GRPE 014 10-02-03

GRPE CGH_2 Experts

(A sub-group of the GRPE Ad-hoc Working Group "Hydrogen/Fuel Cell")

Modified Proposal For A Burst Test For Components Other Than The Container

(See sections highlighted in yellow)

Annex 8

REQUIREMENTS AND APPROVAL TEST PROCEDURES FOR SPECIFIC COMPONENTS OTHER THAN CONTAINERS

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Annex 8: Part A

PROVISIONS REGARDING THE APPROVAL OF SPECIFIC COMPONENTS OTHER THAN CONTAINERS

A1 REFERENCES

The following standards contain provisions that, through reference in this text, constitute provisions of this Annex. Where standards other than ISO standards are referenced they may be replaced by equivalent national standards.

International Organisation for Standardization (ISO) Standards

ISO 37: 1994	Rubber, vulcanised Or Thermoplastic - Determination Of Tensile Stress-strain Properties
ISO 188: 1998	Rubber, Vulcanised Or Thermoplastic - Accelerated Ageing And Heat Resistance Tests
ISO 1307: 1992	Rubber And Plastic Hoses For General purpose Industrial Applications - Bore Diameters And Tolerances, And Tolerances On Length
ISO 1402: 1994	Rubber And Plastic Hoses And Hose Assemblies - Hydrostatic Testing
ISO 1436: 1991	Rubber Hoses And Hose Assemblies - Wire Reinforced Hydraulic Type - Specification
ISO 4672: 1997	Rubber And Plastic Hoses - Sub-ambient Temperature Flexibility Tests
ISO 6957: 1988	Copper Alloys - Ammonia Test For Stress Corrosion Resistance
ISO 9227: 1990	Corrosion Tests In Artificial Atmospheres - Salt Spray Tests
ISO/DIS 11114-4: 2002	Transportable Gas Cylinders – Compatibility Of Cylinders And Valve Materials With Gas Contents – Part 4: Test Methods For Selecting Metallic Materials Resistant To Hydrogen Embrittlement
ISO/WD 17268: 2001	Gaseous Hydrogen – Land Vehicle Filling Connectors

American Society for Testing and Materials (ASTM) Standards

ASTM D572:	Test for Accelerated Aging of Vulcanised Rubber by Oxygen Pressure Method

A2 GENERAL REQUIREMENTS

A2.1 Unless otherwise stated in this Annex all tests shall be performed at 20°C ± 5°C.

A2.2 Explosive gas mixtures shall be prevented from developing during the test procedures described in this Annex.

A2.3 The test period for leakage and pressure tests shall be not less than 3 minutes.

A2.4 Unless otherwise stated the applied test pressure is to be measured at the inlet of the component under test.

A3 APPROVAL REQUIREMENTS

A3.1 GENERAL APPROVAL REQUIREMENTS

A3.1.1 In addition to the requirements given below, the *Manufacturer* shall complete all documents referred to in Part B of this Annex and submit them to the Competent Authority when applying for type approval.

A3.1.2 The *Specific Components* shall be subjected to the applicable test procedures laid down in Table 8A.1 of this Annex. The tests shall be conducted on *Specific Components* that are representative of normal production and complete with identification marks.

A3.1.3 The tests specified in Paragraphs B3 to ~~B9~~ B8 of this Annex shall be conducted on the same samples of *Specific Components* in the sequence given in Table 8A.1 unless otherwise indicated, e.g. for *Fittings* the Corrosion Resistance Test (B3) shall be followed by an Endurance Test (B5), followed by an External leakage Test (B7), and finally by a Hydrostatic Pressure Test (B8). If a *Specific Component* does not contain metallic sub-components the testing shall commence with the first applicable test. The Hydraulic Burst Test (B9) may ~~by choice of the manufacturer either~~ be conducted ~~as the final test of the sequence given in Table 8A.1 or~~ on new samples.

A3.1.4 The documentation and test reports shall be sufficiently detailed that an independent third party test facility could reproduce the appropriate type approval tests and test results.

A3.2 SPECIFIC APPROVAL REQUIREMENTS

A3.2.1 Approval for a *Flexible Fuel Line* shall be given for one of any length with a minimum bending radius specified by the *Manufacturer* and when assembled with a specific type of *Fitting.*

A3.2.2 The construction of *Flexible Fuel Lines* shall be such that any reinforcing interlayer(s) are protected against corrosion by a cover. The cover shall prevent the formation of bubbles between the layer(s).

A3.2.3 The inside diameter of *Flexible Fuel Line* shall be in compliance with Table 1 of ISO 1307.

A3.2.4 *Flexible Fuel Lines* shall have an electrical resistance of less than 1 mega-ohm per meter.

A3.2.5 The profile of *Receptacles* shall comply with ISO 17268.

SPECIFIC COMPONENT	TYPE OF TEST							
	Material Tests B1 & B2	**Corrosion Resistance Test B3**	**Hydraulic Pressure Cycle Test B4**	**Endurance Test B5**	**Internal Leakage Test B6**	**External Leakage Test B7**	**Hydrostatic Pressure Test B8**	**Hydaulic Burst Test B9**
Automatic Valves								
Fittings								
Flexible Fuel Lines								
Heat Exchangers								
Hydrogen Filters								
Manual Valves								
Non-Return Valves								
Pressure Regulators								
Pressure Relief Devices								
Pressure Relief Valves								
Receptacles								
Sensors for Hydrogen Systems								

Table 8A.1: Applicable Test Procedures For Specific Components Other Than Containers

Annex 8: Part B

APPROVAL TEST PROCEDURES FOR SPECIFIC COMPONENTS OTHER THAN CONTAINERS

MATERIAL TESTS

B1 HYDROGEN COMPATIBILITY TEST

B1.1 Sampling

The test applies to the materials used in a *Specific Component* where the material is in contact with hydrogen.
Number of material samples to be tested: 3

B1.2 Procedure and Requirements

i) Aluminium alloys and steels complying with the material requirements of ISO 7866 or ISO 9809 - 1
No additional tests are required if the materials comply with the requirements of ISO 7866 or ISO 9809 – 1.
ii) Other metallic materials
Hydrogen compatibility shall be demonstrated in accordance with ISO/DIS 11114 – 4.
iii) Non-metallic materials
Hydrogen compatibility shall be demonstrated.

B1.3 Results

The results of the tests shall be presented in a test summary.

B2 AGEING TEST

B2.1 Sampling

All non-metallic materials used in a *Specific Component* shall be tested.
Number of material samples to be tested: 3

B2.2 Procedure and Requirements

Special consideration shall be given to safety when conducting this test.

The test shall be undertaken in accordance with ASTM D572. The sample shall be exposed to oxygen at 85°C at 2 MPa for a period of 96 hours. No cracking or visible evidence of deterioration of the test piece(s) is allowed.

B2.3 Results

The results of the tests shall be presented in a test summary.

TESTS OF SPECIFIC COMPONENTS

B3 CORROSION RESISTANCE TEST

B3.1 Sampling

Number of *Specific Components* to be tested: 3

B3.2 Procedure and Requirements

Test i) Metallic components shall be submitted to a 144 hour salt spray test in accordance with ISO 9227 with all connections closed and shall meet the requirements therein.

Test ii) A copper alloy component shall also be submitted to 24 hours immersion in ammonia in accordance with ISO 6957 with all connections closed and shall meet the requirements therein.

B3.3 Results

The results of the tests shall be presented in a test summary.

B4 HYDRAULIC PRESSURE CYCLE TEST

B4.1 Sampling

This test applies to *Pressure Relief Devices*.
Number of *Specific Components* to be tested: 3

B4.2 Procedure and Requirements

Pressure Relief Devices shall be subjected to 1.5 times the number of *Filling Cycles* calculated in accordance with Paragraph 2.4.6 of this Regulation at both the minimum and maximum material temperatures in accordance with Paragraph 2.4.5 of this Regulation.

The pressure shall periodically change from 2 MPa to 1.25 times *Nominal Working Pressure* at a rate not exceeding 4 cycles per minute, except when tested at the minimum material temperature when the maximum test pressure shall be *Nominal Working Pressure*.

If fusible metal is used in a *Pressure Relief Device* it shall show no visible sign of extrusion.

B4.3 Results

The results of the tests shall be presented in a test summary.

B5 ENDURANCE TEST

B5.1 Sampling

Number of *Specific Components* to be tested: 3

B5.2 Procedures And Requirements

B5.2.1 Automatic, Manual & Non-return Valves

The *Specific Component* shall be tested in accordance with the following procedure:

i) Pressurise the Specific Component with dry air, nitrogen, or hydrogen to *Nominal Working Pressure* and subject it to 96% of the total number of test cycles in accordance with Table B5.1 of this Annex at 20°C ± 5°C. A complete test cycle shall take place over a period of not less than 10 ± 2 seconds. When in the closed position the downstream pressure of the component under test is allowed to decay to 0.5 times the *Nominal Working Pressure* of the component. The *Specific Component* shall fulfil the requirements of the Internal and External Leakage Tests (Paragraphs B6 & 7 of this Annex respectively) at this temperature.

ii) The *Specific Component* shall then be operated through 2% of the total number of test cycles at the minimum material temperature in accordance with Paragraph 2.4.5.1 of this Regulation after 2 hours conditioning at this temperature. The *Specific Component* shall fulfil the requirements of the Internal and External Leakage Tests (Paragraphs B6 & 7 of this Annex respectively) at this temperature.

iii) The *Specific Component* shall then be operated through 2% of the total number of test cycles at the maximum material temperature in accordance with Paragraph 2.4.5.1 of this Regulation after 2 hours conditioning at this temperature. The *Specific Component* shall fulfil the requirements of the Internal and External Leakage Tests (Paragraphs B6 & 7 of this Annex respectively) at this temperature.

B5.2.2 Fittings

Fittings shall be subjected to 25 connection/disconnection cycles.

B5.2.3 Flexible Fuel Lines

The length of the flexible part of the *Flexible Fuel Line* with its fittings attached, to be used in the following test shall be calculated as follows:

$$L = \pi R + 2D$$

where:

L = Length of the flexible part of the *Flexible Fuel Line*
R = Minimum bending radius specified by the *Manufacturer*
D= Outside diameter of the *Flexible Fuel Line*

The *Flexible Fuel Line* shall be bent through 180 degrees to the minimum radius specified by the *Manufacturer* and rigidly attached to a fixture in that position by the *Fittings* with which it is to be approved. One end of the *Flexible Fuel Line* shall be plugged and the other end shall be attached to a hydraulic supply. The *Flexible Fuel Line* shall be pressurised quickly by means of a quick opening solenoid valve, such that one cycle consists of holding the

pressure at 1.25 times the *Nominal Working Pressure* for 10 ± 1 seconds (except for *Flexible Fuel Lines* with a required material temperature of 120^0C where the hold pressure shall be 1.37 times *Nominal Working Pressure*) and then reducing it to less than 0.1 times the *Nominal Working Pressure* for 5 ± 0.5 seconds. The total number of test cycles shall be equal to 2.0 times the number of *Filling Cycles* or *Duty Cycles* as appropriate to the use of the *Flexible Fuel Line* in accordance with Paragraph 2.4.6 or 2.4.7 of this Regulation as appropriate. 50% of the test cycles shall be performed at the minimum and the remaining 50% at the maximum material temperature in accordance with Paragraph 2.4.5.1 of this Regulation.

The *Flexible Fuel Line* shall not show any visible signs of damage.

B5.2.4 Pressure Regulators

Pressure Regulators shall be tested in accordance with the following procedure:

i) The *Pressure Regulator* shall be connected to a source of *Leak Test Gas* at *Nominal Working Pressure* and cycled through 95% of the number of *Duty Cycles* calculated in accordance with Paragraph 2.4.7 of this Regulation. One cycle shall consist of flow until stable outlet pressure has been attained, after which the gas flow shall be shutoff by a downstream quick closing valve until stable lockup pressure has been achieved. The *Pressure Regulator* shall fulfil the requirements of the Internal and External Leakage Tests (Paragraphs B6 & B7 of this Annex respectively) conducted at 20°C ± 5°C at intervals of 20, 40, 60, 80 and 100% of the number of cycles required above.

ii) The inlet of the *Pressure Regulator* shall be pressure cycled through 1% of the number of *Duty Cycles* from *Nominal Working Pressure* to 0.5 times the *Nominal Working Pressure* or less. Subsequently the *Pressure Regulator* shall fulfil the requirements of the Internal and External Leakage Tests (B6 & B7) conducted at 20°C ± 5°C.

iii) The cycling procedure in i) above shall be repeated at the maximum material temperature in accordance with Paragraph 2.4.5.1 of this Regulation and at 1.25 times the *Nominal Working Pressure* for 1% of the number of *Duty Cycles*. Subsequently the *Pressure Regulator* shall fulfil the requirements of the Internal and External Leakage Tests (B6 & B7) conducted at the maximum material temperature.

iv) The cycling procedure in ii) above shall be repeated at the maximum material temperature and at 1.25 times the Nominal Working Pressure for 1% of the number of *Duty Cycles*. Subsequently the *Pressure Regulator* shall fulfil the requirements of the Internal and External Leakage Tests (B6 & B7) conducted at the maximum material temperature.

v) The cycling procedure in i) above shall be repeated at the minimum material temperature in accordance with Paragraph 2.4.5.1 of this Regulation and at *Nominal Working Pressure* for 1% of the number of *Duty Cycles*. Subsequently the *Pressure Regulator* shall fulfil the requirements of the Internal and External Leakage Tests (B6 & B7) conducted at the minimum material temperature.

vi) The cycling procedure in ii) above shall be repeated at the minimum material temperature and at *Nominal Working Pressure* for 1% of the number of *Duty Cycles*. Subsequently the *Pressure Regulator* shall fulfil the requirements of the Internal and External Leakage Tests (B6 & B7) conducted at the minimum material temperature.

B5.2.5 Pressure Relief Devices

i) Creep Test

Pressure Relief Devices shall be hydrostatically pressurised to 1.25 times *Nominal Working Pressure* and held for 500 hours at a temperature (T_L) calculated from the following equation:

$$T_L = T\,(0.057)^{(0.34 \log(T/Tf))}$$

where

T_L = Test temperature, ºC
T_f = Activation temperature of the *Pressure Relief Device*, ºC
T = 82ºC
Log is base 10

Pressure Relief Devices shall not show signs of creep and shall fulfil the requirements of the Internal Leakage Test (Paragraph B6 of this Regulation) after being subjected to the above test.

ii) Activation Temperature
Following the Creep Test in i) above, the *Pressure Relief Devices* shall be pressurised with dry air, nitrogen, or hydrogen to *Nominal Working Pressure*. Subsequently the *Pressure Relief Devices* shall be exposed to an increasing temperature cycle starting from ambient temperature with a rate not exceeding 10 °C per minute until the specified activation temperature minus 10 °C is reached and then with a rate of not exceeding 2 °C per minute until the *Pressure Relief Devices* activate. The activation temperature shall correspond to the melting temperature of the fusible metal specified by the *Manufacturer* within a range of ± 2 °C. After activation the *Pressure Relief Devices* shall show no evidence of fragmentation.

B5.2.6 Pressure Relief Valves

Pressurise the *Pressure Relief Valve* for 25 cycles. A test cycle consists of pressurising the *Pressure Relief Valve* to the activation pressure causing the *Pressure Relief Valve* to open and vent. Once the *Pressure Relief Valve* is venting the inlet pressure shall be reduced causing the *Pressure Relief Valve* to re-seat. The cycle time shall be a period of 10 ± 2 s. For the final cycle the activation pressure shall be reported and shall correspond to the activation pressure specified by the *Manufacturer* within a range of ±5%. Activation pressures shall be at least 1.30 times the *Nominal Working Pressure*.

B5.2.7 Receptacles

Receptacles shall be submitted to a number of connection/disconnection cycles equal to three times the number of *Filling Cycles* calculated in accordance with Paragraph 2.4.6 of this Regulation. For each cycle the *Receptacle* shall be pressurised to 1.25 times the *Nominal Working Pressure.* Before depressurising, the nozzle shall be rotated by 90^0.

B5.2.8 Sensors For Hydrogen Systems

If a sensor is intended to be installed into a *Hydrogen Component* and is subjected to the same number of *Duty Cycles* or *Filling Cycles,* it shall be subjected to the same endurance test as the *Hydrogen Component* into which it is installed.

SPECIFIC COMPONENT	NO. OF TEST CYCLES
Automatic Valve	1.5 times the number of *Duty Cycles* or *Filling Cycles* in accordance with Paragraph 2.4.6 or 2.4.7 of this Regulation, as appropriate to the use of the valve.
Manual Valve	50
Non-return Valve	2.0 times the number of *Duty Cycles* or *Filling Cycles* in accordance with Paragraph 2.4.6 or 2.4.7 of this Regulation, as appropriate to the use of the valve.

Table B5.1: Test Cycles For Valves

B5.3 Results

The results of the test shall be presented in a test summary.

B6 INTERNAL LEAKAGE TEST

B6.1 Sampling

Number of *Specific Components* to be tested: 3

B6.2 Procedure

The *Specific Components* shall be tested using *Leak Test Gas* and shall be pressurised at the inlet of the component when it is in its characteristic closed position and with the corresponding outlet port open.

The *Specific Component* shall be tested at the following conditions:

i) At 20°C ± 5°C and at 0.02 times *Nominal Working Pressure* and at *Nominal Working Pressure*. Where an External Leakage Test (Paragraph B7 of this Annex) is also required at this temperature it may be undertaken before the next stage of this test.

ii) At the minimum material temperature in accordance with Paragraph 2.4.5.1 of this Regulation, after 2 hours conditioning at this temperature and at 0.02 times *Nominal Working Pressure* and at *Nominal Working Pressure*. Where an External Leakage Test (Paragraph B7 of this Annex) is also required at this temperature it may be undertaken before the next stage of this test.

iii) At the maximum material temperature in accordance with Paragraph 2.4.5.1 of this Regulation, after 2 hours conditioning at this temperature and at 0.02 times *Nominal Working Pressure* and 1.25 times *Nominal Working Pressure*, except for components with a required material temperature of 120^0C where the higher test pressure shall be 1.37 times *Nominal Working Pressure*.

The component shall be observed for leakage with its outlet port open. The leakage can be determined by a flowmeter installed on the inlet side of the component or by another test method, which has been demonstrated to be equivalent.

B6.3 Requirements

When pressurised the *Specific Component* shall stay bubble free for three minutes or shall not leak internally at a rate exceeding 10 Ncm^3 per hour. The permitted leakage rate is applicable to tests with 100% hydrogen only. Permitted leakage rates for other gases or gas mixtures shall be converted to an equivalent leakage rate to that for 100% hydrogen.

B6.4 Results

The results of the test shall be presented in a test summary.

B7 EXTERNAL LEAKAGE TEST

B7.1 Sampling

Number of *Specific Components* to be tested: 3

B7.2 Procedure

The *Specific Components* shall be tested using *Leak Test Gas* at the following conditions:

i) At 20°C ± 5°C and at 0.02 times *Nominal Working Pressure* and at *Nominal Working Pressure*.

ii) At the minimum required material temperature, in accordance with Paragraph 2.4.5.1 of this Regulation, after 2 hours conditioning at this temperature and at 0.02 times *Nominal Working Pressure* and at *Nominal Working Pressure*.

iii) At the maximum required material temperature, in accordance with Paragraph 2.4.5.1 of this Regulation, after 2 hours conditioning at this temperature and at 0.02 times *Nominal Working Pressure* and 1.25 times *Nominal Working Pressure*, except for components with a required material temperature of 120^0C where the higher test pressure shall be 1.37 times *Nominal Working Pressure*.

For heat exchangers this test shall only be undertaken on the hydrogen circuit.

B7.3 Requirements

Throughout the test the *Specific Component* shall be free from leakage through stem or body seals or other joints, and shall not show evidence of porosity in casting, demonstrated by a surface active agent without formation of bubbles for 3 minutes or measured with a combined leakage and permeation rate less than 10 Ncm^3 per hour (for *Flexible Fuel Lines* only 10 Ncm^3 per hour per meter) or it shall be tested by using a demonstrated equivalent test method. The permitted leakage rate is applicable to tests with 100% hydrogen only. Permitted leakage rates for other gases or gas mixtures shall be converted to an equivalent leakage rate to that for 100% hydrogen.

B7.4 Results

The results of the test shall be presented in a test summary.

B8 HYDROSTATIC PRESSURE TEST

B8.1 Sampling

Number of *Specific Components* to be tested: 3

B8.2 Procedure And Requirements

The *Specific Component* shall be pressurised to 1.5 times *Maximum allowable Working Pressure* for a period of 10 minutes with the outlets plugged.

The *Specific Component* shall not leak nor show any visible evidence of rupture or permanent distortion.

B8.3 Results

The results of the test shall be presented in a test summary.

B9 HYDRAULIC BURST TEST

B9.1 Sampling

Number of *Specific Components* to be tested: 3

B9.2 Procedure ~~And Requirements~~

~~The hydraulic burst test shall be carried out using a test rig, which allows pressure to be increased at a controlled rate.~~ The test shall be carried out ~~in~~ at ambient temperature. The rate of pressurisation shall not exceed 1 MPa/s and the duration of the test shall be at least 40 s. The *Specific Component* shall be pressurised at a controlled rate until failure. ~~The pressure against time curve or pressure against volume curve shall be plotted.~~ The maximum pressure achieved during the test shall be recorded as the burst pressure. The component shall be visually inspected after failure.

B9.3 Requirements

For a *Specific Component* upstream of and including the first *Pressure Regulator*, the component shall fail at a pressure higher than 3.0 times *Nominal Working Pressure.* For a *Specific Component* downstream of the first *Pressure Regulator* the component shall shall fail at a pressure higher than 3.0 times *Maximum Allowable Working Pressure.* ~~The *Specific Component* shall fail at a pressure higher than 4 times *Maximum Allowable Working Pressure.* There shall be no~~In neither case shall there be evidence of fragmentation or brittle ~~behaviour~~failure.

B9.3 Results~~Parameters to monitor and record~~

~~- burst pressure;~~
~~- description of failure;~~
~~- pressure/time curve or pressure/volume curve~~.

The ~~results of the test~~failure pressure, a description of the mode of failure and a pressure/time curve or pressure/volume curve ~~-~~shall be presented in a test summary.