exposure is consistent with realistic installation. Each unit shall be pressurized to 125 percent of the service pressure and exposed for 144 hours to a salt spray (fog) test as specified in ASTM B117 (Standard Practice for Operating Salt Spray (Fog) Apparatus) except that in the test of one unit, the pH of the salt solution shall be adjusted to 4.0 ± 0.2 by the addition of sulfuric acid and nitric acid in a 2:1 ratio, and in the test of the other unit, the pH of the salt solution shall be adjusted to 10.0 ± 0.2 by the addition of sodium hydroxide. Following these tests, each pressure relief device shall meet the requirements of the Leak Test (B.8.1.7) and the Bench Top Activation Test (B.8.1.8).

B.8.1.5 Stress Corrosion Test.

For HPRDs containing components made of a copper-based alloy (e.g., brass), one HPRD unit shall be tested. The HPRD shall be disassembled, all copper alloy components shall be degreased and then the HPRD shall be reassembled before it is continuously exposed for ten days to a moist ammonia-air mixture maintained in a glass chamber having a glass cover.

Aqueous ammonia having a specific gravity of 0.94 shall be maintained at the bottom of the glass chamber below the sample at a concentration of at least 20 ml per liter of chamber volume. The sample shall be positioned 35(±5) mm above the aqueous ammonia solution and supported in an inert tray. The moist ammonia-air mixture shall be maintained at atmospheric pressure at +35(±5)ºC. Brass units shall not exhibit cracking or delamination due to this test.

B.8.1.6 Drop and Vibration Test

(1) Six HPRD units shall be dropped from a height of 2 m at ambient temperature onto a smooth concrete surface. Each sample shall be allowed to bounce on the concrete surface after the initial impact. One unit shall be dropped in six orientations (opposing directions of 3 orthogonal axes). If each of the six dropped samples do not show visible exterior damage that indicates that the part is unsuitable for use, then it shall proceed to step (b).

(2) Each of the six HPRD units dropped in step (a) and one additional unit not subjected to a drop shall be mounted in a test fixture in accordance with manufacturer's installation instructions and vibrated 30 minutes along each of the three orthogonal axes at the most severe resonant frequency for each axis. The most severe resonant frequencies shall be determined using an acceleration of 1.5 g and sweeping through a sinusoidal frequency range of 10 to 500Hz within 10 minutes. The resonance frequency is identified by a pronounced increase in vibrational amplitude. If the resonance frequency is not found in this range, the test shall be conducted at 500 Hz. Following this test, each sample shall not show visible exterior damage that indicates that the part is unsuitable for use. Then it shall meet the requirements of the Leak Test (B.8.1.8) and the Bench Top Activation Test (B.8.1.9).

B.8.1.7 Leak Test

The HPRD unit shall be held at 125% NWP with hydrogen gas for one hour at ambient temperature before leakage is measured. The method for measuring is at the discretion of the testing facility; the accuracy, response time and calibration of the measurement method shall be documented. The total hydrogen leak rate shall be less than 0.2 Ncc/hr.

B.8.1.8 Bench Top Activation Test

Two new HPRD units shall be tested without being subjected to other design qualification tests in order to establish a baseline time or pressure for activation.

(1) The test setup shall consist of either an oven or chimney which is capable of controlling air temperature and flow to achieve +600(± 10)°C in the air surrounding the HPRD. The HPRD unit shall not be exposed directly to flame. The HPRD unit shall be mounted in a fixture that shall be documented.

(2) Place a thermocouple in the oven or chimney to monitor the temperature. The temperature shall remain within the acceptable range for two minutes prior to running the test.

(3) Insert the pressurized HPRD unit into the oven or chimney, and record the time for the device to activate. Prior to insertion into the oven or chimney, pressurize one new HPRD unit to no more than 25% NWP; pressurize the pre-tested (B.8.1.2.1.a, c, d, e or g) HPRD units to no more than 25% NWP; and pressurize one new HPRD unit to 100% NWP.

(4) HPRD units previously subjected to testing in B.8.1.1, B.8.1.3, B.8.1.4 or B.8.1.6 shall activate within a period no more than two minutes longer than the baseline activation time of the new HPRD unit that was pressurized to up to 25% NWP.
(5) The difference in the activation time of the two HPRD units that had not undergone previous testing shall be no more than 2 minutes.

B.8.1.9 Flow Rate Test
(1) Nine HPRD units shall be tested for flow capacity. The nine units shall consist of one unit from those previously tested in each of B.8.1.1, B.8.1.3, B.8.1.4, B.8.1.5 or B.8.1.6, and three new HPRD units.
(2) Each HPRD unit be activated according to B.8.1.8. After activation and without cleaning, removing parts, or reconditioning, each HPRD unit shall be subjected to flow test using hydrogen, air or an inert gas.
(3) Flow rate testing shall be conducted with a gas inlet pressure of 2(±0.5) MPa. The outlet shall be ambient pressure. The inlet temperature and pressure shall be recorded.
(4) Flow rate shall be measured with accuracy within ±2 percent. The lowest measured value of the nine pressure relief devices shall not be less than 90 percent of the highest flow value.
(5) Flow rate shall be recorded as the lowest measured value of the nine pressure relief devices tested in NL per minute ($0^oC$ and 1 atmosphere) corrected for hydrogen.

**B.8.2 TYPE APPROVAL Qualification Performance Tests for Check Valve and Shut-Off Valve**

Testing shall be performed with hydrogen gas having gas quality compliant with ISO 14687-2/SAE J2719. All tests shall be performed at ambient temperature $20(\pm 5)^oC$ unless otherwise specified. The check valve and automatic shut-off valve qualification performance tests are specified as follows:

B.8.2.1 Hydrostatic Strength Test
The outlet opening in components shall be plugged and valve seats or internal blocks made to assume the open position. One unit shall be tested without being subjected to other design qualification tests in order to establish a baseline burst pressure, other units shall be tested as specified in subsequent tests.
(1) A hydrostatic pressure of 250% NWP shall be applied to the inlet of the component for three minutes. The component shall be examined to ensure that rupture has not occurred.
(2) The hydrostatic pressure shall then be increased at a rate of less than or equal to 1.4 MPa/sec until component failure. The hydrostatic pressure at failure shall be recorded. The failure pressure of previously tested units shall be no less than 80 percent of the failure pressure of the baseline, unless the hydrostatic pressure exceeds 400% NWP.

B.8.2.2 Leak Test
One unit shall be tested at ambient temperature without being subjected to other design qualification tests. Three temperature regimes are specified:
(1) Ambient temperature: condition the unit at $20(\pm 5)^oC$; test at 5% NWP and 150%

(2) High temperature: condition the unit at +85($\pm$5)$^{o}$C; test at 5% NWP and 150%
(3) Low temperature: condition the unit at -40($\pm$5)$^{o}$C; test at 5% NWP and 100%NWP.
Additional units shall undergo leak testing as specified in subsequent tests (B.8.2.3, B.8.2.4, B.8.2.5 and B.8.2.8) with uninterrupted exposure to the temperatures specified in those tests.

Plug the outlet opening with the appropriate mating connection and apply pressurized hydrogen to the inlet. At all specified test temperatures, condition the unit for one minute by immersion in a temperature controlled fluid (or equivalent method). If no bubbles are observed for the specified time period, the sample passes the test. If bubbles are detected, the leak rate shall be measured by an appropriate method. The leak rate shall not exceed 10 Ncc/hour of hydrogen gas.

B.8.2.3 Extreme Temperature Continuous Valve Cycling Test

(1) The total number of operational cycles shall be 11,000 for the check valve and 50,000 for the automatic shut-off valve. The valve unit shall be installed in a test fixture corresponding to the manufacturer's specifications for installation. The operation of the unit shall be continuously repeated using hydrogen gas at all specified pressures.
An operational cycle shall be defined as follows:
   (a) For a check valve, connect the check valve to a test fixture and apply pressure in six pulses to the check valve inlet with the outlet closed. Then vent pressure from the check valve inlet. Lower the pressure on the check valve outlet side to < 60% NWP prior to the next cycle.
   (b) For an automatic shut-off valve, connect the shut-off valve to a test fixture and apply pressure continuously to the both the inlet and outlet sides.
An operational cycle shall consist of one full operation and reset within an appropriate period as determined by the testing agency.

(2) Testing shall be performed on a unit stabilized at the following temperatures:
   (a) Ambient Temperature Cycling. The unit shall be undergo operational (open/closed) cycles at 125% NWP through 90 percent of the total cycles with the part stabilized at 20 ($\pm$5)$^{o}$C. At the completion of the ambient temperature operational cycles, the unit shall comply with the ambient temperature leakage test specified in B.8.2.2.
   (b) High Temperature Cycling. The unit shall then undergo operational cycles at 125% NWP through 5 percent of the total operational cycles with the part stabilized at +85($\pm$5)$^{o}$C. At the completion of the +85$^{o}$C cycles, the unit shall comply with the high temperature (+85$^{o}$C) leakage test specified in B.8.2.2.
   (c) Low Temperature Cycling. The unit shall then undergo operational cycles at 100% NWP through 5 percent of the total cycles with the part stabilized at -40$^{o}$C. At the completion of the -40$^{o}$C operational cycles, the unit shall comply with the low temperature (-40$^{o}$C) leakage test specified in B.8.2.2.

(3) Check valve Chatter Flow Test. Following 11,000 operational cycles and leak tests, subject the check valve to 240 hours of chatter flow at a flow rate that causes the most chatter (valve flutter). At the completion of the test the check valve shall comply with the ambient temperature leakage test specified in B.8.2.2 and the strength test in B.8.2.1.

B.8.2.4 Salt Corrosion Resistance Test

AISI series 300 Austenitic stainless steels are exempt from corrosion resistance testing. Materials used in valve units shall be subjected by the test agency to this test except where the applicant submits declarations of results of tests carried out on the material provided by the manufacturer.

The component shall be supported in its normally installed position and exposed for 150 hours to a salt spray (fog) test as specified in ASTM B117 (Standard Practice for Operating Salt Spray (Fog) Apparatus). If the component is expected to operate in vehicle underbody service conditions, then it shall be exposed for 500 hours to the salt spray (fog) test. The temperature within the fog chamber shall be maintained at 30-35$^{o}$C). The saline solution shall consist of 5 percent sodium chloride and 95 percent distilled water, by weight. Immediately following the corrosion test, the sample shall be rinsed and gently cleaned of salt deposits, examined for distortion, and then shall comply with the requirements of the ambient temperature leakage test specified in B.8.2.2.

B.8.2.5 Vehicle Environment Test

Resistance to degradation by exposure to automotive fluids may be determined by the following test, by comparable published data, or by known properties (e.g. 300 series stainless steel). The decision about the applicability of test data and known properties will be at the discretion of the testing authority.

(1) The inlet and outlet connections of the valve unit shall be connected or capped in accordance with the manufacturers installation instructions. The external surfaces of the valve unit shall be exposed for 24 hours at 20 (+5)oC to each of the following fluids:
- Sulfuric acid - 19 percent solution by volume in water;
- Sodium hydroxide - 25 percent solution by weight in water
- Ammonium nitrate - 28 percent by weight in water; and
- Windshield washer fluid (50 percent by volume methyl alcohol and water).

The fluids shall be replenished as needed to ensure complete exposure for the duration of the test. A distinct test shall be performed with each of the fluids. One component may be used for exposure to all of the fluids in sequence.

(2) After exposure to each chemical, the component shall be wiped off and rinsed with water and examined. The component shall not show signs of mechanical degradation that could impair the function of the component such as cracking, softening, or swelling. Cosmetic changes such as pitting or staining are not considered failures.

(3) At the conclusion of all exposures, the unit(s) shall comply with the requirements of the ambient temperature leakage test specified in B.8.2.2 and the strength test in B.8.2.1.

B.8.2.6 Atmospheric Exposure Test

The atmospheric exposure test applies to qualification of check valves; it does not apply to qualification of automatic shut-off valves.

(1) All non-metallic materials which that provide a fuel containing seal, and which are exposed to atmosphere, for which a satisfactory declaration of properties is not submitted by the applicant shall, when tested, not crack or show visible evidence of deterioration after exposure to oxygen for 96 hours at 70°C at 2 MPa in accordance with ASTM D572 (Standard Test Method for Rubber- Deterioration by Heat and Oxygen)

(2) All elastomers shall demonstrate resistance to ozone by one or more of the following:
- Specification of elastomer compounds with established excellent resistance to ozone.
- Component testing in accordance with ISO 1431/1, ASTM D1149, or equivalent test methods

B.8.2.7 Electrical Tests

The electrical tests apply to qualification of the automatic shut-off valve; they do not apply to qualification of automatic check valves.

(1) Abnormal Voltage Test. Connect the solenoid valve to a variable DC voltage source. Operate the solenoid valve as follows:
  (a) at 1.5 times the rated voltage establish equilibrium (steady state temperature) hold for one hour.
  (b) Increase the voltage to two times the rated voltage or 60 volts whichever is less and hold for one minute.
  (c) Any failure must not result in external leakage, open valve, or a similar unsafe condition.

  The minimum opening voltage at NWP and room temperature shall be less than or equal to 9 V for a 12 V system and less than or equal to 18 V for a 24 V system.

(2) Insulation Resistance Test**.** Apply 1,000 V D.C. between the power conductor and the component casing for at least two seconds. The minimum allowable resistance for that component shall be 240 kΩ.

B.8.2.8 Vibration Test

Vibrate the valve unit, pressurized to its 100% NWP with hydrogen and sealed at both ends, for 30 minutes along each of the three orthogonal axes at the most severe resonant frequencies. The most severe resonant frequencies shall be determined by the following: acceleration of 1.5 g with a sweep time of 10 minutes, within a sinusoidal frequency range of 10 to 500Hz. If the resonance frequency is not found in this range the test shall be conducted at 500 Hz. Following this test, each sample shall not show visible exterior damage that indicates that the part is unsuitable for use. At the completion of the test, the unit shall comply with the requirements of the ambient temperature leakage test specified in B.8.2.2.

B.8.2.9 Stress Corrosion Cracking Resistance

Brass valves with a history of satisfactory field experience shall be exempt from this requirement if documentation can be submitted to the testing agency to justify exemption to this requirement. Brass valves for which a satisfactory declaration of properties is not submitted shall be tested.

The brass unit shall be subjected to the stresses normally imposed on it as a result of assembly. The component shall be degreased and then continuously exposed for ten days to a moist ammonia-air mixture maintained in a glass chamber having a glass cover. Aqueous ammonia having a specific gravity of 0.94 shall be maintained at the bottom of the glass chamber below the sample at a concentration of 21.2 ml per liter of chamber volume. The sample shall be positioned 38 mm (1.5 in) above the aqueous ammonia solution and supported in an inert tray. The moist ammonia-air mixture shall be maintained at atmospheric pressure with the temperature constant at +35(±2)ºC. Brass units shall not exhibit cracking or delamination due to this test.

B.8.2.10 Pre-Cooled Hydrogen Exposure Test

The valve unit shall be subjected to pre-cooled hydrogen gas at -40 ºC at a flow rate of 30 g/s at external temperature of 20(±5) ºC for a minimum of three minutes. The unit shall be de-pressurized and re-pressurized after a two minute hold period. This test shall be repeated ten times. This test procedure shall then be repeated for an additional ten cycles, except that the hold period shall be increased to 15 minutes. The unit shall then comply with the requirements of the ambient temperature leakage test specified in B.8.2.2.