Developing Standards for Hydrogen and Fuel Cell Vehicles (FCVs) and plans for Fork Lift Applications in 2010

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Fuel Cell Seminar

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SAE FCV Committee

- **Developing vehicle and systems-level, performance-based standards based on best available knowledge.**
- **Cooperating with other organizations to verify current standards and develop new capabilities, when appropriate.**
  - DOE-funded verfication testing of methodologies
  - Japan Automobile Research Institute (JARI)
  - CSA Standards
- **Overall objective**
  - Use FCVs as current ICEs are used (without restrictions)
  - Facilitate rapid advances by the industry
  - Provide a technical basis for national and global requirements
- New Work Item: Fork Lifts
  - Goal: Bring FCV System performance standards for fork lift applications. To work in conjunction with UL-CSA

Why the Focus on Systems-level Performance-based Requirements?

- Establishes clear expectations for the vehicle system based on foreseeable use
- Addresses all parts, connections, and interactions within the system
- Provides flexibility for future development
  - Does not dictate specific components or configurations
  - Avoids arbitrary flow down of requirements to components
- Ensures direct connection to requirements for the targeted vehicle applications
  - Standard passenger
  - Heavy-duty commercial

SAE FCV *ENABLING* STANDARDS

Document Numbers and Subjects

- **Documents for vehicles:**
  - SAE J1766 Post-crash electrical safety *
  - SAE J2572 Measuring fuel consumption and range *
  - SAE J2578 Integration of hydrogen and electrical systems on FCVs *
  - SAE J2579 Vehicular hydrogen systems (TIR) *
  - SAE J2600 Compressed hydrogen fueling receptacles
  - SAE J2719 Hydrogen quality (TIR) *
  - SAE J2760 Hydrogen system terminology (TIR)*
  - SAE J2799 70 MPa hydrogen fueling receptacle and interface (TIR)*
  - SAE J2601 Compressed hydrogen fueling protocol (TIR) **
  - **Documents for Industrial Vehicles:**
  - SAE J2919 Compressed Hydrogen Storage Systems in Industrial Equipment (TIR) **

* Published

** To be Published

SAE J2578 and J2579

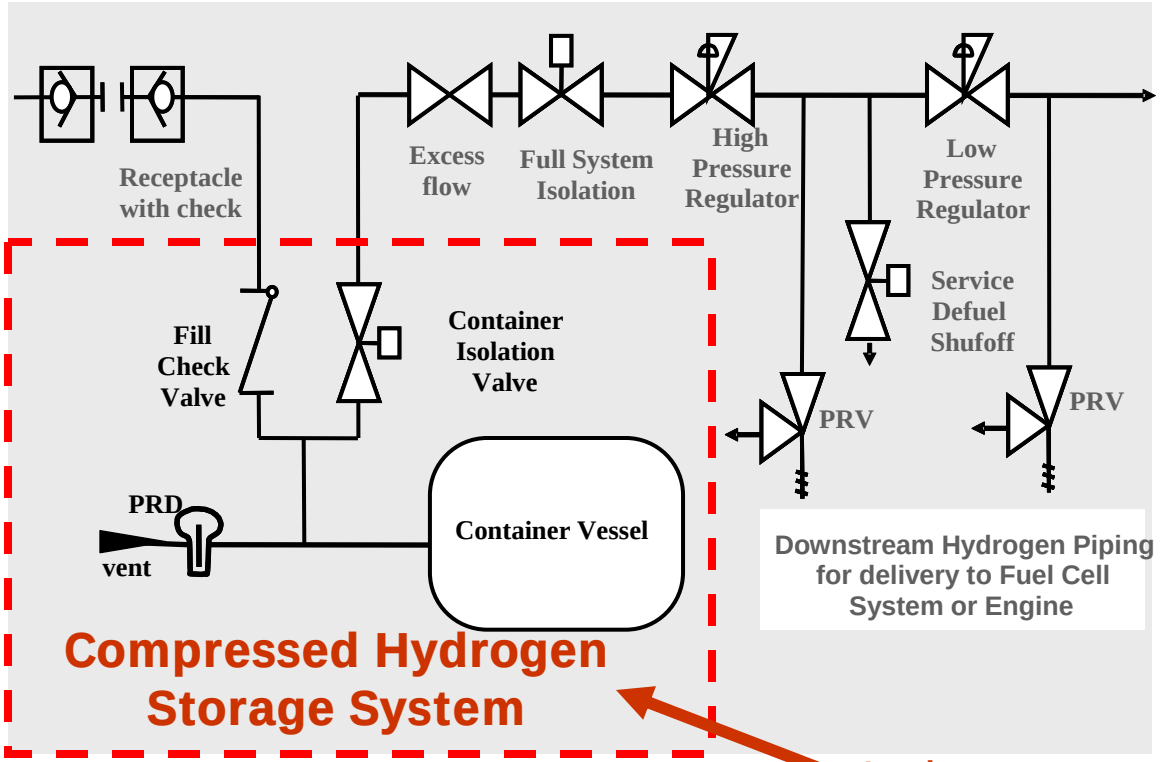
Principle of "Design for Safety"

- **No single credible failure should cause unreasonable safety risk to persons or uncontrolled vehicle behavior**
  - Fail-safe design
  - Isolation and separation of hazards to prevent cascading of events
  - Fault Management with staged-warning and shutdowns

- **Isolation and containment of stored hydrogen is required to practice fault management on hydrogen and fuel cell vehicles.**

SAE J2579: Vehicular Hydrogen Systems

Typical Hydrogen Storage System Addressed in SAE J2579



Includes all components and parts that form the primary pressure boundary for stored hydrogen

Isolates stored hydrogen from --

- the remainder of the fuel system
- the surrounding environment

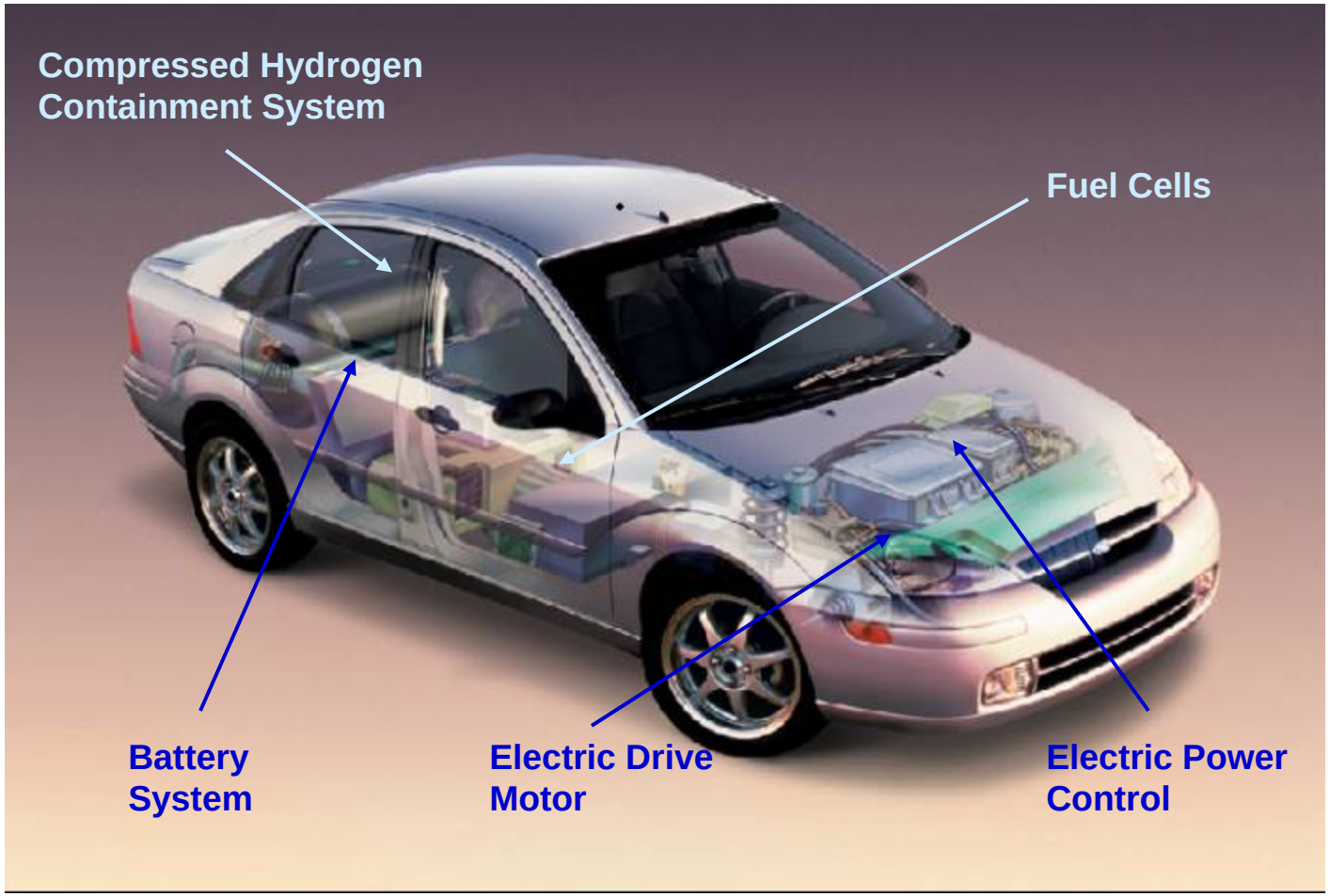
SAE J2579: Vehicular Hydrogen Systems

While general hydrogen system and storage requirements are considered, the focus of the document is design and qualification of the Compressed Hydrogen Storage System (CHSS) over the service life of the vehicle.

- **Expected Service Performance**
  - Fast fills and static holds with hydrogen over the full operating temperature range
  - Covers the expected service life of most vehicles
- **Durability under Extended Usage and Extreme Conditions**
  - Accounts for possible tank damage and chemical exposure
  - Considers possibility of extended use by performing hydraulic cycles.
- **Performance under Service-terminating Conditions**
  - Engulfing fire (bonfire) tests to demonstrate that the PRD(s) can protect the CHSS
  - Penetration tests to demonstrate robustness of the wrap
  - Burst (and perhaps other) tests to show consistency

SAE J2578: Fuel Cell Vehicles (FCVs)

Integrating hydrogen, electrical, and fuel cell systems



SAE J2578: Management of Electrical Issues

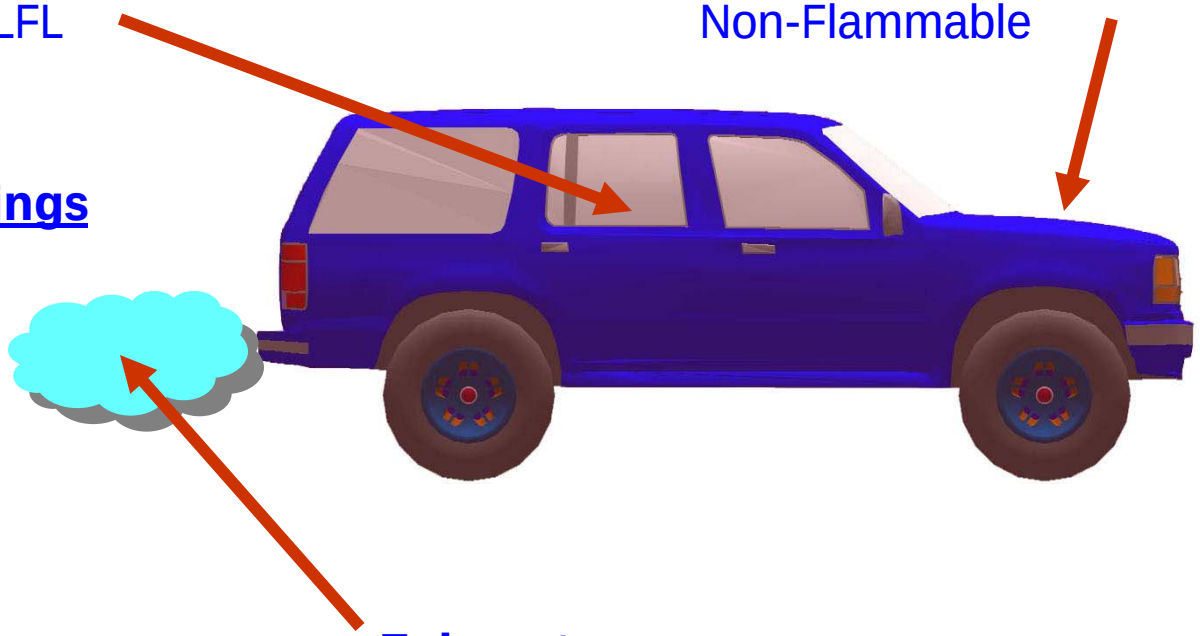
Based on Existing Electric Vehicle (EV) Standards and on-going harmonization activities with ISO TC22/SC21

- Electrical shock protection
  - Electrical Isolation
  - Supplemental insulation, barriers, and enclosures
  - De-energization
- High voltage dielectric withstand
- High voltage wire and connectors
- Over-current protection
- Labeling and access to live parts
- Automatic disconnects
- Manual disconnect functions

SAE J2578: Management of Hydrogen Discharges

Passenger Compartment
Less than 25% LFL

Other Compartments
Non-Flammable



General Surroundings
Less than 25% LFL

Exhaust
Locally non-hazardous

SAE J2799 70 MPa Hydrogen Fueling Receptacle and Interface (TIR)

- Defines the receptacle configuration and provides performance-based test methods for verification for 70MPa. 35MPa is covered under SAE J2600.

SAE J2601 Compressed Hydrogen Fueling Protocol (TIR)

- Allows fast fills within technical capability of the compressed hydrogen storage system as defined in J2579.
- Defines requirements and protections needed to be incorporated in the dispenser standards.

Importance of a Hydrogen Fueling Vehicle Protocol

- Hydrogen fueling is critical to the success of a hydrogen economy.
- Hydrogen fueling is not yet standardized.
- Hydrogen fueling protocol must manage the heat of compression.
- Hydrogen fueling protocol must manage unknowns.

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SAE J2601 & CSA 4.3

SAE TIR J2601

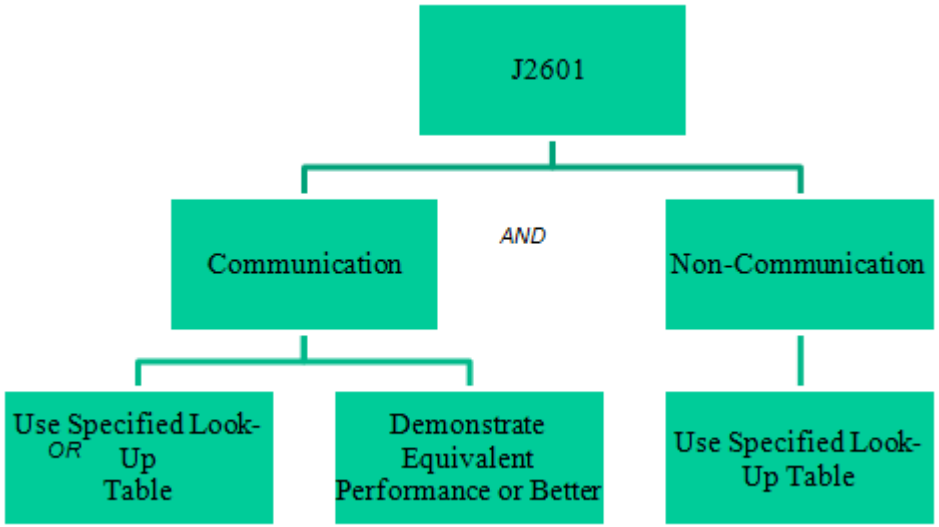
Vehicle H2 Limits & Targets

- Non-Communication Tables
- Communications
- Light Duty Vehicles

CSA TIR 4.3

H_2 Dispenser Confirmation

- Testing Device (H.D.T.A.*)
- Test Procedure



*Hydrogen Dispenser Test Apparatus

SAE TIR J2601

After **8** years in the making, J2601 is to be released in 2009.

What is J2601?

- Only Industry-Wide Light Duty Hydrogen Vehicle Fueling Protocol 35 & 70MPa: Created by Math Modeling and Confirmed by System Testing
- Supersedes all previous partnership protocols (CaFCP/NE,etc)

What does it cover?

- Light Duty Hydrogen Vehicle Fueling (1-10kg @70 Mpa & 1-7kg @35MPa). Type III & IV tanks only.
- Dispenser Protocol for non & communications
- Meets U.S. DOE 2015 goals with Type 'A' Dispenser
- V.2 (2010) will cover bus, forklift and residential fueling

Hydrogen Fueling Protocol Approach

Technical Goals for Compressed Hydrogen Fueling

- Maintain the safety limits of storage system.
  - Max. Gas Temperature: 85 C
  - Max. Pressure: 87.5 MPa (70 MPa NWP) and 43.8 MPa (35 MPa NWP)
- Achieve target desired customer attributes.
  - Fueling Time: 3-5 minutes Ramp Rate (Type A Station)
  - Typical State of Charge Range : 90% to 100% (density based on NWP at 15 C)

Options for Compressed Hydrogen Fueling Protocol

- Vehicle to station interface strategies
  - Communication: vehicle transmits tank parameters through electrical interface
  - Non-communication: vehicle provides tank pressure only
- Station key control factors
  - Pre-cooling of hydrogen: station conditions H_2 temperature prior to dispensing
  - Hydrogen delivery rate: station provides fill rate per mass or pressure vs. time
  - Fill termination: station determines end pressure and/or density that meets goals

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World Wide OEM / Hydrogen Supplier Support

Letter of Understanding

on the Development and Market Introduction of Fuel Cell Vehicles

Key criteria for the hydrogen fuelling stations are:

- All hydrogen stations are publicly accessible and integrated into branded conventional fuelling stations,
- All hydrogen stations meet the requirements of SAEJ2601,
- All hydrogen stations are located smartly to enable customer access,
- The hydrogen is offered at a reasonable price to the customers.

Plans for Fork Lift Applications

- SAE Fuel Cell Committee has created a sub team (in conjunction with the safety group) to develop hydrogen storage systems standards (SAE J2919)
- SAE J2601 is to be updated in 2010 to include fork lift fueling for both communications and non-communications.
- Plans are to work in conjunction with CSA & UL to establish standards in conjunction with the next revision of UL 2267

J2601 Fueling Procedure Logic-Tree