GTR Proposal For H_2 Releases From Vehicles

Delivered by OICA to the 3rd SGS meeting in Washington, D.C. on 13 May, 2008

Headline topic

- What **target**(s) are we trying to achieve (for information to SGS only – not to be included in the GTR)
- **Requirement**(s) to achieve that target
- **Demonstration of compliance** with the requirement(s)
- **Rationale**/Justification (for information to SGS only – not to be included in the GTR)

1. Post-crash

Target
Limit the maximum hydrogen discharge following a crash to a defined level

Requirement
The rate of uncontrolled hydrogen gas leakage measured and calculated by the following procedure shall not exceed 120 NL per minute average within 60 minutes after the crash.

Demonstration of compliance
The crash tests used to evaluate post-crash hydrogen leakage are those already applied in the respective jurisdictions.

To evaluate possible hydrogen discharge following the vehicle crash tests, the following procedure should be used.

a) Compressed Gaseous Hydrogen Storage:

The gas container shall be filled with helium to minimum 90% of the nominal working pressure. The main stop valve and shut-off valves, etc. for hydrogen gas, located in the downstream hydrogen gas piping, shall be kept open immediately prior to the impact.

The pressure and temperature of the gas shall be measured immediately before the impact and 60 minutes after the impact either inside the gas container or upstream of the first pressure-reducing valve downstream of the gas container.

The rate of hydrogen gas leakage shall be measured by the following procedure.
The helium gas pressure immediately before the impact and 60 minutes after the impact, upstream of the first pressure-reducing valve either within the gas container or the one located downstream of the gas container shall be converted to the pressure at 0°C using equation1.

Equation 1: $P_0' = P_0 \times \{273 / (273 + T_0)\}$
where:
P_0' : Helium gas pressure converted to pressure at 0 °C before impact (MPa abs)
P_0 : Measured helium gas pressure before impact (MPa abs)

T_0 : Measured helium gas temperature before impact (°C)

$P_{60}' = P_{60} \times \{273 / (273 + T_{60})\}$
where:
P_{60}' : Helium gas pressure converted to pressure at 0 °C 60 minutes after impact (MPa abs)
P_{60} : Measured helium gas pressure 60 minutes after impact (MPa abs)
T_{60} : Measured helium gas temperature 60 minutes after impact (°C)

The gas density calculated from equation 2 before the impact and 60 minutes after the impact shall be calculated using the pressure at 0°C converted from the helium gas pressure upstream of the first pressure-reducing valve within the gas container or the one located downstream of the gas container obtained from equation 1.

Equation 2: $\rho_0 = -0.0052 \times (P_0')^2 + 1.6613 \times P_0' + 0.5789$
where:
ρ_0 : Helium gas density before impact (kg/m^3)
$\rho_{60} = -0.0052 \times (P_{60}')^2 + 1.6613 \times P_{60}' + 0.5789$
where:
ρ_{60} : Helium gas density 60 minutes after impact (kg/m^3)

The helium gas volume before the impact and 60 minutes after impact shall be calculated from equation 3 using the gas density obtained from equation 2. However, the internal volume shall be the internal volume of the gas container in cases where the helium gas pressure has been measured inside the gas container; and the internal volume of the container down to the first pressure-reducing valve located downstream of the gas container in cases where the helium gas pressure has been measured upstream of the first pressure-reducing valve located downstream of the gas container.

Equation 3: $Q_0 = \rho_0 \times V \times (22.4 / 4.00) * 10^{-3}$
where:
Q_0 : Helium gas volume before impact (m^3)
V : Internal volume (L)

$Q_{60} = \rho_{60} \times V \times (22.4 / 4.00) * 10^{-3}$
where:
Q_{60} : Helium gas volume 60 minutes after impact (m^3)
V : Internal volume (L)

The rate of helium gas leakage shall be calculated.
$\Delta Q = (Q_0 - Q_{60}) \times 10^3$
$RHe = \Delta Q / 60$
where:
ΔQ : Volume of helium gas leakage 60 minutes after impact (NL)
RHe : Rate of helium gas leakage (NL/min)

The rate of helium gas leakage shall be converted to the rate of hydrogen gas leakage.
$RH = 1.33 \times RHe$
where:
RH : Rate of hydrogen gas leakage (NL/min)

b) Liquid Hydrogen Storage:

The fuel storage container shall be filled with liquid nitrogen (LN2) to minimum the mass equivalent of the maximum quantity of LH2 that may be contained in the inner vessel and then the system shall be pressurized with a gaseous N2 up to typical operating pressure.

The main stop valve and shut-off valves, etc. for hydrogen, located in the downstream hydrogen gas piping, shall be kept open immediately prior to the impact.

After the collision, the liquid hydrogen storage system must be tight, i.e. bubble free* if using detecting spray. No uncontrolled release of the test fluid is allowed.

** With bubble detection spray, any leakage in the range above 0,1Pa l/s can be detected. In case of N2 used as test fluid, the corresponding detectable hydrogen leakage would be about 0,5 Pa l/s (that is far below 1 NL per minute!).*

Rationale

The maximum post crash hydrogen leakage is based on the heat energy equivalent to maximum post crash leakages from gasoline vehicles.

2. Pressure relief systems

Target

To mitigate potential hazards from hydrogen pressure relief system discharges.

Requirements

The hydrogen gas discharge from **pressure relief devices at the gas container or upstream of the first pressure regulator located downstream of the gas container of CGH2 systems** shall not be directed

- into or towards the vehicle passenger or luggage compartments
- into or towards any vehicle wheel housing
- towards hydrogen gas containers
- forward from the vehicle, or horizontally from the back or sides of the vehicle

The hydrogen gas discharge from **other pressure relief systems** shall not be directed

- towards exposed electrical terminals, exposed electrical switches or other ignition sources
- into or towards the vehicle passenger or luggage compartments
- into or towards any vehicle wheel housing
- towards hydrogen gas containers

Demonstration of compliance

Visual Inspection of the PRD and PRV discharge outlet.

Rationale

In case of a vehicle fire first responders can approach the vehicle from the front.
Defined release directions also avoid damaging of the structure or integrity of other containers.
Gas release from pressure relief devices may be ignited by intention depending on the safety strategy.

3. Single failure conditions

Target

To mitigate potentially hazardous conditions within enclosed or semi enclosed volumes on the vehicle resulting from a single failure.

Requirement

If a single failure downstream of the main hydrogen shut off valve results in a hydrogen concentration in air greater than 4% by volume within enclosed or semi enclosed volumes on the vehicle, the main hydrogen shutoff valve shall close.
Any single failure downstream of the main hydrogen shut off valve shall not result in a hydrogen concentration in air greater than 4% by volume in the passenger compartment.

Demonstration of compliance

[Preparation:
The test shall be conducted without any influence of wind.
Special attention shall be paid to the test environment as during the test flammable mixtures of hydrogen and air may occur.
Prior to the test the vehicle has to be prepared to allow remotely controllable hydrogen releases from the hydrogen system. The number and location of the release points downstream of the main hydrogen shutoff valve shall be defined by the vehicle manufacturer taking worst case leakage scenarios into account.
Only for the purpose of the test hydrogen concentration detectors have to be installed in enclosed or semi enclosed volumes on the vehicle.
If there is structure taken to prevent hydrogen from intruding into passenger compartments, it is not necessary to have H2 concentration measurement points in the passenger compartments.
Example hydrogen concentration measurement locations can be found in the document “Examples of hydrogen concentration measurement points for testing”.

Procedure:
- i) Vehicle doors, windows and other covers shall be closed.
- ii) Start the propulsion system, allow it to warm up to its normal operating temperature and leave it operating at idle for the test duration.
- iii) A leak shall be simulated using the remote controllable function.
- iv) The hydrogen concentration shall be measured continuously until the concentration does not rise anymore for 3 minutes or until the main hydrogen shutoff valve is closed.
- v) If during the test the hydrogen concentration at one of the measurement locations exceeds 4% significantly, the test shall be terminated.]*

[ ] this part of the proposal still needs to be confirmed*

Rationale

The requirement in this section applies only to single failures downstream of the main shutoff valve. Requirements for hydrogen components upstream of the main shutoff valve are covered by the hydrogen storage system leakage/permeation and installation requirements.
Hydrogen leak detection can be achieved using different technologies. This test and the associated requirements should address all possible leak detection strategies on

vehicles.

4. Fuel Cell Vehicle exhaust system

Target

Limit hydrogen releases from the vehicle exhaust system e.g. purge

Requirement

The following criteria shall be met locally at the point of discharge throughout normal operation including start-up and shutdown:

Less than 4% average concentration of hydrogen in air by volume in any moving 3 seconds time interval

Alternatively separate provisions shall be made to show concrete rationales and justifications that it is not hazardous at all to exceed instantaneously over 4% concentration of hydrogen.

Demonstration of compliance

i) The fuel cell system of the test vehicle shall be warmed up.

ii) The measuring device shall be warmed up before use.

iii) Place the measuring section of the measuring device on the centre line of the exhaust gas flow within 100 mm from the exhaust gas outlet.

iv) Perform the test procedure below while continuously measuring the hydrogen concentration:

With the vehicle in a stationary state, start the fuel cell system. After a lapse of at least one minute turn off the system and continue the measurement until the fuel cell system shut down procedure is complete.

5. Fully functional vehicle excluding the vehicle exhaust

Requirements are stated elsewhere

Rationale

No requirements are necessary as releases from a fully functional system are considered non hazardous because

i) Potentially hazardous releases are controlled by the requirements regarding hydrogen leakages resulting from a single failure for the sections downstream of the hydrogen system main shutoff valve (§ 3 of this draft)

ii) For the sections upstream of the hydrogen system main shutoff valve, releases are covered by the hydrogen storage system leakage/permeation and installation requirements.