SGS 3 - 9

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

Contents

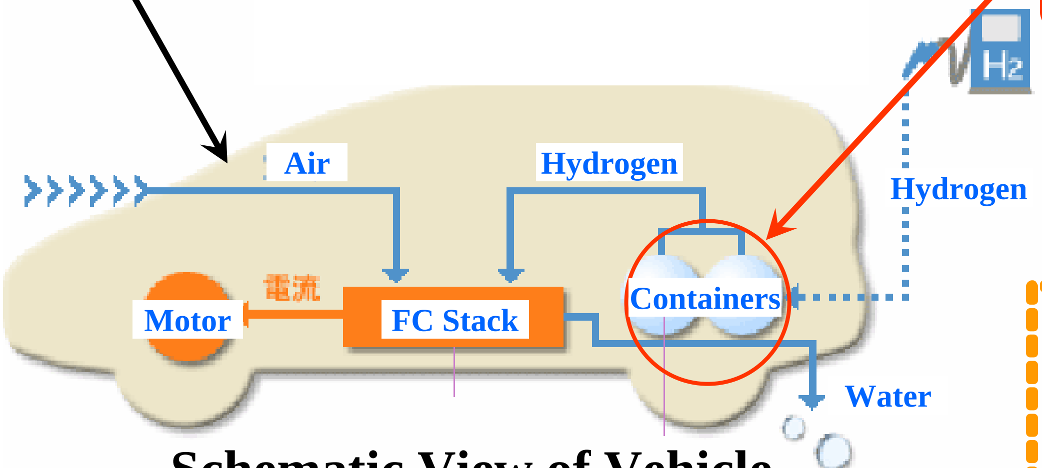
1. Summary of Japanese current standard for hydrogen containers
   (Standard name : JARI S 001)

2. Future revision plan of technical standard for hydrogen containers in Japan

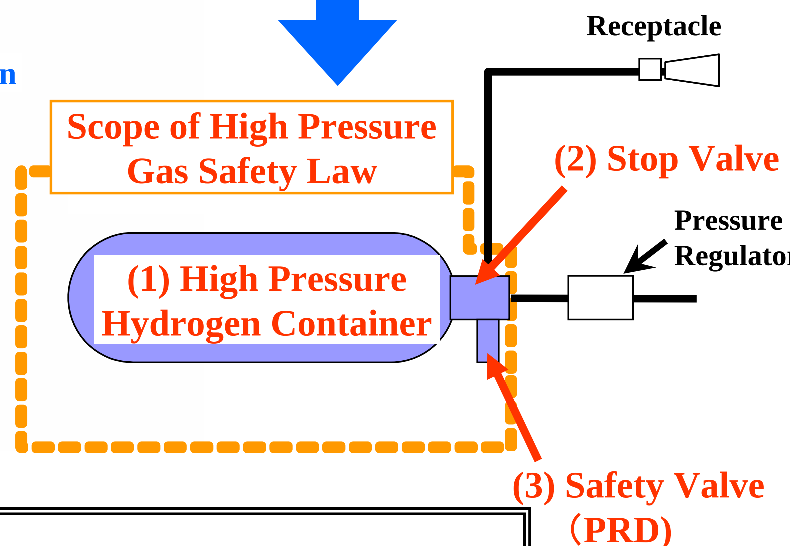
Scope of Regulations in Japan

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)**

Technical standard

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 (2^{nd} DIS) for Hydrogen Containers. Both of them have been derived from CNG standards.**

Premises of Discussion

< 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

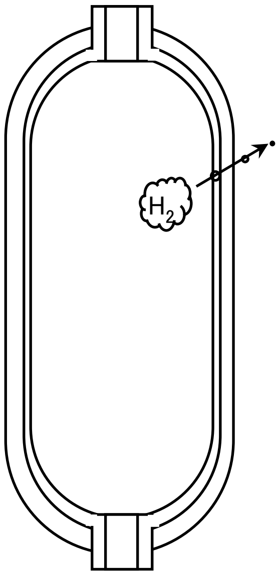
Regulation of High Pressure Hydrogen Containers

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

Example of Discussion Points (2)

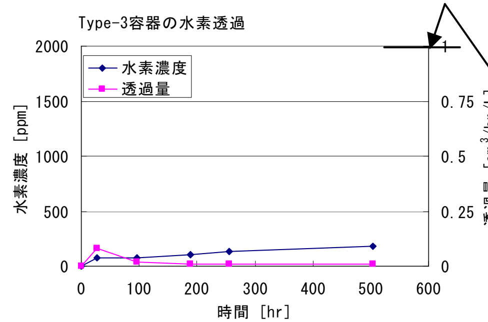
Gas Permeation Test of Hydrogen

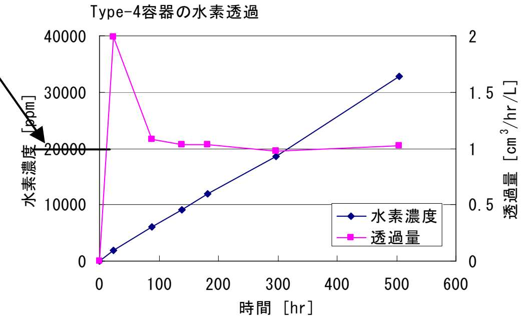
VH3-Container(40L) **VH4-Container(65L)**

Test sample

Test Chamber

Permeation : 1[cm^3/hr/L]





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

Permeation of Hydrogen

VH3-Container : Very low permeation

VH4-Container : Permeation after 500hr : 1.02[cm^3/hr/L]

International standards

- **ISO/CD15869 : Criteria : 1.0 [cm^3/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])

NGV2 → Betten No.9
→ HGV2

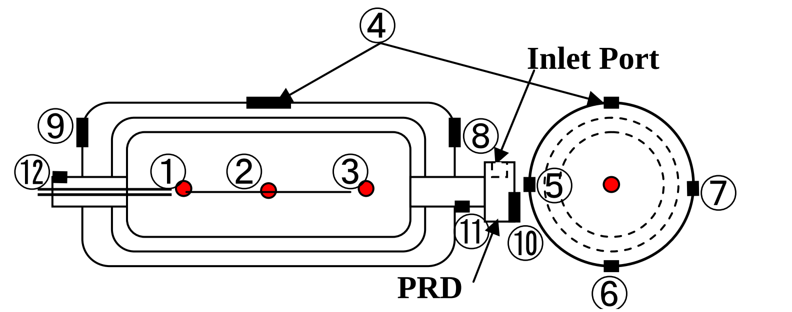
The allowable limit is 2.0[cm3/hr/L] for VH4-Container

Safety criteria in garage

Example of Discussion Points (3)

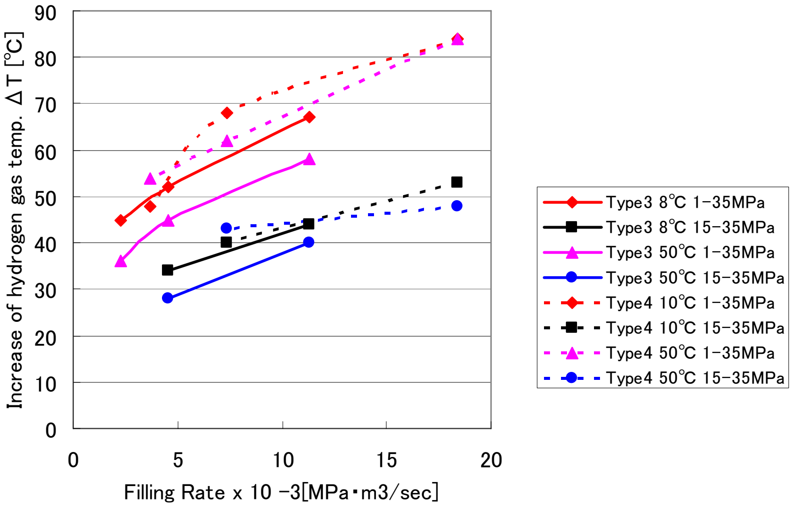
Fast Fill Test of Hydrogen

Check the temperature range during fast fill



Test view of VH3-Container

Test view of VH4-Container



Relation between gas temperature and filling rate

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

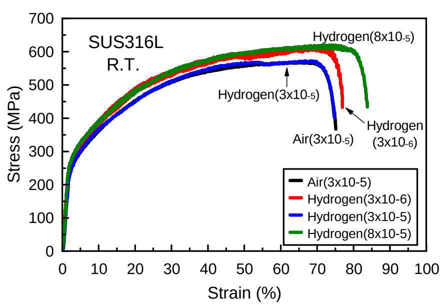
Example of Discussion Points (4)

Material

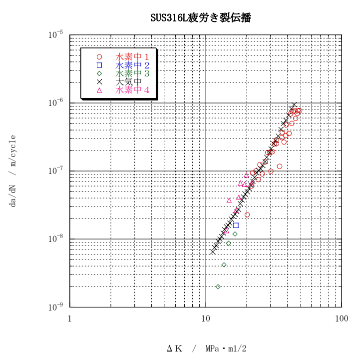
Influence of hydrogen atmosphere on ductility of material

Test items

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



Stress-strain curve of SUS316L

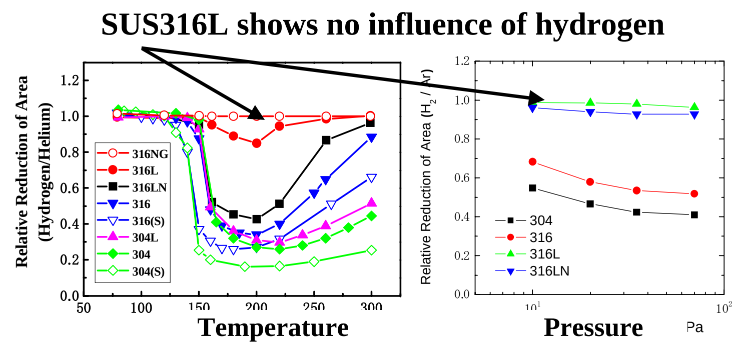


Fatigue crack propagation of SUS316L

Selection of materials

Preferential material for literature review by JARI

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



Influence of hydrogen on reduction of area

Preferential 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

Article	Contents
Article 1 (Scope)	VH3-Container and VH4-Container are permitted
	The tanks for compressed hydrogen vehicle within a scope not exceeding 15 years displayed by stamping
Article 2 (Definitions of Terms)	Stress ratio : 2.25
Article 3 (Materials)	SUS316L, A6061T6
Article 4 (Thickness)	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
Article 6 (Methods of Machining and Heat Treatment)	The compression stress of the liner at atmospheric pressure is less than the yield strength of the liner after autofrettage
Article 7 (Container Inspection)	Maximum filling pressure shall be 35 MPa or less
	Internal cubic capacity shall be 360L or less
Article 8 (Design Inspection in Design Confirmation Test)	The results of measurements of the yield strength of materials at or near the boss shall be checked
Article 11 (Room Temperature Pressure Cycle Test in Design Confirmation Test)	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
Article 13 (Bonfire Test in Design Confirmation Test)	The gas filled into the container shall be hydrogen gas
Article 14 (Drop Test in Design Confirmation Test)	In the vertical drop test the lowest portion of the container is at least 35 mm from the floor
Article 15 (Gas Permeation Test in Design Confirmation Test)	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
Article 17 (Hydrogen Gas Cycle Test in Design Confirmation Test)	A pressure in excess of the maximum filling pressure shall be added at least 1,000 times
Article 19 (Permissible Defect Confirmation Test in Design Confirmation Test)	The speed of fatigue crack propagation data of SUS316L and A6061-T6 shall be used

March 2005 : Enforcement of the technical standard

Contents

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.

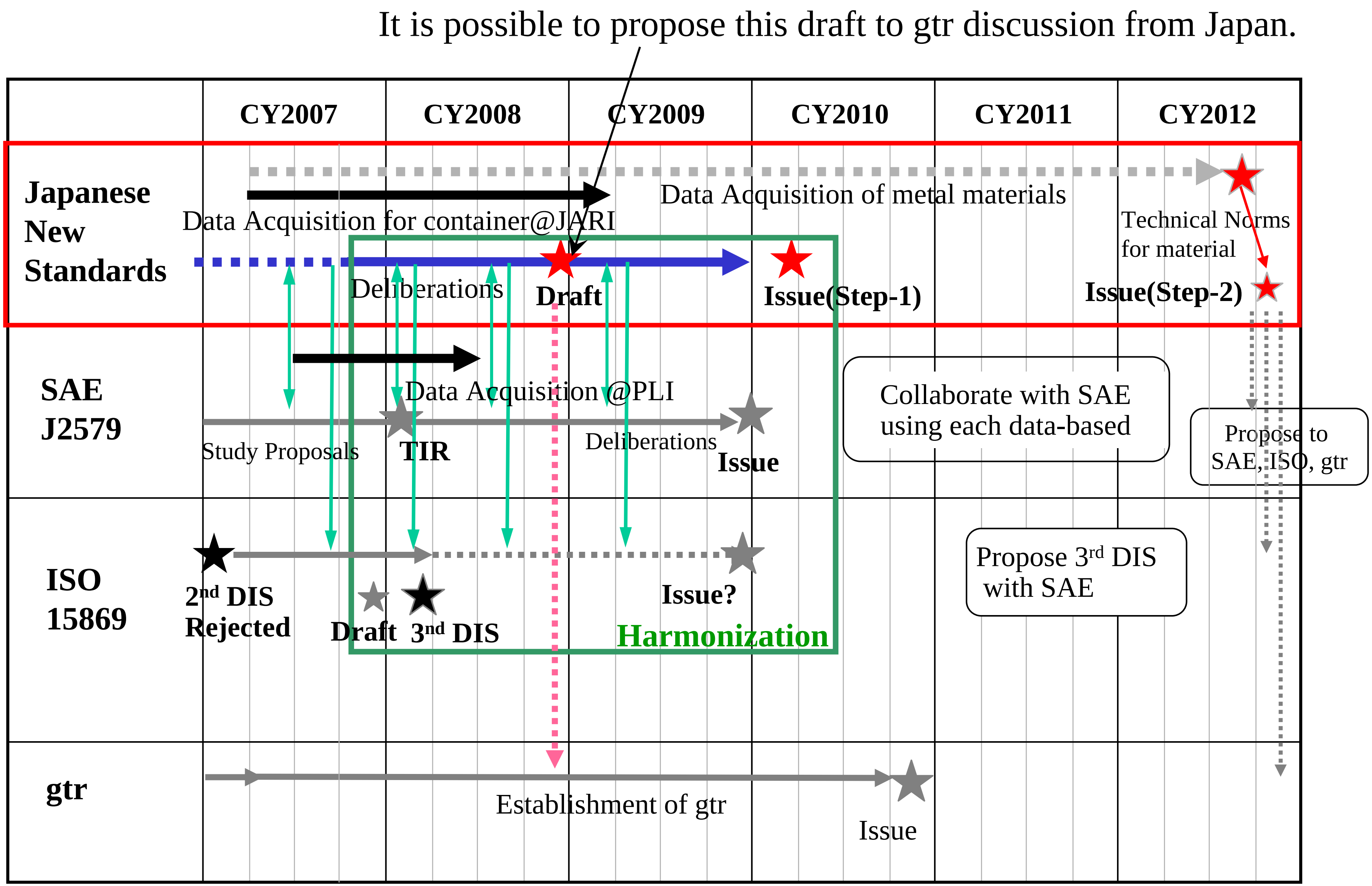
(Only SUS316L and A6061-T6 are designated in the current standards)

<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



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).

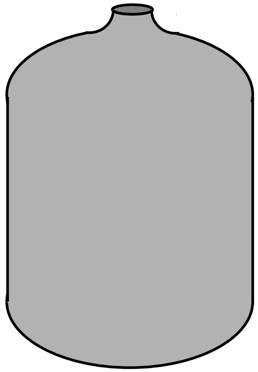
3) To guarantee the Container strength after Durability tests reflected Vehicle usage and Lifetime.

a) To change the cycle numbers and condition of burst pressure test.

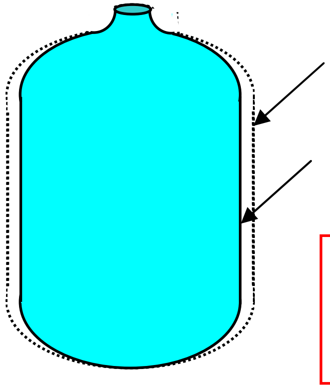
b) To execute the sequential loading tests.

Outline of New Standard for Containers

Current (JARI S 001)



New Standard



Current standard applied

New standard applied
(Inner volume the same; CFRP reduced)

- **Safety guaranteed**
- **Lighter weight and Lower cost (reduction of CFRP used; lower grade)**

Current:

- **-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:

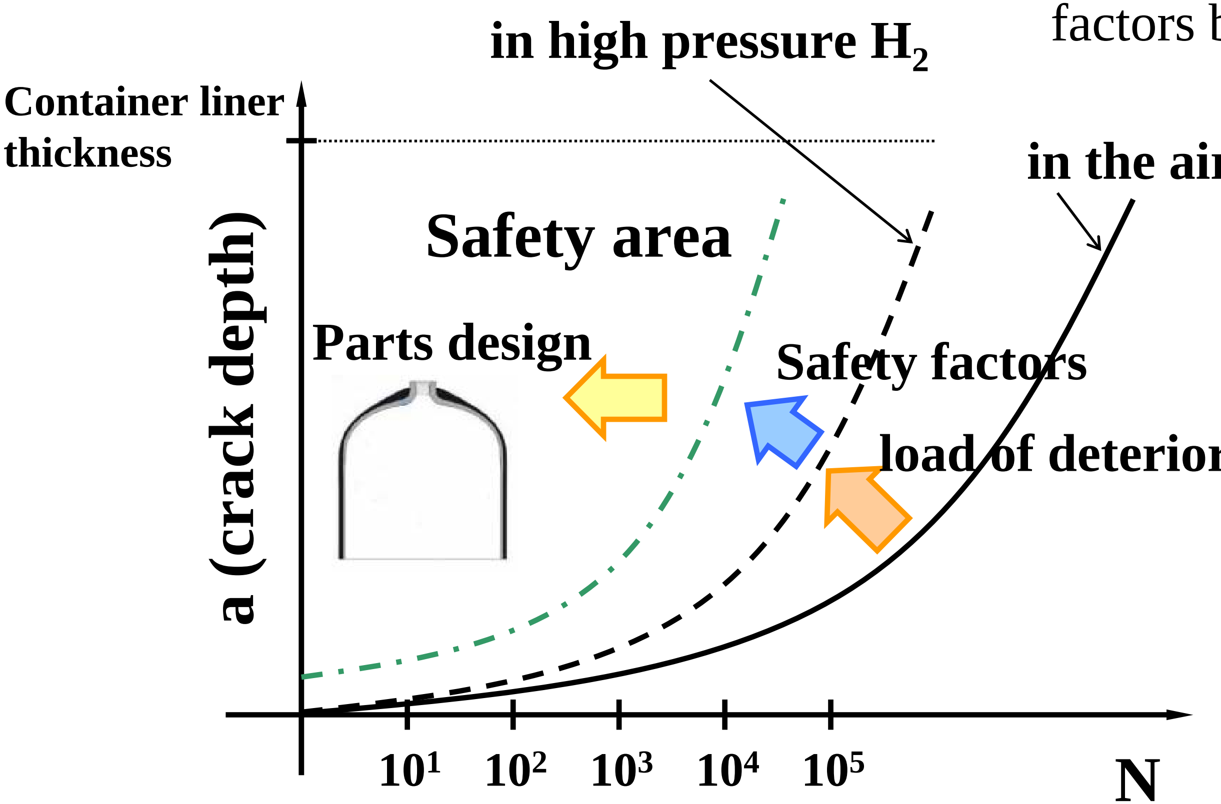
- **-Maximum Working Pressure 70 MPa**
- **-Durability strength guaranteed in consideration of Vehicles Usage and Lifetime.**
  = Sequential Loading Test (chemical exposure, low and high temperatures, fatigue, pressure, burst)
- **-Burst Pressure**
  Working Pressure reduced (After Durability Test)
- **-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

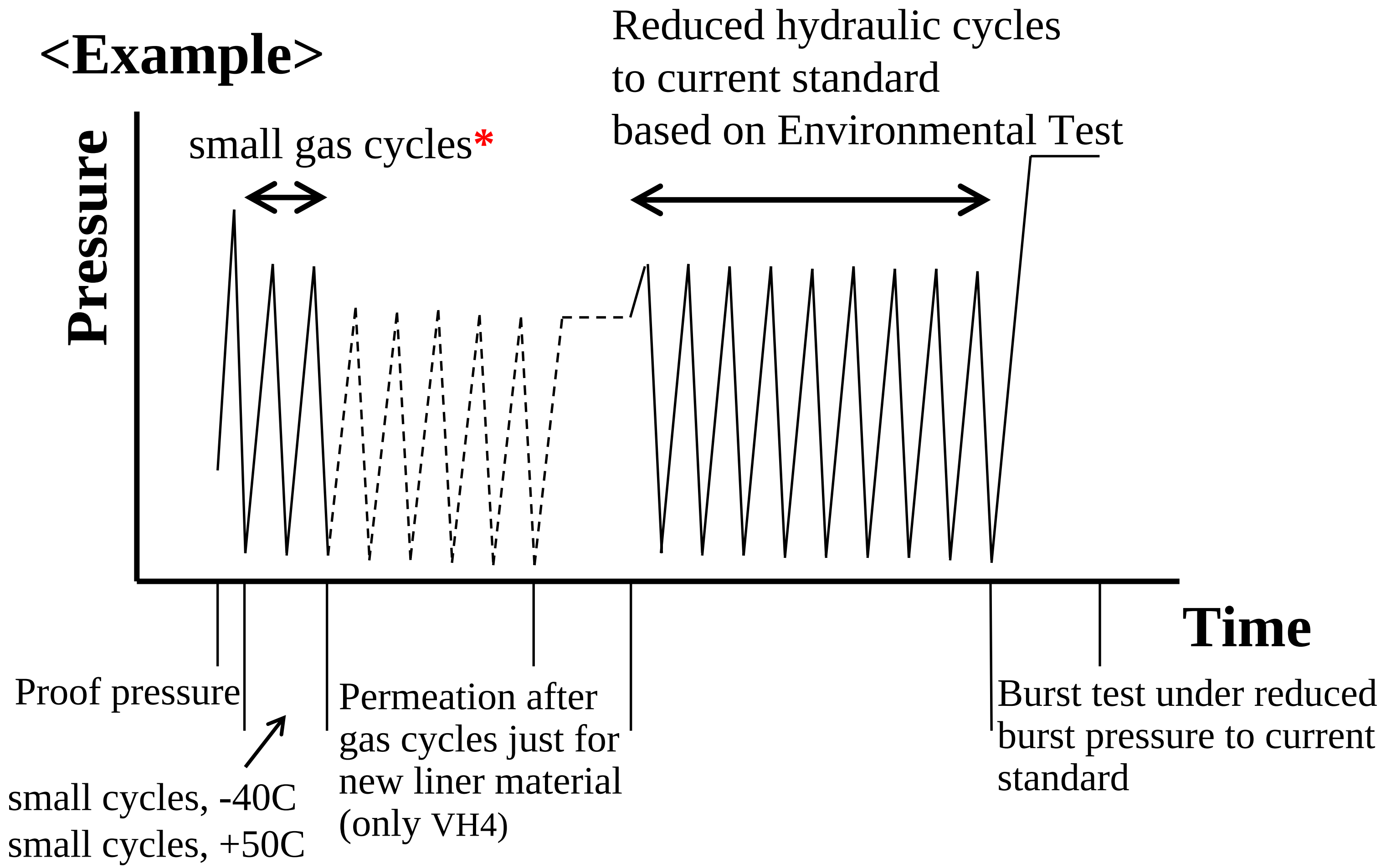


<Crack growth curve>

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.

<Example>



*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)	New Standard (Draft)
Expansion Measurement Test	**1) Proof pressure test**
	2) Extreme temperature pressure cycling test — Discharge at −40℃, small cycles; Refuel from +50℃, small cycles
Hydrogen Gas Cycling Test	**3) Hydrogen Gas Cycling Test (VH4)** — Continue cycling until static reaches saturation
Gas Permeation Test	**4) Gas Permeation Test (VH4)** — To verify permeation after saturation.
Environmental Test	**5) Environmental Test** — Reduced cycles; combination of Ambient Temp, Low Temp and High temp
	6) Burst test at end of life
Composite Flaw Tolerance Test	Composite Flaw Tolerance Test — Reduced cycles
Bonfire Test	Bonfire Test — Adjustment Flame Length according to Container Length
Ambient Cycling Test	Ambient Cycling Test — Reduced cycles
Drop Test	Drop Test — Reduced cycles
Maximum Defect Size Inspection Test	Maximum Defect Size Inspection Test (VH3) — Reduced cycles
Interlaminate Shear Test	X No need for C-FRP Container (VH3)
Hydrostatic Burst Test	X Change to Hydrostatic Burst Pressure Test — Decision of Burst Pressure criteria
Accelerated Stress Rupture Test	X No need for C-FRP Container (VH3)

Sequential Loading Test

1) -> 2) -> 3) ->4) -> 5) -> 6)

Comparison of Standards for Hydrogen Containers

<Summary of basic conditions>

Items	ISO DIS15869.3	SAE J2579 draft Jan.2008	JARI S 001	Revision plan to JARI S 001
Fuel types	Hydrogen and CNG blends more than 2% hydrogen	Hydrogen	Hydrogen	Hydrogen
Scope	Container, (Include the system as Alternative type tests)	Storage system (Container,PRD, Shut off valve, etc)	Container (PRD,Shut off valve are in JARI S 002)	the same as JARI S 001
Container types	Type1,2,3,4	No limit	Type3,4	Type3,4
Working pressure	No limit, 15degree C	No limit, 15degree C	Less than 35MPa, 35degree C	Less than 70MPa, 35degree C
Service life	15 years	No limit	15 years	15 years
Test method	each test for a brand -new cylinder (Add the sequential test as Alternative type tests)	add the sequential test for worst-case conditions	each test for a brand-new cylinder	add the sequential loading test for end of life

- reference information -

Comparison of Standards for Hydrogen Containers

<Summary of main tests>

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

Thank you for your attention