Submitted by the expert from USA

Informal document **GRSP-51-21-Rev.1**
(51st GRSP, 21–25 May 2012,
agenda item 8)

Proposed amendment to document ECE/TRANS/WP.29/GRSP/2012/12

The text reproduced below was prepared by the secretary from the UN Global Technical Regulation (UN GTR) on safety of hydrogen fuel cell vehicle aim to reflect the result of hydrogen vehicle working group and correct to appropriate wording, i.e. editorial and clarification.

The modifications to the text of ECE/TRANS/WP.29/GRSP/2012/12 are marked in highlighted in yellow or marked as strikethrough.

Proposal

I. Statement of technical rationale and justification

(i) Rationale for paragraph 5.1.1.1. baseline initial burst pressure

52. Paragraph 5.1.1.1. establishes the midpoint initial burst pressure, BP_O, and verifies that initial burst pressures of systems in the qualification batch are within the range BP_O ± 10 per cent. BP_O is used as a reference point in performance verification (paras. 5.1.2.8. and 5.1.3.5.) and verification of consistency within the qualification batch~~Paragraph 5.1.1.1. verifies that BP_O is greater than or equal to [200 per cent] NWP to screen for capability to sustain 180 per cent NWP at end-of-life with minimal loss of strength during qualification testing.~~

Paragraph B .5.1.1.1. verifies that BPO is greater than or equal to 225 per cent NWP or 330% NWP (for glass fiber composites), ~~a~~ values tentatively selected without data-driven derivation but instead based on historical usage and applied here as ~~a~~ placeholders with the expectation that ~~a lower minimum value (200 per cent NWP or lower) is under evaluation and hence new~~ data or analysis will be available for reconsideration of the topic in Phase 2 of the development of this GTR. For example, a 200 per cent minimum initial burst pressure requirement can be supported by the data-driven performance-linked justification that a greater-than 180 per cent NWP end-of-service burst requirement (linked to capability to survive the maximum fueling station over-pressurization) combined with a 20 per cent lifetime decline (maximum allowed) from median initial burst strength is equivalent to a requirement for a median initial burst strength of 225 per cent NWP, which corresponds to a minimum burst strength of 200per cent NWP for the maximum allowed 10per cent variability in initial strength. The interval between Phase I and Phase II provides opportunity for development of new data or analysis pertaining to a 225 per cent NWP (or another per cent NWP) minimum prior to resolution of the topic in Phase 2.

56. Regardless of the container failure mode, this requirement provides sufficient protection for safe container use over the life of the vehicle. The minimum distance travelled prior to a container leaking would depend on a number of factors including the

number of cycles chosen by the Contracting Party and the fill mileage for the vehicle. Regardless, the minimum design of 5500 cycles before leak and using only 200 miles per fill provides over 1 million miles before the container would fail by leakage. Worst case scenario would be failure by rupture in which case the container shall be capable of withstanding ~~[~~22,000~~]~~ cycles. For vehicles with nominal on-road driving range of 480 km (300 miles) per full fuelling, ~~[~~22,000~~]~~ full fill cycles corresponds to over 10 million km (6 million miles), which is beyond a realistic extreme of on-road vehicle lifetime range (see discussion in para.5.1.1.2.2. below). Hence, either the container demonstrates the capability to avoid failure (leak or rupture) from exposure to the pressure cycling in on-road service, or leakage occurs before rupture and thereby prevents continued service that could potentially lead to rupture.

57. A greater number of pressure cycles, ~~[~~22,000~~]~~, is required for demonstration of resistance to rupture (in the absence of intervening leak) compared to the number of cycles required for demonstration of resistance to leak (between 5500 and 11,000) because the higher severity of a rupture event suggests that the probability of that event per pressure cycle should be lower than the probability of the less severe leak event. Risk = (probability of event) x (severity of event).

(e) Rationale for paragraphs 5.1.5 and 6.2.6 qualification tests for storage-system hydrogen-flow closures

70. Test procedures for qualification of hydrogen-flow closures within the hydrogen storage system were developed by the International Organization of Vehicle Manufacturers (OICA) as outgrowths of discussions within CSA workgroups for **TPRD1**:2009 and HGV3.1 (as yet unpublished), and reports to those CSA workgroups testing sponsored by US-DOE and performed at Powertech Laboratories to verify closure test procedures under discussion within CSA. Differences between the requirements established herein and the CSA documents derive primarily from differences in scope: CSA requirements encompass all on road applications including heavy duty applications.

117. Requirements for closures of the hydrogen storage system (TPRD, automatic shut-off valve and check valve) have been developed by CSA (HGV3.1 and **T**PRD-1).

(d) Results of closure tests are to be recorded by the testing laboratory and made available to the manufacturer. In the Flow Rate Test, the flow rate is recorded as the lowest measured value of the eight pressure relief devices tested in NL per minute (0 °C and 1 atmosphere) corrected for hydrogen~~.~~

(e) The Atmospheric Exposure Test (para. 6.2.6.2.6) derives from two historical tests. The Oxygen Ageing Test was contained in CSA NGV3.1 and harmonized with ISO CD 12619 Part 2 (hydrogen components) and ISO 15500 Part 2 (CNG components). The Ozone resistance test drew the requirements and test procedure from the ECE R110 requirement for CNG Components, and has been added to both the hydrogen and CNG components documents at CSA.

128. This section (specifies the rationale for the performance requirements established in paragraph 7.2. for the integrity of the liquefied hydrogen storage system. Manufacturers are expected to ensure that all production units ~~meet~~ comply with the requirements of performance verification testing in paragraphs 7.2.1. to 7.2.4.

1. The following test procedure will be considered for long-term stress rupture:

~~(f) Introduction of glass fibre containers that have an initial burst pressure of 330 per cent NWP is to be optional for each Contracting Party.~~

J.Existing Regulations, Directives, and International Standards

2. Storage system

(a) National regulations and directives:

(a) China — Regulation on Safety Supervision for Special Equipment

(b) China — Regulation on Safety Supervision for Gas Cylinder

(c) Japan – High Pressure Gas Safety Act.

Comment [MV1]: Japan edit; also renumber following sections.

B. Text of Regulation

2. Scope

This regulation applies to all hydrogen fuelled vehicles of Category 1-1 and 1-2, with a gross vehicle mass (GVM) of 4,536 ~~[4,500]~~ kilograms or less, ~~**excluding vehicles that use blended hydrogen fuel.**~~

~~**[optional: restrict the scope to only carbon fiber wrapped container]**~~

3.28. "*Hydrogen-fuelled vehicle*" indicates any motor vehicle that uses compressed gaseous or liquefied hydrogen as a fuel to propel the vehicle, including fuel cell and internal combustion engine vehicles. Hydrogen fuel for passenger vehicles is specified in ISO 14687-2 and SAE J2719.

Table 1

Overview of Performance Qualification Test Requirements

5.1.1. Verification Tests for Baseline ~~Performance~~ Metrics

~~1~~5.1.1.1. Baseline Initial Burst Pressure

~~1~~5.1.1.2. Baseline Initial Pressure Cycle Life

~~1~~5.1.2. Verification Test for Performance Durability (sequential hydraulic tests)

~~1~~5.1.2.1. Proof Pressure Test

~~1~~5.1.2.2. Drop (Impact) Test

~~1~~5.1.2.3. Surface damage

~~1~~5.1.2.4. Chemical Exposure and Ambient Temperature Pressure Cycling Tests

~~1~~5.1.2.5. High Temperature Static Pressure Test

~~1~~5.1.2.6. Extreme Temperature Pressure Cycling

~~1~~5.1.2.7. Residual Proof Pressure Test

~~1~~5.1.2.8. Residual Strength Burst Test

~~1~~5.1.3. Verification Test for Expected On-road Performance (sequential pneumatic tests)

5.1.1. Verification Tests for Baseline ~~Performance~~ Metrics

~~1~~5.1.1.1. Baseline Initial Burst Pressure

~~1~~5.1.1.2. Baseline Initial Pressure Cycle Life

~~1~~5.1.3.1. Proof Pressure Test

~~1~~5.1.3.2. Ambient and Extreme Temperature Gas Pressure Cycling Test (pneumatic)

~~1~~5.1.3.3. Extreme Temperature Static Gas Pressure Leak/Permeation Test (pneumatic)

~~1~~5.1.3.4. Residual Proof Pressure Test

~~1~~5.1.3.5. Residual Strength Burst Test (Hydraulic)

~~1~~5.1.4. Verification Test for Service Terminating Performance in Fire

~~1~~5.1.5. Verification Test for Closure Durability

5.1.1.1. Baseline Initial Burst Pressure

Three (3) new containers randomly selected from the design qualification batch of at least 10 containers, are hydraulically pressurized until burst (para. 6.2.2.1. test procedure). The manufacturer shall supply documentation (measurements and statistical analyses) that establish the midpoint burst pressure of new storage containers, BPO.

All containers tested shall have a burst pressure within ±10 per cent of BPO and greater than or equal to a minimum BPmin of **225** per cent NWP**.**

~~[~~In addition~~, [Contracting Parties may require]~~ containers having glass-fiber composite as a primary constituent to have a minimum burst pressure greater than ~~(~~330 or 350~~)~~ percent NWP.~~]~~

Comment [t2]: Japan proposes to change to 350%

5.1.5. Verification Test for Performance Durability of Primary Closures

Manufacturers shall maintain records that confirm that closures that isolate the high pressure hydrogen storage system (the TPRD(s), check valve(s) and shut-off valve(s) shown in Figure 1) ~~meet~~ comply with the requirements described in the remainder of this Section.

6.1.3. Compliance Test for Single Failure Conditions

6.1.3.2.1.4. 6.1.3.2.1.4. For the purpose of the test, a hydrogen concentration detector is installed where hydrogen gas may accumulate most in the passenger compartment (e.g. near the headliner) when testing for compliance with 5.2.1.4.2 and hydrogen concentration detectors are installed in enclosed or semi enclosed volumes on the vehicle where hydrogen can accumulate from the simulated hydrogen releases when testing for compliance with 5.2.1.4.3 (see para. 6.1.3.2.1.3.).

6.1.3.2.2.5. When testing for compliance with 5.2.1.4.2, the test is successfully completed if the hydrogen concentration in the passenger compartment does not exceed 1.0 per cent. **When testing for compliance with B.5.2.1.4.3,** the test is successfully completed if the tell-tale warning and shut-off function are executed at (or below) the levels specified in paragraph ~~5.2.1.4.2. and~~ 5.2.1.4.3.; otherwise, the test is failed and the system is not qualified for vehicle service.

6.2.4.1. Gas Pressure Cycling Test (Pneumatic). At the onset of testing, the storage system is stabilized at the specified temperature, relative humidity and fuel level for at least 24 hrs. The specified temperature and relative humidity is maintained within the test environment throughout the remainder of the test. (When required in the test specification, the system temperature is stabilized at the external environmental temperature between pressure cycles.) The storage system is pressure cycled between less than 2(+0/-1~~(±1~~) MPa and the specified maximum pressure (±1MPa). If system controls that are active in vehicle service prevent the pressure from dropping below a specified pressure, the test cycles shall not go below that specified pressure. The fill rate is controlled to a constant 3-minute pressure ramp rate, but with the fuel flow not to exceed 60 g/s; the temperature of the hydrogen fuel dispensed to the container is controlled to the specified temperature. The defuelling rate is controlled to greater than or equal to the intended vehicle's maximum fuel-demand rate. The specified number of pressure cycles is conducted. If devices and/or controls are used in the intended vehicle application to prevent an extreme internal temperature, the test may be conducted with these devices and/or controls (or equivalent measures).

6.2.4.2. Gas Permeation Test (Pneumatic). A storage system is fully filled with hydrogen gas (full fill density equivalent to 100 per cent NWP at 15 °C is ~~113~~ 115 per cent NWP at 55 °C) and held at 55 °C in a sealed container. The total steady-state discharge rate due to leakage and permeation from the storage system is measured.

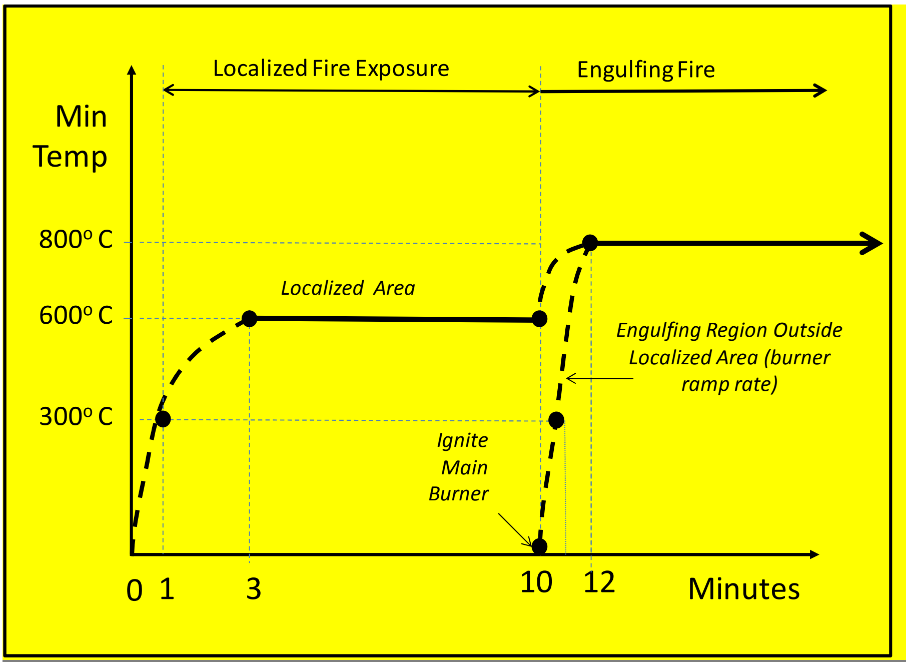
6.2.5. Test Procedures for Service Terminating Performance in Fire (para. 5.1.4.)

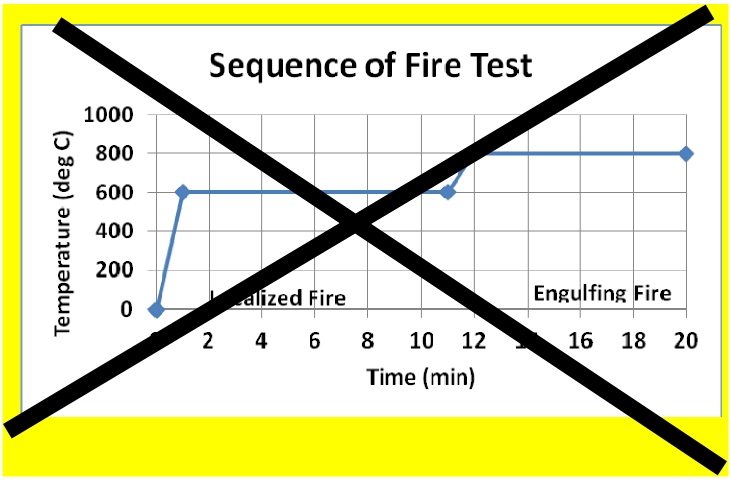
6.2.5.1.2. Method 2: Qualification for a Specific Vehicle Installation

(f) As shown in Figure 7 the temperature of the thermocouples in the localized fire area has increased continuously to at least 300 °C within 1 minute of ignition, to at least 600 °C within 3 minutes of ignition, and a temperature of at least 600 °C is maintained for the next ~~5~~ 7 minutes. The temperature in the localized fire area shall not exceed 900 °C during this period. Compliance to the thermal requirements begins 1 minute after entering the period with minimum and maximum limits and is based on a 1-minute rolling average of each thermocouple in the region of interest. (Note: The temperature outside the region of the initial fire source is not specified during these initial 8 minutes from the time of ignition.)

~~[The below profiles for fire time are being considered by SGS group:~~

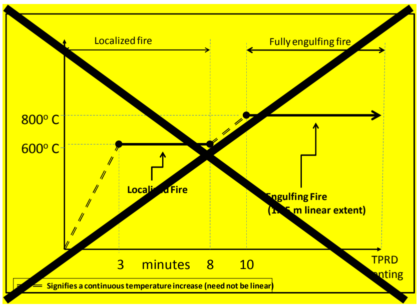
Figure 7
Temperature profile of fire test





~~Figure 8~~

~~**Sequence of fire test**~~



Engulfing Portion of the Fire Test

Within the next 2-minute interval, the temperature along the entire surface of the test article shall be increased to at least 800 °C and the fire source is extended to produce a uniform temperature along the entire length up to 1.65 meters and the entire width of the test article (engulfing fire). The minimum temperature is held at 800°C, and the maximum temperature shall not exceed 1100 °C. Compliance to thermal requirements begins 1 minute after entering the period with constant minimum and maximum limits and is based on a 1-minute rolling average of each thermocouple.

The test article is held at temperature (engulfing fire condition) until the system vents through the TPRD and the pressure falls to less than 1 MPa. The venting shall be continuous (without interruption), and the storage system shall not rupture. An additional release through leakage (not including release through the TPRD) that results in a flame with length greater than 0.5 m beyond the perimeter of the applied flame shall not occur.

Summary of Fire Test Protocol

	Localized Fire Region	Time Period	Engulfing Fire Region (Outside the Localized Fire Region)
Action	Ignite Burners	0-1 Minute	No Burner Operation
Minimum Temperature	Not specified		Not specified
Maximum Temperature	Less than 900°C		Not specified
Action	Increase Temperature and Stabilize Fire for Start of Localized Fire Exposure	1-3 Minutes	No Burner Operation
Minimum Temperature	Greater than 300°C		Not specified
Maximum Temperature	Less than 900°C		Not specified
Action	Localized Fire Exposure Continues	3-10 Minutes	No Burner Operation
Minimum Temperature	1-minute Rolling Average Greater Than 600°C		Not specified
Maximum Temperature	1-minute Rolling Average Less Than 900°C		Not specified
Action	Increase Temperature	10-11 Minutes	Main Burner Ignited at 10 Minutes
Minimum Temperature	1-minute Rolling Average Greater Than 600°C		Not specified
Maximum Temperature	1-minute Rolling Average Less Than 1100°C		Less than 1100°C
Action	Increase Temperature and Stabilize Fire for Start of Engulfing Fire Exposure	11-12 Minutes	Increase Temperature and Stabilize Fire for Start of Engulfing Fire Exposure
Minimum Temperature	1-minute Rolling Average Greater Than 600°C		Greater than 300°C
Maximum Temperature	1 minute Rolling Average Less Than 1100°C		Less than 1100°C
Action	Engulfing Fire Exposure Continues	12 Minutes - end of test	Engulfing Fire Exposure Continues
Minimum Temperature	1-minute Rolling Average Greater Than 800°C		1-minute Rolling Average Greater than 800°C
Maximum Temperature	1 minute Rolling Average Less Than 1100°C		1-minute Rolling Average Less than 1100°C

Documenting Results of the Fire Test

The arrangement of the fire is recorded in sufficient detail to ensure the rate of heat input to the test article is reproducible. The results include the elapsed time from ignition of the fire to the start of venting through the TPRD(s), and the maximum pressure and time of evacuation until a pressure of less than 1 MPa is reached. Thermocouple temperatures and container pressure are recorded at intervals of every 10 sec or less during the test. Any failure to maintain specified minimum temperature requirements based on the 1-minute rolling averages invalidates the test result. Any failure to maintain specified maximum temperature requirements based on the 1-minute rolling averages invalidates the test result only if the test article failed during the test.

6.2.6. Test Procedures for Primary Closures within the Compressed Gaseous Hydrogen Storage System (para. 5.1.5. requirement).

6.2.6.1.1. Pressure Cycling Test.

Five TPRD units undergo 11,000 internal pressure cycles with hydrogen gas having gas quality compliant with ISO 14687-2/SAE J2719. The first five pressure cycles are between 2(+0/-1)MPa and 150 per cent NWP(+2/-0 MPa); the remaining cycles are between 2(+0/-1)MPa and 125 per cent NWP(+2/-0 MPa). The first 1500 pressure cycles are conducted at a TPRD temperature of +85°C(+0/-5°C). The remaining cycles are conducted at a TPRD temperature of +55°C(+/- 5°C). The maximum pressure cycling rate is ten cycles per minute. Following this test, the pressure relief device shall ~~meet~~comply with the requirements of the Leak Test (B 6.2.6.1.8.), Flow Rate Test (paragraph 6.2.6.1.10.) and the Bench Top Activation Test (paragraph 6.2.6.1.9.).

6.2.6.1.3. Temperature Cycling Test

(a) An unpressurized TPRD is placed in a liquid bath maintained at -40°C (+5/-0°C) at least two hours. The TPRD is transferred to a liquid bath maintained at +85 °C (+0/-5°C) within five minutes, and maintained at that temperature at least two hours. The TPRD is transferred to a liquid bath maintained at -40 °C (+5/-0°C) within five minutes

(b) Step (a) is repeated until 15 thermal cycles have been achieved.

(c) With the TPRD conditioned for a minimum of two hours in the -40°C(+5/-0°C) liquid bath, the internal pressure of the TPRD is cycled with hydrogen gas between 2MPa(+0/-1MPa) and 80 per cent NWP (+2/-0MPa) for 100 cycles while the liquid bath is maintained at –40°C(+5/-0°C).

(d) Following the thermal and pressure cycling, the pressure relief device shall comply with the low temperature (-40C) leak test as specified in paragraph 6.2.6.1.8. ~~except that the Leak Test and Flow Rate Test (para. 6.2.6.1.10.) are conducted at - 40°C, and the Bench Top Activation Test (para. 6.2.6.1.9.)~~. After the Leak Test, the TPRD shall comply with the requirements of the Bench Top Activation Test (para. 6.2.6.1.9), and then the Flow Rate Test (para. 6.2.6.1.10).

6.2.6.1.4. Salt Corrosion Resistance Test

Two TPRD units are tested. Any non-permanent outlet caps are removed. Each TPRD unit is installed in a test fixture in accordance with the manufacturer's recommended procedure so that external exposure is consistent with realistic installation. Each unit is ~~pressurized to 125 per cent of the service pressure and~~ exposed for ~~150~~500 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 sulphuric 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. The temperature within the fog chamber is maintained at 30-35^{0}C).

~~If the component is expected to operate in vehicle underbody service conditions, then it is exposed for 500 hours to the salt spray (fog) test. The temperature within the fog chamber is maintained at 30-35 °C).~~ Following these tests, each pressure relief device shall ~~meet~~ comply with the requirements of the Leak Test (para. 6.2.6.1.8.), Flow Rate Test (para. 6.2.6.1.10.) and Bench Top Activation Test (para. 6.2.6.1.9.).

6.2.6.1.5. Vehicle Environment Test

Resistance to degradation by external exposure to automotive fluids is 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 is at the discretion of the testing authority.~~

(a) The inlet and outlet connections of the TPRD are connected or capped in accordance with the manufacturers installation instructions. The external surfaces of the TPRD are exposed for 24 hours at 20 (±5) °C to each of the following fluids:

(i) Sulphuric acid - 19 per cent solution by volume in water;

(ii) Sodium hydroxide - 25 per cent solution by weight in water

(iii) Ammonium nitrate - 28 per cent by weight in water; and

(iv) Windshield washer fluid (50 per cent by volume methyl alcohol and water).

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

(b) After exposure to each fluid, the component is 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 failures.~~

(c) The component shall not show signs of physical degradation that could impair the function of the component, specifically: cracking, softening, or swelling. Cosmetic changes such as pitting or staining are not failures. At the conclusion of all exposures, the unit(s) shall comply with the requirements of the Leak Test (para. 6.2.6.1.8.), Flow Rate Test (para. 6.2.6.1.10.) and Bench Top Activation test (para. 6.2.6.1.9.).

6.2.6.1.6. Stress Corrosion Cracking Test.

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

6.2.6.1.7. Drop and Vibration Test

(a) Six TPRD units are dropped from a height of 2 m at ambient temperature (20 +/-5°C) onto a smooth concrete surface. Each sample is allowed to bounce on the concrete surface after the initial impact. One unit is dropped in six orientations (opposing directions of 3 orthogonal axes: vertical, lateral and longitudinal). If each of the six dropped samples does not show visible exterior damage that indicates that the part is unsuitable for use, it shall proceed to step (b).

(b) Each of the six TPRD units dropped in step (a) and one additional unit not subjected to a drop are mounted in a test fixture in accordance with manufacturer's installation instructions and vibrated 30 minutes along each of the three orthogonal axes (vertical, lateral and longitudinal at the most severe resonant frequency for each axis. The most severe resonant frequencies are determined using an acceleration of 1.5 g and sweeping through a sinusoidal frequency range of 10 to 40 Hz within 10 minutes. The resonance frequency is identified by a pronounced increase in vibration 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. It shall subsequently comply with ~~meet~~ the requirements of the Leak Test (para. 6.2.6.1.8.), Flow Rate Test (para. 6.2.6.1.10.) and Bench Top Activation Test (para. 6.2.6.1.9.).

6.2.6.1.8. Leak Test

One TPRD that has not undergone previous testing is tested at ambient, high and low temperatures without being subjected to other design qualification tests. The unit is held for one hour at each temperature and test pressure before testing. The three temperature test conditions are:

(1) Ambient temperature: condition the unit at 20(+/-5) °C; test at 5 per cent NWP (+0/-2MPa) and 150 per cent NWP (+2/-0MPa)

(2) High temperature: condition the unit at +85 (+0/-5)°C; test at 5 per cent NWP (+0/-2MPa) and 150 per cent NWP (+2/-0MPa)

(3) Low temperature: condition the unit at -40(+5/-0) °C; test at 5 per cent NWP (+0/-2MPa) and 100 per cent NWP (+2/-0MPa).

Additional units undergo leak testing as specified in other tests in para. 6.2.6.1 with uninterrupted exposure at the temperature specified in those tests.

At all specified test temperatures, the unit is conditioned 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 is measured by an appropriate method. The total hydrogen leak rate shall be less than ~~216Nml/hr~~ 10 NmL/hr.

6.2.6.1.10. Flow Rate Test

(e) ~~Flow rate is recorded as the lowest measured value of the eight pressure relief devices tested in NL per minute (0 °C and 1 atmosphere) corrected for hydrogen.~~

6.2.6.2. Compressed Hydrogen Storage Qualification Performance Tests for Check Valve and ~~Automatic~~ Shut-Off Valve

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

6.2.6.2.1. Hydrostatic Strength Test

(a) A hydrostatic pressure of 250 per cent NWP (+2/-0MPa) is applied to the inlet of the component for three minutes. The component is examined to ensure that rupture has not occurred.

6.2.6.2.2. Leak Test

One unit that has not undergone previous testing is tested at ambient, high and low temperatures without being subjected to other design qualification tests. The unit is held for one hour at each temperature and test pressure before testing.

The three temperature test conditions are ~~specified~~:

(~~a~~1) Ambient temperature: condition the unit at 20(+/-5) °C; test at 5 per cent NWP (+0/-2MPa) and 150 per cent NWP (+2/-0MPa)

(~~b~~2) High temperature: condition the unit at +85 (+0/-5)°C; test at 5 per cent NWP (+0/-2MPa) and 150 per cent NWP (+2/-0MPa)

(~~c~~3) Low temperature: condition the unit at -40(+5/-0) °C; test at 5 per cent NWP (+0/-2MPa) and 100 per cent NWP (+2/-0MPa). ~~Additional units undergo leak testing as specified in other tests in para. 6.2.6.2. with uninterrupted exposure to the temperatures specified in those tests.~~

Additional units undergo leak testing as specified in other tests in para. 6.2.6.2 with uninterrupted exposure at the temperature specified in those tests.

The outlet opening is plugged with the appropriate mating connection and pressurized hydrogen is applied to the inlet. At all specified test temperatures, the unit is conditioned 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 is measured by an appropriate method. The leak rate shall not exceed ~~216~~ 10 Nml/hr of hydrogen gas.

6.2.6.2.3. Extreme Temperature Continuous Valve Cycling Test:

(a) The total number of operational cycles is ~~50000~~ 11000 for the check valve and 50000 for the shut-off valve. The valve unit are installed in a test fixture corresponding to the manufacturer's specifications for installation. The operation of the unit is continuously repeated using hydrogen gas at all specified pressures.

An operational cycle shall be defined as follows:

(i) A check valve is connected to a test fixture and 100 per cent NWP (+2/-0MPa) ~~pressure~~ is applied in six pulses to the check valve inlet with the outlet closed. The pressure is then vented from the check valve inlet. The pressure is lowered on the check valve outlet side to ~~<~~less than 60 per cent NWP prior to the next cycle.

Comment [t3]: Provide definition for pulse and rationale for six pulses.

(ii) An ~~automatic~~ shut-off valve is connected to a test fixture and pressure is applied continuously to the both the inlet and outlet sides.

An operational cycle consists of one full operation and reset ~~within an appropriate period as determined by the testing agency~~.

(b) Testing is performed on a unit stabilized at the following temperatures:

(i) Ambient Temperature Cycling. The unit undergoes operational (open/closed) cycles at 125 per cent NWP (+2/-0MPa) through 90 per cent of the total cycles with the part stabilized at 20 (~~±~~+/-5) °C. At the completion of the ambient temperature operational cycles, the unit shall comply with the ambient temperature leak test specified in para. 6.2.6.2.2.

(ii) High Temperature Cycling. The unit then undergoes operational cycles at 125 per cent NWP (+2/-0MPa) through 5 per cent of the total operational cycles with the part stabilized at +85 (+0/-5)°C. At the completion of the +85°C cycles, the unit shall comply with the high temperature (+85 °C) leak test specified in paragraph 6.2.6.2.2.

(iii) Low Temperature Cycling. The unit then undergoes operational cycles at 100 per cent NWP (+2/-0MPa) through 5 per cent of the total cycles with the part stabilized at -40(+5/-0) °C. At the completion of the -40 °C operational cycles, the unit shall comply with the low temperature (-40 °C) leak test specified in paragraph 6.2.6.2.2.

(c) Check valve Chatter Flow Test. Following 11,000 operational cycles and leak tests in para. 6.2.6.2.3(b), the check valve is subjected to ~~240~~24 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 leak test (para. 6.2.6.2.2.) and the strength test (para. 6.2.6.2.1.).

6.2.6.2.4. Salt Corrosion Resistance Test

~~Components having all surfaces in contact with hydrogen composed of AISI series 300 Austenitic stainless steels are exempt from corrosion resistance testing. Materials used in valve units are subjected to this test except where the applicant submits declarations of results of tests carried out on the material provided by the manufacturer.~~

The component is supported in its normally installed position and exposed for ~~150~~500 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, it is subsequently exposed for 500 hours to the salt spray (fog) test~~. The temperature within the fog chamber is maintained at 30-35 °C). The saline solution consists of 5 per cent sodium chloride and 95 per cent distilled water, by weight.

Immediately after the corrosion test, the sample is rinsed and gently cleaned of salt deposits, examined for distortion, and then shall comply with ~~meet~~ the requirements of:

(a~~1~~) The component shall not show signs of physical degradation that could impair the function of the component, specifically: cracking, softening or swelling. Cosmetic changes such as pitting or staining are not failures.

(b~~2~~) the ambient temperature Leak Test (para. 6.2.6.2.2.) ~~and~~

(c~~3~~) the Hydrostatic Strength Test (para. 6.2.6.2.1.).

6.2.6.2.5. Vehicle Environment Test

Resistance to degradation by exposure to automotive fluids is 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 is at the discretion of the testing authority.~~

(a) The inlet and outlet connections of the valve unit are connected or capped in accordance with the manufacturers installation instructions. The external surfaces of the valve unit are exposed for 24 hours at 20 (±5) °C to each of the following fluids:

(i) Sulphuric acid -19 per cent solution by volume in water;

(ii) Sodium hydroxide - 25 per cent solution by weight in water

(iii) Ammonium nitrate – 28 per cent by weight in water; and

(iv) Windshield washer fluid (50 per cent by volume methyl alcohol and water).

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

(b) After exposure to each chemical, the component is wiped off and rinsed with water.

(c) The component shall not show signs of **physical** degradation that could impair the function of the component, **specifically**: cracking, softening, or swelling. Cosmetic changes such as pitting or staining are not failures. At the conclusion of all exposures, the unit(s) shall comply with the requirements of the ambient temperature leakage test (para. 6.2.6.2.2.) and Hydrostatic Strength Test (para. 6.2.6.2.1.).

6.2.6.2.6. Atmospheric Exposure Test

The atmospheric exposure test applies to qualification of check valves~~; it does not apply to qualification of~~ and automatic shut-off valves if the component has non-metallic materials exposed to the atmosphere during normal operating conditions.

6.2.6.2.7. Electrical Tests

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

(a) Abnormal Voltage Test. The solenoid valve is connected to a variable DC voltage source. The solenoid valve is operated as follows:

(i) An equilibrium (steady state temperature) hold is established for one hour at 1.5 times the rated voltage.

(ii) The voltage is increased to two times the rated voltage or 60 volts, whichever is less, and held for one minute.

(iii) Any failure shall not result in external leakage, open valve or an unsafe condition such as smoke, fire or melting.

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.

(b) Insulation Resistance Test. 1,000 V D.C. is applied between the power conductor and the component casing for at least two seconds. The minimum allowable resistance for that component is 240 kΩ.

6.2.6.2.8. Vibration Test

The valve unit is pressurized to its 100 per cent NWP (+2/-0MPa) with hydrogen, sealed at both ends, and vibrated for 30 minutes along each of the three orthogonal axes (vertical, lateral and longitudinal) at the most severe resonant frequencies. The most severe resonant frequencies are determined by acceleration of 1.5 g with a sweep time of 10 minutes within a sinusoidal frequency range of 10 to ~~500~~ 40Hz. If the resonance frequency is not found in this range the test is conducted at ~~500~~ 40Hz. Following this test, each sample shall not show visible exterior damage that indicates that the performance of the part is compromised. At the completion of the test, the unit shall comply with the requirements of the ambient temperature leak test specified in para. 6.2.6.2.2.

6.2.6.10. Pre-Cooled Hydrogen Exposure Test

The valve unit is subjected to pre-cooled hydrogen gas at -40(+5/-0) ºC at a flow rate of 30 g/s at external temperature of 20(±5) ºC for a minimum of three minutes. The unit is de-pressurized and re-pressurized after a two minute hold period. This test is repeated ten times. This test procedure is then repeated for an additional ten cycles, except that the hold period is increased to 15 minutes. The unit shall then comply with the requirements of the ambient temperature leak test specified in para. 6.2.6.2.2.

6.3.5.1.3. ~~It is allowed to modify~~ **Contracting parties may allow modifications to** the fuel system so that an appropriate amount of fuel can be used to run the engine or the electrical energy conversion system.

The following paragraphs regarding the physical protection will remain in brackets for further discussion:

[5.3.1.2.4.3. Electric power train consisting of combined DC- and AC-buses

If AC high voltage buses and DC high voltage buses are galvanically connected, isolation resistance between the high voltage bus and the electrical chassis shall have a minimum value of 500 Ω/volt of the working voltage.

However, if all AC high voltage buses are protected by one of the two following measures, isolation resistance between the high voltage bus and the electrical chassis shall have a minimum value of 100 ohms/volt of the working voltage.

(a) double or more layers of solid insulators, electrical protection barriers or enclosures that meet the requirement in paragraph 5.3.1.2.3. independently, for example wiring harness;

(b) mechanically robust protections that have sufficient durability over vehicle service life such as motor housings, electronic converter cases or connectors.]

[5.3.2.2.3. Physical protection

For protection against direct contact with high voltage live parts, the protection IPXXB shall be provided.

In addition, for protection against electric shock which could arise from indirect contact, the resistance between all exposed conductive parts and electrical chassis shall be lower than 0.1 ohm when there is current flow of at least 0.2 amperes.

This requirement is satisfied if the galvanic connection has been established by welding. In case of doubts a measurement shall be made.]

[6.3.5.2.4. Physical Protection

Following the vehicle crash test, any parts surrounding the high voltage components are opened, disassembled or removed without the use of tools. All remaining surrounding parts shall be considered part of the physical protection.

The Jointed Test Finger described in para. 6.3.3. is inserted into any gaps or openings of the physical protection with a test force of 10 N ± 10 per cent for electrical safety assessment. If partial or full penetration into the physical protection by the Jointed Test Finger occurs, the Jointed Test Finger shall be placed in every position as specified below.

Starting from the straight position, both joints of the test finger are rotated progressively through an angle of up to 90 degrees with respect to the axis of the adjoining section of the finger and are placed in every possible position.

Internal electrical protection barriers are considered part of the enclosure

If appropriate, a low-voltage supply (of not less than 40 V and not more than 50 V) in series with a suitable lamp is connected between the Jointed Test Finger and high voltage live parts inside the electrical protection barrier or enclosure

6.3.5.2.5. Acceptance conditions

The requirements of para. 5.3.2.2.3. are met if the Jointed Test Finger described in para. 6.3.3. is unable to contact high voltage live parts.

If necessary a mirror or a fibrescope may be used in order to inspect whether the Jointed Test Finger touches the high voltage buses.

If this requirement is verified by a signal circuit between the Jointed Test Finger and high voltage live parts, the lamp shall not light.]