Post-crash hydrogen leakage limit for FMVSS No. 307

This document describes the calculations that derive the maximum post-crash hydrogen gas leakage limit in the proposed in FMVSS No. 307, *Fuel system integrity of hydrogen vehicles*, from the maximum post-crash gasoline leakage limit in FMVSS No. 301, *Fuel system integrity*.

1 Mass leakage limit of hydrogen gas based on energy equivalency

Based on FMVSS No. 301 S5.5 and S5.6, gasoline fuel spillage in any fixed or moving barrier crash test should not exceed:

- 28 gram, from impact until motion of the vehicle has ceased
- A total of 142 gram, in the five-minute period, following cessation of motion
- 28 g, during any one-minute interval, following the five-minute period

This means the total allowable mass leakage of gasoline fuel from impact through the 60-minute interval after motion has ceased is:

28 gram + 142 gram + 28 gram/minute × 55 minutes = 1.7 kg

From this, total allowable energy loss from impact through the 60-minute interval after motion has ceased can be calculated as:

1.7 kg × 42,700 KJ/kg = 72,590 KJ

where 42,700 KJ/kg is the average lower heating value (energy content) for gasoline and diesel.[1] For hydrogen, equating the 72,590 KJ for gasoline fuel to the total amount of allowable energy loss for hydrogen, we can calculate:

72,590 KJ/119,863 KJ/kg = 0.6056 kg = 606 g

[1] U.S. DOE Transportation Energy Data Book, Appendix B Conversions, Table B.4 Heat Content for Various Fuels, page B-5, http://cta.ornl.gov/data/appendix_b.shtml; Table 6.9 Properties of Conventional and Alternative liquid fuels, page 6-16, http://cta.ornl.gov/data/chapter6.shtml
From Table 6.9:
Weight of Gasoline: 2.834 kg/gallon, diesel: 3.21 kg/gallon, average of gasoline and diesel: 3.022 kg/gallon;
From Table B.4:
Heat content (LHV) of gasoline: 115,400 btu/gallon, diesel: 128,700 btu/gallon, an average of gasoline and diesel: 122,050 btu/gallon = 42.6 MJ/kg
(1 btu = 0.001055 MJ)

where 119.863 MJ/kg is the lower heating value (energy content) for hydrogen gas.[2] Therefore, the total allowable mass leakage of hydrogen gas from the time of impact through the 60-minute interval after impact is 606 g.

2 Allowable volumetric flow rate of hydrogen after crash tests

From the total allowable hydrogen mass leakage of 606 g, total allowable volumetric leakage with a reference temperature of 288 °K during 60-minute interval after motion has ceased can be calculated as follows:

$$\frac{606\ \text{g}}{2.0159\ \text{gram/mole}} \times \frac{22.41\ \text{liter}}{\text{mole}} \times \frac{288}{273} = 7107\ \text{NL}$$

where 2.0159 gram/mole is the molar weight of a hydrogen molecule and 22.41 liter/mole is the molar volume of hydrogen at standard conditions, and the factor 288/273 adjusts the calculation for a temperature of 15 °C. Therefore, the allowable volumetric flow rate of hydrogen from the time of impact through the 60-minute interval after motion has ceased is: [3]

7107 NL/60 minutes = 118 NL/minute

[2] U.S. DOE Transportation Energy Data Book, Appendix B Conversions, Table B.1 Hydrogen Heat Content, page B-4, http://cta.ornl.gov/data/appendix_b.shtml

[3] SAE J2578_201408 Appendix A, A.1, A.1.1., Notes (a)
Since the loss between the time of impact and motion ceased typically represents the loss of gas from the downstream fuel supply system and is small enough to be neglected when compared with the gas leakage from the compressed hydrogen gas storage system after crash, therefore the total allowable volumetric loss is divided by 60 minutes, a time interval after motion has ceased.