(c) Leak-free parking at full fill (para. 5.1.3.3.)

(i) Leak and permeation are risk factors for fire hazards for parking in confined spaces such as garages;

(ii) The leak/permeation limit is characterized by the many possible combinations of vehicle and garages, and the associated test conditions. The leak/permeation limit is defined to restrict the hydrogen concentration from reaching 25 per cent Lower Flammability Limit (LFL) by volume. ~~with worst credible conditions of a tight, very hot (55 °C) garage having a low air exchange rate (0.03 volumetric air exchanges per hour).~~ The conservative 25 per cent LFL limit is conventionally adopted as the maximum concentration to accommodate concentration inhomogeneities and is equivalent to 1% hydrogen concentration in air. Data for hydrogen dispersion behaviour, garage and vehicle scenarios, including garage sizes, air exchange rates and temperatures, and the calculation methodology are found in the following reference prepared as part of the European~~C~~ Network of Excellence (NoE) HySafe: P. Adams, A. Bengaouer, B. Cariteau, V. Molkov, A.G. Venetsanos, "Allowable hydrogen permeation rate from road vehicles", Int. Journal of Hydrogen Energy, volume 36, issue 3, 2011 pp 2742-2749;

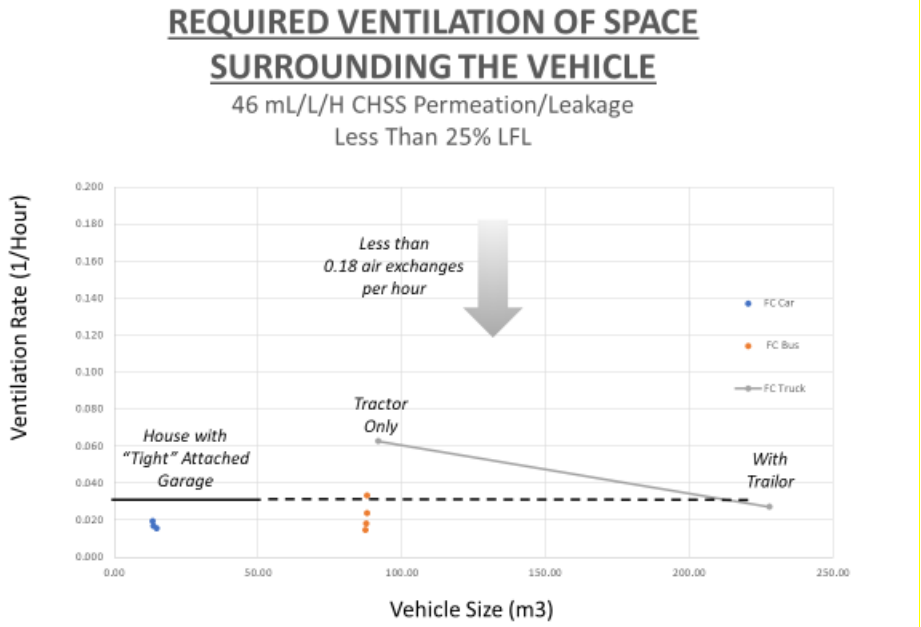
(iii) Worst case ventilation in structures where hydrogen vehicles can be parked is expected to be at or below 0.18 air changes per hour under worst case conditions, but the exact design value is highly dependent on the type and location of structures in which the vehicles are parked. In the case of light-duty passenger vehicles, an extremely low air exchange rate (of 0.03 volumetric air changes per hour) has been measured in "tight" wood frame structures (with plastic vapor barriers, weather-stripping on the doors, and no vents) that are sheltered from wind and are very hot (55 °C) with little daily temperature swings that can cause density-driven infiltration. The resulting discharge limit ~~measured at 55°C and 115 per cent NWP (full fill at 55 °C) following specified pneumatic pressure cycling of the storage system is scalable depending on the vehicle size around a nominal value of~~for a light-duty vehicle is 150 mL/min (at 115 per cent NWP for full fill at 55°C) ~~for a~~when the vehicle fits into a garage ~~size~~ of 30.4 m3. Since the discharge limit has been found to be reasonably scalable depending on the vehicle size, t~~T~~he scaling factor, R = (Vwidth+1)*(Vheight+0.~~0~~5)*(Vlength+1)/ 30.4 where Vlength, Vwidth, and Vheight are the dimensions of the vehicle in meters, ~~accommodates~~ allows calculation of the discharge limit for alternative garage/vehicle combinations to those used ~~in the derivation of the rate~~to determine the 150 mL/min discharge limit cited above~~, and accommodates small vehicles that could be parked in smaller garages~~.

(iv) These vehicle-level leak/permeation requirements are consistent with the proposals developed by the EU (NoE) HySafe (see above reference). ~~The permeation values measured for individual storage container systems used in a vehicle would total to less than the vehicle limit;~~

~~(iv)~~ For ease of compliance testing, however, the discharge requirement has been specified in terms of ~~storage system~~allowable leak/~~-~~permeation from each container in the storage system instead of the total vehicle-level discharge limit (in iii above) ~~permeation as a means of compliance~~to be ~~is~~ consistent with the proposals developed by the EU NoE HySafe. In this case, the leak/permeation limit measured at 55 °C and 115 per cent NWP is 46 mL/h/L-water-capacity ~~of~~ for each container in the storage system such that the ~~.~~ vehicle discharge is not exceeded. The use of this limit is applicable to light-duty vehicles that are smaller or larger than the base described in iii above. If, for example, ~~-~~the total water capacity of the light-duty vehicle storage system is ~~less greater than~~ 330 L (or less) and the garage size is ~~no smaller than~~ 50 m3, then the 46 m L/h/L-water-capacity requirement results in a steady-state hydrogen concentration of no more than 1 per cent. This can be shown by calculating the allowable discharge from the light-duty vehicle based on the requirement ~~(An upper limit per storage system~~ of 46 mL/h/L ~~(~~per container volume capacity~~)~~ (that is, 46 mL/h/L x 330L ~~(system volume capacity)~~ / (60 min/hr) = 253 mL/min) and showing that it is ~~per storage system, which~~ comparable to the allowable discharge based on the garage size of 50 m3 with an air exchange rate of 0.03 volumetric air exchanges per hour (that is, ~~that derived from the alternative approach~~ 150 mL/min x 50 m3 / 30.4 m3 = 247 mL/min ~~(scaling factor R=1.645~~). Since both results are essentially the same, the hydrogen ~~whic~~concentration in the garage is not expected to exceed ~~h results in a~~ 1 per cent for light-duty vehicles with storage systems of ~~concentration). This permeation specification has been adopted under the assumption that storage capacity ~~~330L (or less) ~~is not expected for the vehicles within the scope of this gtr, so~~in ~~garages less than~~ 50m3 garages. The ~~can be accommodated~~;

(v new) The use of 46 m L/h/L-water-capacity requirement for storage system containers is also conservatively scalable to larger medium-duty and heavy-duty vehicles. Figure ? shows the required volumetric air exchange rate for the garage various vehicle size. Examples of current or currently-planned vehicles are shown on the figure. Light-duty vehicles which can possibly parked in tight, very hot garages (as described above with down to 0.03 volumetric air changes per hour) are expected to comply with the 25% LFL hydrogen limit over the possible vehicle size range. Most medium-duty and heavy-duty vehicles also also require 0.03 volumetric air exchanges (or less), even though medium-duty and heavy-duty vehicles not expected to be parked in such “tight” garages as is the case with ligh-duty vehicles. Given that medium-duty and heavy-duty vehicles are expected to be operated in more open (naturally-ventilated) or mechanically-ventilated spaces, the 46 m L/h/L-water-capacity requirement for storage system containers provides reasonable margin in the event of mechanical ventilation failures, for example, without needing to adopt a different requirement from the limit already established for light-duty vehicles;

Figure ?


REQUIRED VENTILATION OF SPACE SURROUNDING THE VEHICLE
46 mL/L/H CHSS Permeation/Leakage
Less Than 25% LFL
Ventilation Rate (1/Hour)
0.200
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
0.00
50.00
100.00
150.00
200.00
250.00
Vehicle Size (m3)
Less than 0.18 air exchanges per hour
Tractor Only
House with "Tight" Attached Garage
With Trailor
FC Car
FC Bus
FC Truck