Japanese Technical Standard for Hydrogen Containers
- current standard and future revision plan -

May. 2008

Transmitted by
Japan Automobile Standards Internationalization Center (JASIC)
Contents

1. Summary of Japanese current standard for hydrogen containers
   (Standard name: JARI S 001)

2. Future revision plan of technical standard for hydrogen containers in Japan
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1. Summary of Japanese current standard for hydrogen containers
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Scope of Regulations in Japan

Vehicle: Road Transportation Vehicle Law

Containers & Components
(High Pressure Gas Safety Law)

Schematic View of Vehicle
(Fuel Cell Vehicle)

Regulation:
(1) High Pressure Hydrogen Containers → JARI S 001(2004)
(2) Stop Valve & (3) Safety Valve (PRD) → JARI S 002(2004)
Current Standards Situation in Japan

- Current Japanese Technical Standards (JARI S 001 & S 002) have already been applied as regulations since March 2005.

  JARI S 001(2004)
  Technical Standards for Containers for Compressed-Hydrogen Vehicle Fuel Device

  JARI S 002(2004)
  Technical Standards for Components (valve and PRD) for Compressed-Hydrogen Vehicle Fuel Device

- Especially JARI S 001 has almost same concept as ISO 15869.2 (2nd DIS) for Hydrogen Containers. Both of them have been derived from CNG standards.
< Reference Regulation >
Current Japanese CNG regulations
These are called KHK Reiji-kijun Betten No.9 & 10

< Container Types Limitation >
VH3(Type3) : Metal liner and full-rap CFRP
VH4(Type4) : Plastic liner and full-rap CFRP

< Discussion Points >
Kind of filling gas : Natural Gas → Hydrogen
Maximum Filling pressure : 26MPa → 35MPa
- Selection of available material at 35MPa Hydrogen
- Demonstration test
- Harmonization with international standards
Example of Discussion Points (1)

Relation to Reference Regulation

KHK Reiji-kijun Betten No.9
Interpretation of technology regulation for Compressed natural gas container for automobile applications

Regulation of High Pressure Hydrogen Containers

Kind of filling gas: Hydrogen
Molecular weight / size: Small

- Embrittlement of material
- Increase of permeation
- Fast filling

1) Harmonization with international standards
2) Demonstration test

Example of discussion
Permeation of Hydrogen
Gas Permeation Test of Hydrogen

VH3-Container(40L)  VH4-Container(65L)

Test sample

Test Chamber

International standards
- ISO/CD15869 : Criteria : 1.0 [cm³/hr/L]
- EIHP Rev.12b : Criteria : 1.0 [cm³/hr/L]
- HGV2Rev.12-03 : Criteria : 2.0 [cm³/hr/L]
  (- Betten No.9 (Natural Gas) :
    Criteria : 0.25 [cm³/hr/L] )

Safety criteria in garage

Permeation of Hydrogen

VH3-Container : Very low permeation
VH4-Container : Permeation after 500hr : 1.02[cm³/hr/L]

The allowable limit is 2.0[cm³/hr/L] for VH4-Container

Example of Discussion Points (2)
Example of Discussion Points (3)

Fast Fill Test of Hydrogen

Check the temperature range during fast fill

Test view of VH3-Container

Test view of VH4-Container

Gas temperature might touch to 85 deg-C during fast fill

It is able to conduct fast fill under 85 deg-C by choice of suitable filling rate

Settle upper limit temperature under 85 deg-C in this regulation

Relation between gas temperature and filling rate

Type3 8°C 1-35MPa
Type3 8°C 15-35MPa
Type3 50°C 1-35MPa
Type3 50°C 15-35MPa
Type4 10°C 1-35MPa
Type4 10°C 15-35MPa
Type4 50°C 1-35MPa
Type4 50°C 15-35MPa
Example of Discussion Points (4)

**Material**

Influence of hydrogen atmosphere on ductility of material

Test items
- Tensile strength
- Fatigue strength
- Delayed fracture
- Fatigue crack propagation

<table>
<thead>
<tr>
<th>Hydrogen Pressure, P/MPa</th>
<th>Temperature Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>304</td>
<td>SUS316L</td>
</tr>
<tr>
<td>316</td>
<td>SUS316L</td>
</tr>
<tr>
<td>316L</td>
<td>SUS316L</td>
</tr>
<tr>
<td>316LN</td>
<td>SUS316L</td>
</tr>
</tbody>
</table>

**Selection of materials**

 Preferential material for literature review by JARI

Stainless steel: SUS304, 304L, 316, 316L etc.
Aluminum alloy: A6061-T6, A7071 etc.

SUS316L shows no influence of hydrogen

Preferred material tested by JRCM

Stainless steel: SUS 316L
Aluminum alloy: A6061-T6
Cupper alloy: C3771 (for component)

The description of equivalent materials

Standard material
Stainless steel: SUS 316L
Aluminum alloy: A6061-T6

SUS 316L and A6061-T6 shows no or very little hydrogen effect on embrittlement → Available metals in this regulation
## Outline of Technical Standard

<table>
<thead>
<tr>
<th>Article</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Article 1 (Scope)</strong></td>
<td>VH3-Container and VH4-Container are permitted The tanks for compressed hydrogen vehicle within a scope not exceeding 15 years displayed by stamping</td>
</tr>
<tr>
<td><strong>Article 2 (Definitions of Terms)</strong></td>
<td>Stress ratio : 2.25</td>
</tr>
<tr>
<td><strong>Article 3 (Materials)</strong></td>
<td>SUS316L, A6061T6</td>
</tr>
<tr>
<td><strong>Article 4 (Thickness)</strong></td>
<td>The thickness is such that no yielding occurs at or near the container boss when the pressure is 1.5 times that of the maximum filling pressure</td>
</tr>
<tr>
<td><strong>Article 6 (Methods of Machining and Heat Treatment)</strong></td>
<td>The compression stress of the liner at atmospheric pressure is less than the yield strength of the liner after autofrettage</td>
</tr>
<tr>
<td><strong>Article 7 (Container Inspection)</strong></td>
<td>Maximum filling pressure shall be 35 MPa or less Internal cubic capacity shall be 360L or less</td>
</tr>
<tr>
<td><strong>Article 8 (Design Inspection in Design Confirmation Test)</strong></td>
<td>The results of measurements of the yield strength of materials at or near the boss shall be checked</td>
</tr>
<tr>
<td><strong>Article 11 (Room Temperature Pressure Cycle Test in Design Confirmation Test)</strong></td>
<td>The test shall be carried out by shuttling between pressure of up to 2 MPa and pressure equal to or greater than 125% of the maximum filling pressure</td>
</tr>
<tr>
<td><strong>Article 13 (Bonfire Test in Design Confirmation Test)</strong></td>
<td>The gas filled into the container shall be hydrogen gas</td>
</tr>
<tr>
<td><strong>Article 14 (Drop Test in Design Confirmation Test)</strong></td>
<td>In the vertical drop test the lowest portion of the container is at least 35 mm from the floor</td>
</tr>
<tr>
<td><strong>Article 15 (Gas Permeation Test in Design Confirmation Test)</strong></td>
<td>Hydrogen gas shall be used for the permeation test The rate of hydrogen gas permeation is less than 2 cm³ per hour per liter of container internal cubic capacity</td>
</tr>
<tr>
<td><strong>Article 17 (Hydrogen Gas Cycle Test in Design Confirmation Test)</strong></td>
<td>A pressure in excess of the maximum filling pressure shall be added at least 1,000 times</td>
</tr>
<tr>
<td><strong>Article 19 (Permissible Defect Confirmation Test in Design Confirmation Test)</strong></td>
<td>The speed of fatigue crack propagation data of SUS316L and A6061-T6 shall be used</td>
</tr>
</tbody>
</table>

**March 2005 : Enforcement of the technical standard**
1. Summary of Japanese current standard for hydrogen containers
   (Standard name : JARI S 001)

2. Future revision plan of technical standard for hydrogen containers in Japan
Necessity of Japanese Standards Revision

JARI S 001 & S 002 are enough standards for initial introduction of FCVs to the market. But it is necessary to consider the revision for future mass popularization of FCVs.

1) Light-weight and Low-cost high-pressure hydrogen containers and components are necessary.

2) Expansion of designated materials is necessary. (In Japanese case, the current standards limit the materials that can be used in high-pressure hydrogen environment for Influence of Hydrogen on crack growth)

3) Finally standardization of material evaluation methods is necessary.
Outline of Japanese New Standards Schedule

The first target issue date of new standards is Mar.2010 (Japanese FY2009)

The standardized material evaluation methods in high-pressure hydrogen environment will take a long time. So these activities are divided by 2 steps.

<Step-1> Until Mar.2010 (Japanese FY2009)
1) Improvement of evaluation tests for design performance.
2) Expansion of designated materials.
   (Only SUS316L and A6061-T6 are designated in the current standards)

<Step-2> Until Mar.2013 (Japanese FY2012)
Prepare standardized materials evaluation methods in high-pressure hydrogen environment and refer to it in the new technical standards to increase the freedom to select materials.
(Facilitate the implementation of new materials.)
Draft Schedule with International Harmonization

It is possible to propose this draft to gtr discussion from Japan.

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Japanese New Standards</td>
<td>Data Acquisition for container @ JARI</td>
<td>Deliberations</td>
<td>Draft</td>
<td>Issue (Step-1)</td>
<td>Issue (Step-2)</td>
<td></td>
</tr>
<tr>
<td>SAE J2579</td>
<td>Study Proposals</td>
<td>Data Acquisition @ PLI</td>
<td>TIR</td>
<td>Deliberations</td>
<td>Issue</td>
<td></td>
</tr>
<tr>
<td>ISO 15869</td>
<td>2nd DIS Rejected</td>
<td>Draft 3rd DIS</td>
<td>Issue?</td>
<td>Harmonization</td>
<td></td>
<td></td>
</tr>
<tr>
<td>gtr</td>
<td></td>
<td>Establishment of gtr</td>
<td></td>
<td>Issue</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Concepts of New Standard for Containers

1) To change the maximum working pressure from 35MPa to 70MPa.

2) To consider the Vehicle usage, Lifetime, Load conditions and Prospective Performance.
   a) To change the pressure cycling test condition reflected the FCV cruising distance as a result of prospective performance and lifetime.
   b) To change the extreme temperature cycling test condition reflected actual low and high temperature (under high speed hydrogen supply and fast filling).

3) To guarantee the Container strength after Durability tests reflected Vehicle usage and Lifetime.
   a) To change the cycle numbers and condition of burst pressure test.
   b) To execute the sequential loading tests.
Outline of New Standard for Containers

Current (JARI S 001)

- Maximum Working Pressure 35 MPa
- Strength guaranteed in a brand-new cylinder = Independent Loading Tests
- Burst Pressure > Working Pressure x 2.25
- Fatigue Life > 11,250 Cycles
- Materials Designated (A6061-T6, SUS316L)

New Standard

- New standard applied (Inner volume the same; CFRP reduced)
- Safety guaranteed
- Lighter weight and Lower cost (reduction of CFRP used; lower grade)

- Maximum Working Pressure 70 MPa
- Durability strength guaranteed in consideration of Vehicles Usage and Lifetime.
  = Sequential Loading Test (chemical exposure, low and high temperatures, fatigue, pressure, burst)
- Burst Pressure
  Working Pressure reduced (After Durability Test)
- Fatigue Life cycles reduced
- Expansion of materials selection through standardization of materials evaluation method.
Preparation data for Expansion of designated materials

On the containers (limited lifetime > 11,250 cycles in the current standard)
Crack growth curve based on the deterioration factors will be needed for parts design.

*need to grasp the deterioration factors by preliminary tests
Japanese ideas for new standards on Sequential Loading Test

Sequential loading test should be simplified with independent material evaluations under the conditions of real usage.

*Gas cycle tests are going to be minimized or deleted by definition of designated materials for liner
Comparison of Current Standard and New in Japan (Draft)

Current (JARI S 001)
- Expansion Measurement Test
- Hydrogen Gas Cycling Test
- Gas Permeation Test
- Environmental Test
- Composite Flaw Tolerance Test
- Bonfire Test
- Ambient Cycling Test
- Drop Test
- Maximum Defect Size Inspection Test
- Interlaminate Shear Test
- Hydrostatic Burst Test
- Accelerated Stress Rupture Test

New Standard (Draft)
- 1) Proof pressure test
- 2) Extreme temperature pressure cycling test
- 3) Hydrogen Gas Cycling Test (VH4)
  - Continue cycling until static reaches saturation
- 4) Gas Permeation Test (VH4)
  - To verify permeation after saturation.
- 5) Environmental Test
  - Reduced cycles
  - combination of Ambient Temp, Low Temp and High temp
- 6) Burst test at end of life

Sequential Loading Test
1) -> 2) -> 3) -> 4) -> 5) -> 6)
- 2) ➔ 3) ➔ 4) ➔ 5) ➔ 6)

- Decision of Burst Pressure criteria
- X No need for C-FRP Container (VH3)
- X Change to Hydrostatic Burst Pressure Test
- X No need for C-FRP Container (VH3)
## Comparison of Standards for Hydrogen Containers

### <Summary of basic conditions>

<table>
<thead>
<tr>
<th>Items</th>
<th>ISO DIS15869.3</th>
<th>SAE J2579 draft Jan.2008</th>
<th>JARI S 001</th>
<th>Revision plan to JARI S 001</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fuel types</strong></td>
<td>Hydrogen and CNG blends more than 2% hydrogen</td>
<td>Hydrogen</td>
<td>Hydrogen</td>
<td>Hydrogen</td>
</tr>
<tr>
<td><strong>Scope</strong></td>
<td>Container, (Include the system as Alternative type tests)</td>
<td>Storage system (Container,PRD, Shut off valve, etc)</td>
<td>Container (PRD, Shut off valve are in JARI S 002)</td>
<td>the same as JARI S 001</td>
</tr>
<tr>
<td><strong>Container types</strong></td>
<td>Type 1,2,3,4</td>
<td>No limit</td>
<td>Type 3,4</td>
<td>Type 3,4</td>
</tr>
<tr>
<td><strong>Working pressure</strong></td>
<td>No limit, 15degree C</td>
<td>No limit, 15degree C</td>
<td>Less than 35MPa, 35degree C</td>
<td>Less than 70MPa, 35degree C</td>
</tr>
<tr>
<td><strong>Service life</strong></td>
<td>15 years</td>
<td>No limit</td>
<td>15 years</td>
<td>15 years</td>
</tr>
<tr>
<td><strong>Test method</strong></td>
<td>each test for a brand-new cylinder (Add the sequential test as Alternative type tests)</td>
<td>add the sequential test for worst-case conditions</td>
<td>each test for a brand-new cylinder</td>
<td>add the sequential loading test for end of life</td>
</tr>
</tbody>
</table>
## Comparison of Standards for Hydrogen Containers

### <Summary of main tests>

<table>
<thead>
<tr>
<th>Items</th>
<th>ISO DIS15869.3</th>
<th>SAE J2579 draft Jan.2008</th>
<th>JARI S 001</th>
<th>Revision plan to JARI S 001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burst pressure</td>
<td>Minimum stress ratio more than 2.0 (carbon, &lt;35MPa)</td>
<td>more than 1.8*NWP</td>
<td>Burst pressure ratio more than 2.25</td>
<td>To be reduced</td>
</tr>
<tr>
<td>Durability test cycles</td>
<td>11,250 cycles, or 5,500 cycles with a tamper-proof counter system</td>
<td>(Personal vehicles) not less than 5,500 (Commercial vehicles) not less than 11,250</td>
<td>11,250 cycles</td>
<td>To be reduced</td>
</tr>
<tr>
<td>Gas cycling test</td>
<td>1,000 cycles for type4 container</td>
<td>(defined in the sequential test)</td>
<td>11,000 cycles for type4 container</td>
<td>under studying</td>
</tr>
<tr>
<td>Permeation test</td>
<td>2cm³/hr/litre/35MPa, 2.8cm³/hr/litre/70MPa (70Ncc/min at 20C as alternative type tests)</td>
<td>150Ncc/min, 125%NWP at 85C</td>
<td>2cm³/hr/litre</td>
<td>under studying</td>
</tr>
<tr>
<td>sequential test</td>
<td>As alternative type tests 1)extreme temp gas cy (25%cy -40C, 25cy +50C), 2)stress rupture, 3)extreme temp gas cy (25%cy +50C, 25% -40C), 3)repeat 2), 5)permeation, 6)proof pressure(1.8*), 7)burst</td>
<td>1)proof pressure, 2)extreme temp gas cy (25%cy -40C, 25cy +50C), 3)stress rupture, 4)extreme temp gas cy (25%cy +50C, 25% -40C), 5)stress rupture, 6)permeation, 6)proof pressure(1.8*), 7)burst</td>
<td>No required</td>
<td>(Tentative ideas) 1)proof pressure, 2)gsa cycling, 3)extreme temperature gas cycling (-40,+50C,small cycles), 4)permeation, 5)Environmental, 6)burst</td>
</tr>
</tbody>
</table>
Thank you for your attention