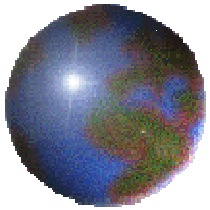
Informal document **GRSP-49-28**
(49th GRSP, 16-20 May 2011,
agenda item 7)



Hydrogen Fueled Vehicle Global Technical Regulation (GTR)

Subgroup Safety (SGS)
Nha Nguyen

49th GRSP Session
May 2011

Overview

- Background
- Global Technical Regulation (GTR) goals and safety requirements
- Hydrogen GTR Objectives
- GTR Milestones and Timeline
- GTR Details

Background
Hydrogen-Fueled Vehicle GTR

- The HFV GTR is co-sponsored by Japan, Germany and US; Germany as the overall 'task manager'; US and Japan co-chair the meetings; US also acts as the Secretariat of the Sub-group on Hydrogen Safety (SGS)

- GTR Objectives:
  - Attains equivalent levels of safety as those for conventional gasoline powered vehicles
  - Performance based (not design specific) and traceability of requirements to on-road performance
  - Data driven and science-based
  - System/Whole vehicle-based
  - Objectively measurable compliance

- 2007 Action Plan: 2 phases of GTR development

GTR Development Phases

In order to develop the GTR in the context of an evolving hydrogen technology, the trilateral group proposes to develop the GTR in two phases:

- **Phase 1**: Establish a GTR for hydrogen-fueled vehicles based on a component level, subsystems, and whole vehicle crash test approach. For the crash testing, the GTR would specify that each contracting party will use its existing national crash tests but develop and agree on maximum allowable level of hydrogen leakage. The Japanese regulation, and any available research and test data will be used as a basis for the development of this first phase of the gtr.

- **Phase 2***:* Assess future technologies and harmonize crash tests. Amend the GTR to maintain its relevance with new findings based on new research and the state of the technology. Discuss how to harmonize crash test requirements for HFCV regarding whole vehicle crash testing for fuel system integrity.

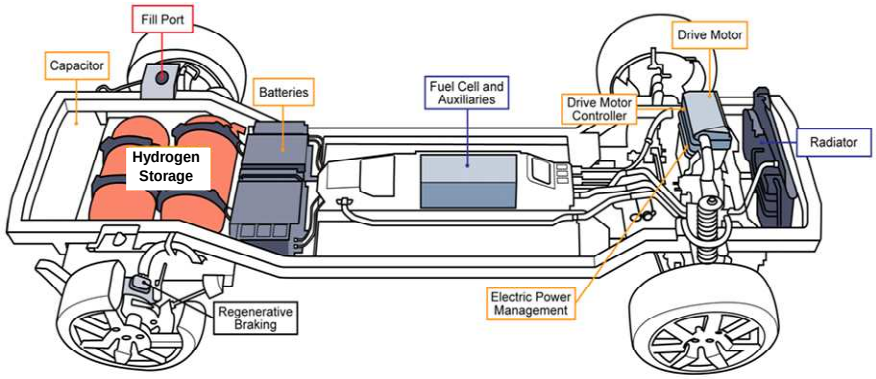
Milestones and Timeline

- June 2007 - WP.29 approved GTR Action Plan - ECE/TRANS/WP.29/2007/41
- 11 Safety Subgroup meetings; next SGS 12th meeting is scheduled for the end of June 2011
- May 2011 - draft GTR as informal document to the Group of Experts on Passive Safety (GRSP)
- June 2011 – SGS-12 meeting
- December 2011 - SGS will submit the draft GTR as 'formal document' to GRSP
- March 2012 - If no objections or substantive changes, GRSP submits GTR as an informal document to WP.29/AC.3
- June 2012 - If no objections or substantive changes, WP.29 votes on the GTR

GTR Scope

- This GTR applies to all hydrogen fueled vehicles of Category 1-1 and 1-2, with a gross vehicle mass (GVM) of 4,536 kilograms or less
  - Compressed gaseous hydrogen system
  - Liquefied hydrogen system
- Motorcycles and buses are not covered and will be addressed in Phase II

Compressed Gaseous Hydrogen System (CGHS) Requirements

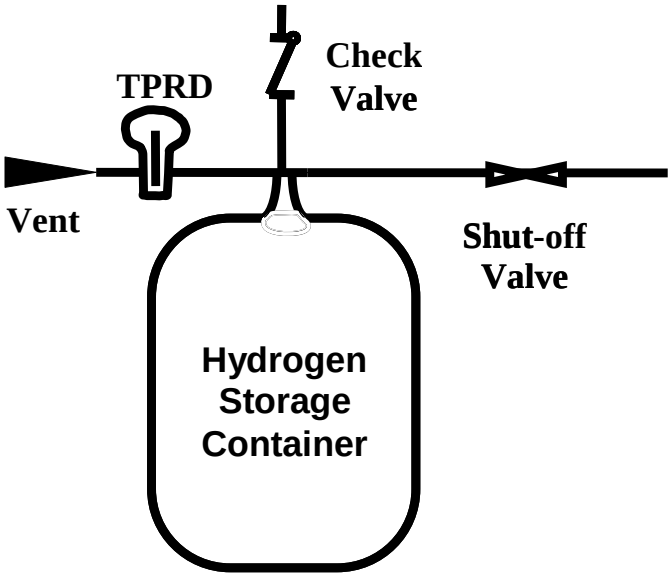


1. High pressure fuel container system
2. Fuel system at vehicle level: in-use and post-crash hydrogen leakage limits
3. Electrical integrity of high voltage system: in-use and post-crash

Compressed Gaseous Hydrogen System Requirements

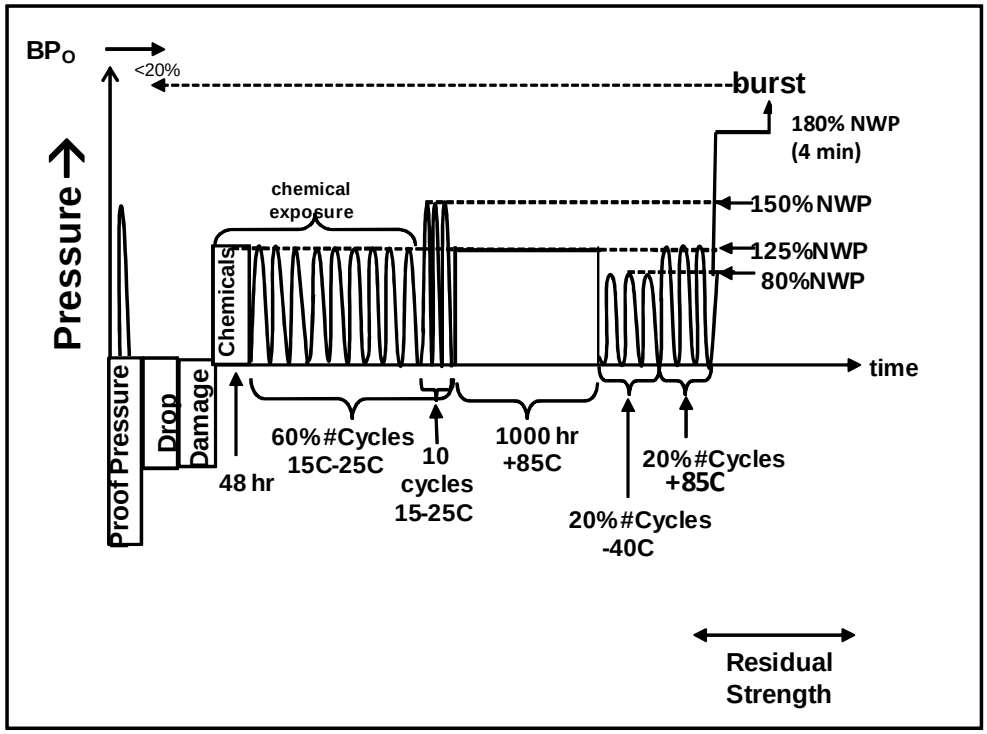
- High pressure fuel container system
  - Verification Test for Performance Durability: sequential hydraulic cycling and static pressure tests
  - Verification Test for Expected On-Road Performance: sequential pneumatic/hydraulic cycling tests
  - Verification Test for Service Terminating Performance: fire test
  - Label requirements: container and vehicle
- Fuel system integrity
  - In-use: fuel leakage mitigation
  - post crash: maximum allowable leakage limit
- Electrical Safety
  - High voltage safety for in-use and post crash

Compressed Gaseous Container



Verification Test for Performance Durability

Sequential hydraulic cycling tests

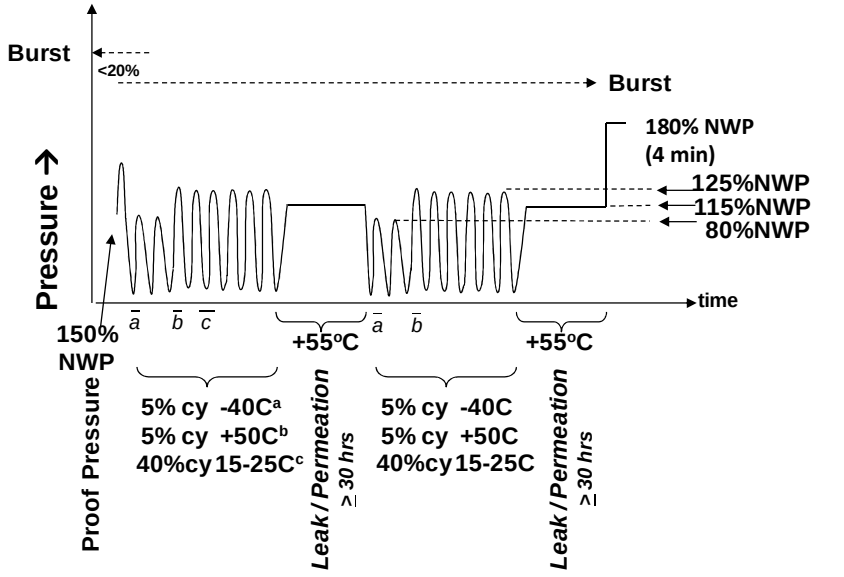


Number of cycles is specified by the individual contracting party (from 5,500 to 11,000)

- Proof pressure test
- Drop (impact) test
- Surface damage
- Chemical exposure and ambient temperature pressure cycling tests
- High temperature static pressure test
- Extreme temperature pressure cycling
- Residual proof pressure test (180% NWP-4 min)
- Residual strength burst test

Verification Test for On-Road Performance

Sequential pneumatic/hydraulic cycling tests



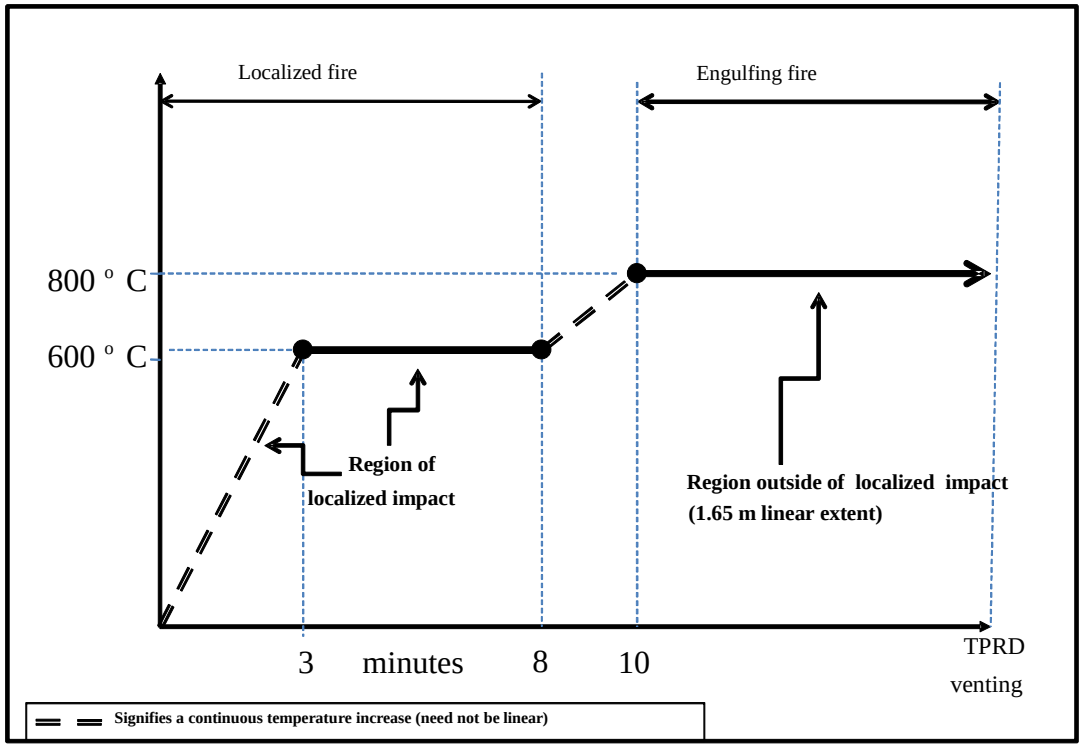
a Fuel/defuel cycles @-40ºC with initial system equilibration @ -40ºC, 5 cycles with +20ºC fuel; 5 cycles with <-35ºC fuel
b Fuel/defuel cycles @+50ºC with initial system equilibration @+50ºC, 5 cycles with <-35ºC fuel
c Fuel/defuel cycles @15-25ºC with service (maintenance) defuel rate, 50 cycles

Number of cycles: 500

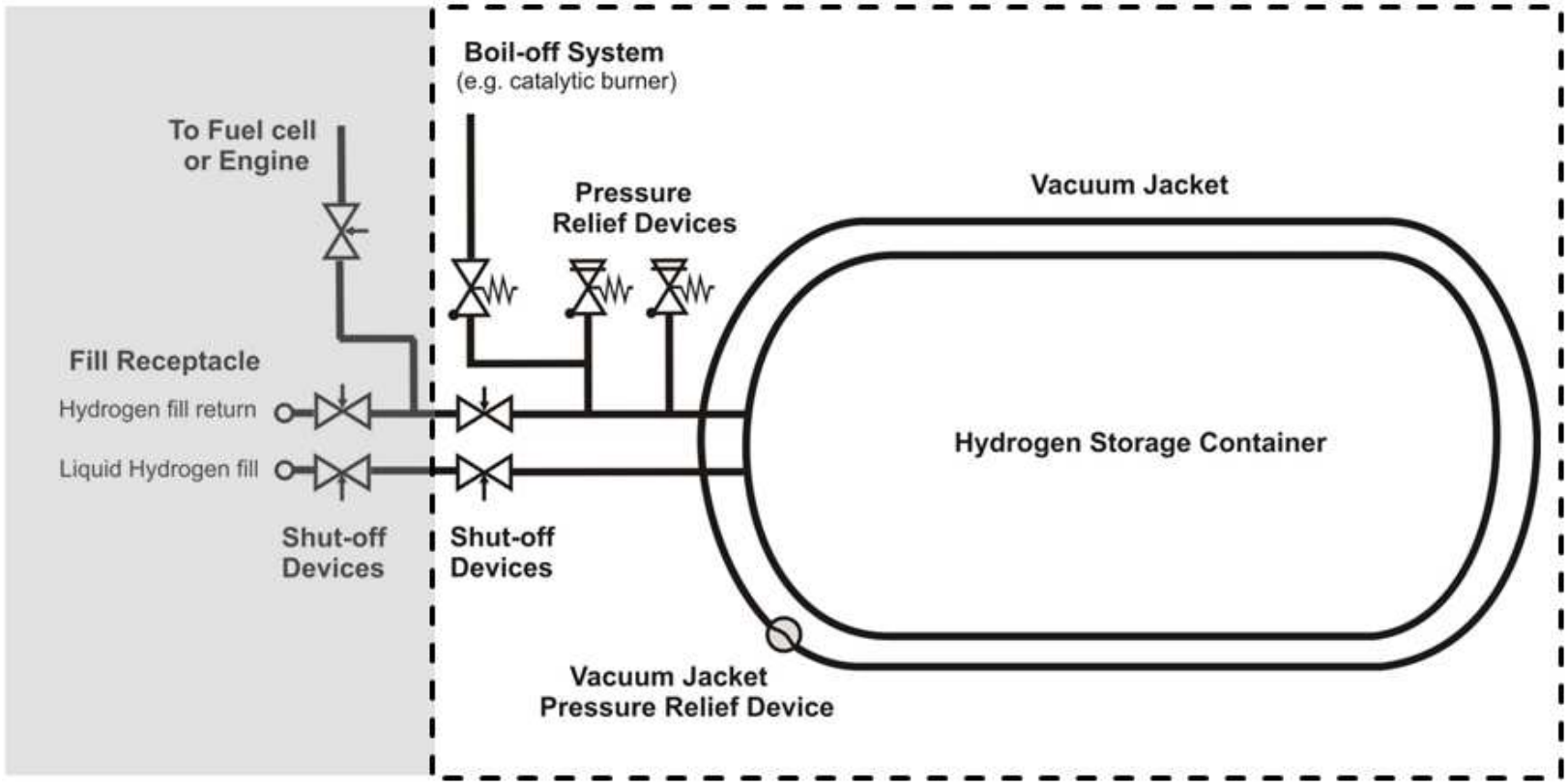
- Proof pressure test
- Ambient and extreme temperature gas pressure cycling test (pneumatic)
- Extreme temperature static gas pressure leak/permeation test (pneumatic)
- Residual proof test (180% NWP – 4 min)
- Residual strength burst test (hydraulic)

Container Fire Test

Combined localized and engulfing fire



Liquefied Hydrogen System



Liquefied Hydrogen System

- Verification of baseline metrics:
  - Proof pressure test
  - Baseline Initial Burst Pressure (hydraulic)
- Verification of on-road performance:
  - Boil-off test
  - Permeation/Leak test
  - Vacuum loss test
- Fire test: *Still under discussion to determine whether localized fire test is required*

Fuel system integrity

- In-use: fuel leakage mitigation and warning
  - Fuel system safety requirements:
    - Fueling port – *to prevent back flow*
    - PRD release direction – *to prevent H2 release into enclosed spaces and wheel wells*
    - Exhaust system – *to prevent build up of H2 in the exhaust system*
    - Hydrogen leakage in enclosed compartments – *No hydrogen can enter the passenger and trunk spaces. However, the vehicle will provide warning to the driver and activate shut off valves of the fuel cylinders if H2 concentration in air exceeding 4% in the semi enclosed or enclosed spaces of the vehicle*
    - Tell-tale: *Shall be yellow in color if the detection system malfunctions ; and shall be red in compliance with hydrogen leakage in the enclosed spaces*

Fuel system integrity

Post crash: Contracting parties maintain their current crash test requirements and apply the following requirements for post crash

- Maximum allowable leakage limit: *average of 118NL per minute within 60 minutes after the crash*
- Controlled leakage into enclosed spaces: *no built up of hydrogen concentration in air of more than 4% in the passenger or trunk/luggage compartments*
- Container Displacement: *The storage container(s) shall remain attached to the vehicle at a minimum of one attachment point*

Electrical Safety

Protection from direct and indirect contact from high voltage

- In-use:
- Protection from direct contact: *Protection of (1) IPXXD inside the passenger or luggage compartment and (2) IPXXB in other areas*
- Electric isolation – *100 Ω/volt for DC and 500 Ω/volt for AC*
  - [*for combined AC and DC buses: 100 Ω/volt providing (1) the electric system consists of double or more layers of solid insulators, (2) mechanically robust protections that have sufficient durability over vehicle service life such as motor housings, electronic converter cases or connectors*]
- Electrical isolation monitoring – *Currently applies only to fuel-cell vehicles*
- Vehicle functional safety: "*At least a momentary indication shall be given to the driver when the vehicle is in "active driving possible mode"*

Electrical Safety

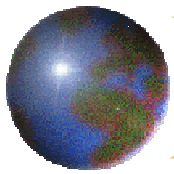
- Post-crash:
  - Maximum voltage - *30 VAC and 60 VDC*
  - Resistance isolation - *100 Ω/volt for DC and 500 Ω/volt for AC*
    - For combined AC/DC buses: *100 Ω/volt providing AC bus meets the physical protection*
  - [*Physical protection: protection of IPXXB*] *NHTSA is conducting safety risk study*
  - [*Energy option at 2.0 Joules*] *inconsistent safety criteria with resistance isolation option.*
  - Electrolyte spillage: *Maximum of 7% spillage in 30 minutes*
  - Battery and RESS retention: *"RESS located inside the passenger compartment shall remain in the location... No part of any RESS that is located outside the passenger compartment for electric safety assessment shall enter the passenger compartment during or after the impact test."*

Component Requirements

- Component qualification requirements: PRD, shut-off valve and check valve
- Fueling receptacle requirements: *to provide proper fueling protocols, performance and location*
- Pressure regulator: *The set pressure of the overpressure protection device shall be lower than or equal to the maximum allowable working pressure for the appropriate section of the hydrogen system*

Outstanding Issues

- Some of the test procedures have not been validated
- Liquefied hydrogen fuel system: *limited experience; post crash and fire test requirements; limited available test data*
- Electric safety:
  - [Post crash barrier option] – *NHTSA research on safety risks*
  - Energy option – *inconsistent criteria; optional requirement*
- Material compatibility (Hydrogen embrittlement): *CP to decide. Complete in Phase 2*



Thank you