

Action Item #18 from 8th SGS Meeting in Geneva by BMW in reconciliation with Glenn W. Scheffler.

B 5. PERFORMANCE REQUIREMENTS

5.1 COMPRESSED HYDROGEN STORAGE SYSTEM

(...)

5.2 LIQUEFIED HYDROGEN STORAGE SYSTEM

This section specifies the requirements for the integrity of a liquefied hydrogen storage system.

The hydrogen storage system will be qualified to the performance test requirements specified in this Section. All liquefied hydrogen storage systems produced for on-road vehicle service must be capable of satisfying requirements of B.5.2.

The manufacturer has to provide the confirmation of hydrogen material compatibility for the inner tank and all components in contact with hydrogen. In order to prove proper design and expected on-road performance of the storage the following tests have to be accomplished:

- Baseline Initial Burst Pressure (hydraulic)
- Proof pressure test
- Boil-off test
- Leak test
- Vacuum loss test
- Bonfire test

The test elements within these performance requirements are summarized in Table B.5.2.

The manufacturer shall specify a maximum allowable working pressure (MAWP) for the inner container fulfilling the following requirements:

- The maximum pressure in the inner container during regular operation shall not exceed the MAWP.
- The opening pressure of the primary pressure relief device (PRD) shall correspond to the MAWP or be less than MAWP.
- The primary pressure relief device for the inner container shall limit the pressure inside the inner container in all cases to not more than 110 per cent of the MAWP.
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- The secondary pressure relief device shall not operate below 110 per cent of the set pressure of the primary pressure relief device.
- In the case of steel inner tanks, the secondary pressure relief device shall limit the pressure in the tank to 136 per cent of the MAWP of the inner tank, if a safety valve is used as second pressure relief device. In case of steel inner tanks, the secondary

pressure relief device shall limit the pressure in the tank to 150 per cent of the Maximum Allowable Working Pressure (MAWP), if a burst disk is used as second pressure relief device. For other materials, an equivalent level of safety shall be demonstrated.

These criteria apply to qualification of storage systems for use in new vehicle production. It does not apply to re-qualification of any single produced system for use beyond its expected useful service or re-qualification after a potentially significant damaging event.

**Table B.5.2
Overview of Performance Qualification Test Requirements**

<p>B.5.2.1 Verification Tests for Baseline Metrics</p> <p>B 5.2.1.1 Baseline Initial Burst Pressure, performed on the inner tank</p>
<p>B.5.2.2 Verification of Material Compatibility</p> <p>Prove of hydrogen compatibility of the materials for the inner container and all components in contact with hydrogen.</p>
<p>B.5.2.3 Verification for Expected On-road Performance</p> <p>B.5.2.3.1 Proof pressure test B.5.2.3.2 Boil-off test B.5.2.3.3 Leak test B.5.2.3.4 Vacuum loss test</p>
<p>B.5.2.4 Verification Test for Service Terminating Performance</p> <p>B.5.2.4.1 Bonfire Test</p>

B.5.2.1 Verification for Baseline Metrics

B.5.2.1.1 Baseline Initial Burst Pressure.

The burst test shall be performed on one sample of the inner tank (hydraulically pressurized), not integrated in its outer jacket and not insulated.

The burst pressure shall be at least equal to the burst pressure used for the mechanical calculations. For steel tanks that is:

- either the Maximum Allowable Working Pressure (MAWP) (in MPa) plus 0.1 MPa multiplied by 3.25;

- or the Maximum Allowable Working Pressure (MAWP) (in MPa) plus 0.1 MPa multiplied by 1.5 and multiplied by R_m/R_p , where R_m means minimum ultimate tensile strength and R_p means minimum yield strength of the container material.

B.5.2.2 Verification for Material Compatibility

Definition of test procedure in order to prove the hydrogen compatibility of materials to be defined.

B.5.2.3 Verification for Expected On-road Performance

B.5.2.3.1 Proof pressure test

The inner container and the pipe work situated between the inner tank and the outer jacket shall withstand an inner pressure test at room temperature any suitable media, according to the following requirements.

The test pressure p_{test} shall be:

$$p_{\text{test}} = 1.3 (\text{MAWP} + 0.1 \text{ MPa})$$

with MAWP being the Maximum Allowable Working Pressure of the inner tank in MPa.

B.5.2.3.2 Boil-off test

A container shall be fueled with liquid hydrogen to the specified maximum filling level. Subsequently hydrogen should be extracted until half filling level and the system should be allowed to completely cool down for at least 24 hours and maximum 48 hours. The container shall be filled to the specified maximum filling level. The container shall pressurize until boil-off pressure is reached. The test shall last for at least another 48 hours after boil-off started and not terminated before the pressure stabilizes.

During the test the inner container pressure shall be monitored. During boil-off the first safety device is not allowed to open and the pressure should stabilize below the lower tolerance of the opening pressure of the first safety device.

B.5.2.3.3 Leak test

After the boil-off test the system shall be kept at boil-off pressure and the total discharge rate due to leakage shall be measured. The maximum allowable discharge from the hydrogen storage system is 150 ml/min for standard passenger vehicles.

[The maximum allowable discharge for systems in larger vehicles is $R \cdot 150 \text{ Ncc/min}$ where $R = (V_{\text{width}}+1) \cdot (V_{\text{height}}+0.5) \cdot (V_{\text{length}}+1)/30.4$ and V_{width} , V_{height} , V_{length} are the vehicle width, height, length (m), respectively.]

B.5.2.3.4 Vacuum loss test

A vacuum loss test shall be conducted with a completely cooled-down container (according to the procedure in B.5.2.3.2). The container shall be filled to the specified maximum filling

level and the vacuum enclosure shall be flooded with air to atmospheric pressure. The test shall be terminated when the first safety device does not open any more.

The pressure of the inner container shall be monitored during the test. The first safety device shall open below or at MAWP and limit the pressure to not more than 110 per cent of the MAWP. In particular, the secondary pressure relief device should not open.

B.5.2.4 Verification Test for Service Terminating Conditions

At least one system must demonstrate the working of the pressure relief system and the absence of rupture under the following service-terminating conditions. Specifics of test procedures are provided in Section 6.

B.5.2.4.1 Bonfire Test.

A hydrogen storage system will be filled to half-full liquid level and exposed to fire in accordance with test procedure 6.4.2.12 TBD. The pressure relief device(s) will release the contained gas in a controlled manner without rupture.

B.5.3. Vehicle Fuel System [....]