SGS 04 - 07

Hydrogen Fuel Cell Vehicle Safety

Research to Support Rulemaking/GTR Objectives

September 2008

Overview

- GTR Action Plan
- Safety Issues
- Alternative Approaches
- Research/Rulemaking Goals
- Research Tasks
- Schedule

GTR Action Plan

ECE/TRANS/WP.29/2007/41 (April 2007)

- Objective
  - Attain equivalent levels of safety to conventional gasoline vehicles
  - Develop a global technical regulation concerning hydrogen/fuel cells
  - Performance based and does not restrict future technologies
- Content:
  - Performance requirements for fuel containers
  - Electrical isolation
  - Maximum allowable hydrogen leakage

Safety issues to be addressed

- Fuel system crashworthiness
  - Hydrogen leakage limits
  - Electrical integrity of high voltage fuel cell propulsion system
  - High pressure container safety
- Safety level consistent with gasoline, CNG, conventional electric hybrids
  - FMVSS Nos. 301, 303, 304, and 305

Approaches to address fuel system crashworthiness

- Hydrogen leakage limits
  - Hydrogen (SAE) vs. helium surrogate (SAE, Japan, OICA, FMVSS)
  - High pressure vs. low pressure and scaling up (SAE)
- Electrical integrity of high voltage fuel cell propulsion system
  - Active fuel cell with hydrogen onboard vs.
  - Inactive fuel cell, system "off" (SAE, AIAM, Japan)
- High pressure container safety
  - Cumulative life cycle and extreme use durability (SAE) vs. discrete testing (i.e., FMVSS, CSA/NGV2, HGV2, ISO, EIHP, etc.)
  - Localized flame impingement (SAE) vs. bonfire (FMVSS, etc.)
  - High pressure (FMVSS No. 303) and/or low pressure (SAE,GM) – vulnerability to impact is greater at low pressure

Issues Associated with Each Fueling Approach for Crash Testing

- High pressure hydrogen
  - + Electrical system is operational
  - + Worse case for leak rate
  - - Poses additional fire hazard
- High pressure helium
  - + Consistent with FMVSS Nos. 301, 303
  - + Non-flammable
  - - Surrogate leak rate is slightly different
  - - Electrical system ***is not*** operational
- Low pressure hydrogen option
  - + Electrical System operational
  - - Must scale up leak rate to represent worse case at high pressure
  - +/- Cylinders more vulnerable to impact at low pressure

Research/Rulemaking goals

- Conduct research to assess all proposed alternatives
  - Confirm that selected alternative detects potential failure
- Prescribe additional requirements if results indicate safety need, e.g.:
  - Localized flame impingement test replaces bonfire test for hydrogen containers
  - Extend post-crash leakage measurement beyond 60 minutes to adjust for reduced flow rate of helium through same sized orifice
- Prefer selecting option that is analogous to and consistent with existing requirements
  - High pressure helium
  - Single crash test for both electrical isolation and fuel leakage

Research Tasks to Support Rulemaking/GTR Objectives

- Localized flame impingement on hydrogen storage cylinders
- Cumulative cylinder life cycle testing
- Comparative assessment of fueling options for crash testing
- Fire safety of proposed leakage limits
- Electrical isolation testing in the absence of hydrogen

Localized flame impingement on hydrogen storage cylinders

- FMVSS No. 304
  - Requires bonfire test
  - Cylinder must survive engulfing fire for 20 minutes or vent contents
- Localized flame impingement (SAE)
  - Real world data indicates Type IV composite cylinders do not vent in localized fire
  - Lack of heat transfer to PRD
  - Composite loses structural integrity, resulting in catastrophic rupture
- Research Task:
  - Localized fire test procedure – Developed by Powertech under contract to Transport Canada.
  - Verification testing – Conducted under contract to NHTSA. Cylinders which have failed in real world fires will be tested and mitigating technologies will be assessed (heat transfer, sensing, shielding)
- Possible Outcome:
  - Requirement for localized flame test

Cumulative cylinder life cycle testing

- Generate simulated real-world life cycle data
  - SAE TIR 2579 expected service and durability testing. (pneumatic gas cycling, parking, extreme temperature, flaw, chemical tolerance, burst)
  - Test procedures developed under contract to DOE/NREL
  - Japan considering similar requirements in new standard, JARI 001 upgrade.
- Research Task:
  - Initial results indicate that altering test protocol effects results
  - Conduct life cycle testing on representative hydrogen storage systems, vary test conditions to represent different service conditions
- Possible Outcome:
  - Requirement for pneumatic rather than hydraulic pressure cycling test (FMVSS No. 304)
  - Requirement for post pressure-cycle burst strength

Comparative assessment of fueling options for crash testing

- Fueling options advocated by industry
  - High pressure hydrogen (SAE)
  - High pressure helium (SAE, Japan)
  - Low pressure hydrogen (SAE,GM)
- Research task:
  - Conduct testing to compare container vulnerability to impact at high and low pressure fill
  - Conduct leakage tests of hydrogen and helium at high and low pressure fill for a range of cylinder sizes
- Possible Outcome:
  - Selection of most appropriate fill option for assessing pass/fail leakage and fuel system vulnerability per FMVSS crash conditions

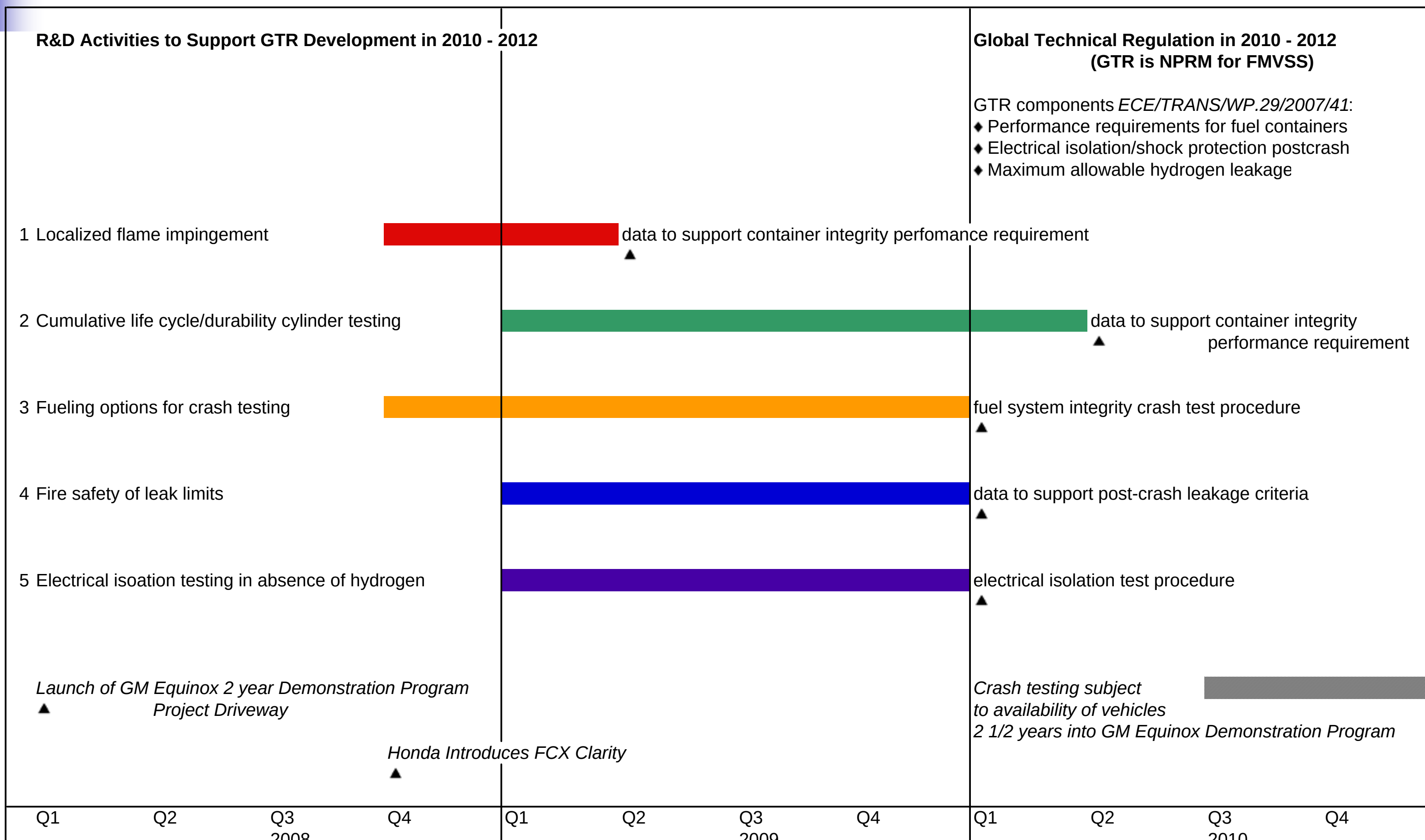
Fire safety of proposed leakage limits

- Hydrogen concentrations exceed lower flammability limit in vehicle compartments
- Research Task:
  - Conduct hydrogen ignition tests in the trunk, engine and occupant compartments of vehicles and crash tested ICE vehicles
- Outcome:
  - Confirmation of the fire safety of proposed leakage limits, which are currently based on the thermal energy equivalent to gasoline

Electrical isolation testing in the absence of hydrogen

- Fuel cell produces no voltage when crash test is conducted using helium surrogate
  - Measure isolation by applying test voltage from an external source (megohmmeter)
- Research Task:
  - Conduct isolation testing with no hydrogen present, using megohmmeter
- Possible Outcome:
  - Confirm that testing can be conducted with the megohmmeter, without inducing damage to the vehicle propulsion circuit

R&D Timeline to Support Rulemaking Objectives



Schedule

- Localized flame impingement on hydrogen storage cylinder: 6 months
- Cumulative cylinder life cycle testing: 15 months
- Comparative assessment of fueling options for crash testing: 15 months
- Fire safety of proposed leakage limits: 12 months
- Electrical isolation testing in the absence of hydrogen: 12 months