Action Item #4 from 8th SGS Meeting in Geneva by BMW in reconcilement with Glenn W. Scheffler.

3.3.2 LIQUEFIED HYDROGEN STORAGE SYSTEM

A.3.3.2.1 As noted previously, hydrogen gas has a low energy density per unit volume. To overcome this disadvantage, the liquefied hydrogen storage system (LHSS) maintains the hydrogen at cryogenic temperatures in a liquefied state.

A.3.3.2.2 A typical liquefied hydrogen storage system (LHSS) is shown Figure 4. Actual systems will differ in the type, number, configuration, and arrangement of the functional constituents. Ultimately, the boundaries of the LHSS are defined by the interfaces which can isolate the stored liquefied (and/or gaseous) hydrogen from the remainder of the fuel system and the environment. All components located within this boundary are subject to the requirements defined in this section while components outside the boundary are subject to general requirements in Section 4. For example, the typical LHSS shown in Figure 4 consists of the following regulatory elements:

- liquefied hydrogen storage container(s),
- shut off devices(s),
- a boil-off system,
- Pressure Relief Devices (PRDs),
- the interconnecting piping (if any) and fittings between the above components.

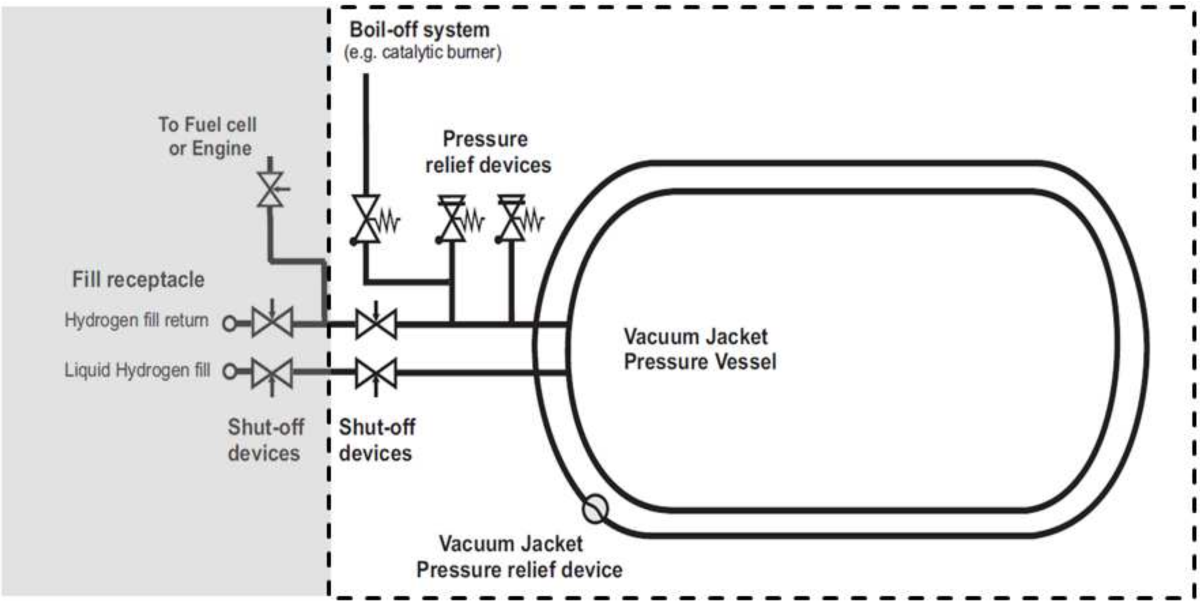

Figure 4. Typical Liquefied Hydrogen Storage System

A.3.3.2.3 When using metallic containers and/or metallic outer jackets the manufacturer must provide a calculation in order to demonstrate that the tank is designed according to the current regional legislation (e.g. in US the ASME Boiler and Pressure Vessel Code, in Europe the Pressure Vessel Directive and in all other countries the applicable regulations for the design of metallic pressure vessels).

A,3.3.2.4 In the case that non-metallic materials are used for the container(s) and/or vacuum jacket(s) in addition to the mandatory tests described in chapter B.5.2 suitable tests have to be accomplished, which assure at least the same level of reliability compared to the use of metallic materials in conjunction with a pressure vessel code.

A.3.3.2.5 During fueling, liquefied hydrogen flows from the fuelling system to the storage container(s). Hydrogen gas from the LHSS returns to the filling station during the fill process so that the liquefied hydrogen can flow into liquefied hydrogen storage container(s) without over pressurizing the system. Two shut-offs are provided on both the liquefied hydrogen fill and hydrogen fill return line to prevent leakage in the event of single failures.

A.3.3.2.6 Liquefied hydrogen is stored at cryogenic conditions. In order to maintain the hydrogen in the liquid state, the container needs to be well insulated, including use of a vacuum jacket that surrounds the storage container. A boil-off system limits heat leakage induced pressure rise in the hydrogen storage container(s) to a pressure specified by the manufacturer. Hydrogen that is vented from the LHSS may be processed or consumed in down-stream systems. Discharges from the vehicle resulting from over-pressure venting should be addressed as part of allowable leak/permeation from the overall vehicle.

A.3.3.2.7 During longer parking times of the vehicle the boil-off valve restricts the pressure to a value specified by the manufacturer and the boil-off system downstream processes the vented hydrogen.

A.3.3.2.8 In case malfunction of the boil-off system, vacuum failure, or external fire, the hydrogen storage container(s) are protected against overpressure by two independent Pressure Relief Devices (PRDs) and the vacuum jacket(s)is protected by a vacuum jacket pressure relief device.

A.3.3.2.9 When hydrogen is released to the propulsion system, it flows from the LHSS through the shut-off valve that is connected to the hydrogen fuel delivery system. In the event that a fault is detected in the propulsion system or fill receptacle, vehicle safety systems usually require the container shut-off valve to isolate the hydrogen from the down-stream systems and the environment.