Material Test Systems in High Pressure Hydrogen Gas at AIST Tsukuba

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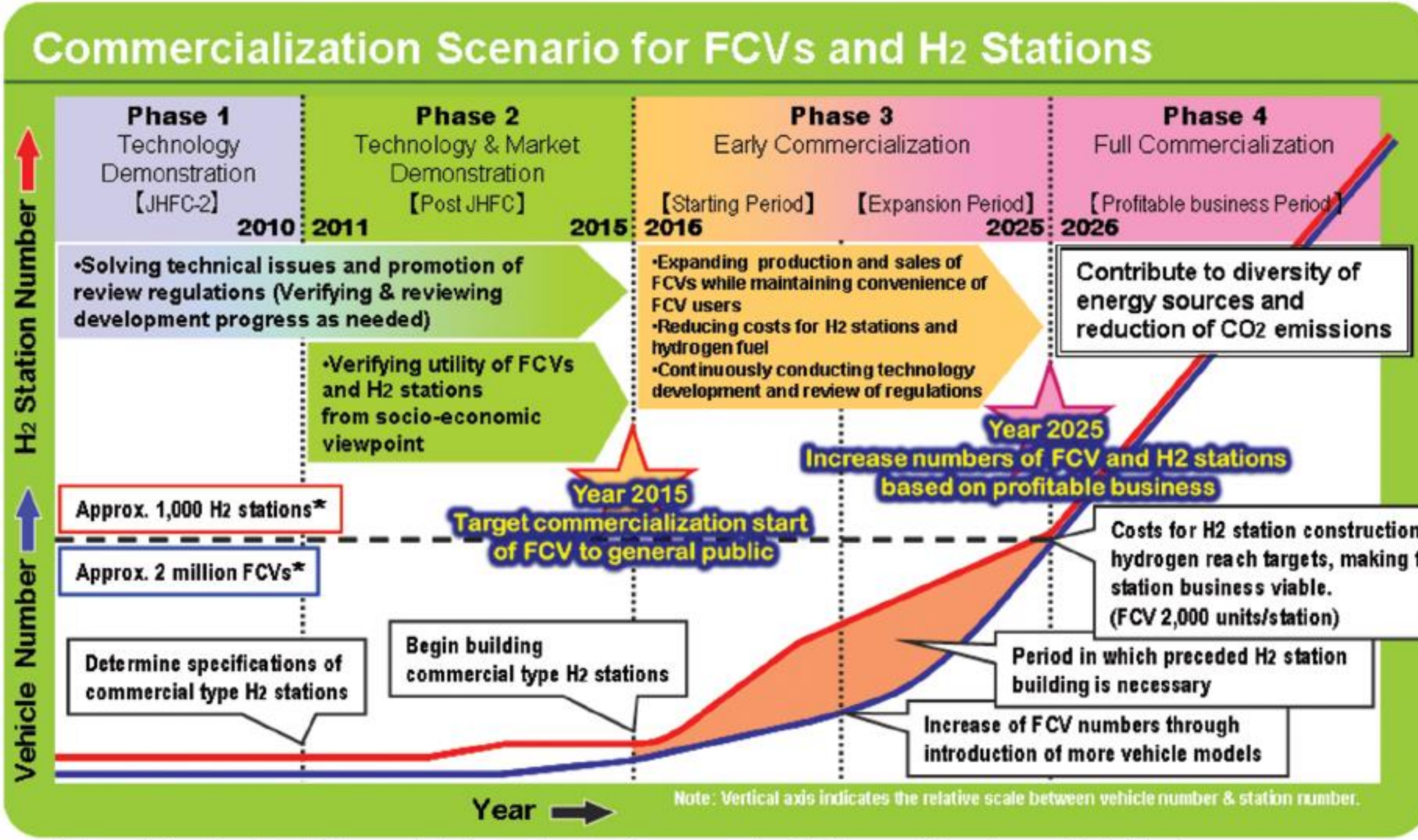
July 2010

FUEL CELL COMMERCIALIZATION CONFERENCE OF JAPAN



* Precondition: Benefit for FCV users (price/convenience etc.) are secured, and FCVs are widely and smoothly deployed

2015 · Commercialize FCV

· Build 100 hydrogen filling station

http://fccj.jp/eng/index.html

AIST

Research Center for Hydrogen Industrial Use and Storage

HYDROGENIUS (Research Center for Hydrogen Industrial Use and Storage)

Collaborative Research Center between Kyusu University and AIST (National Institute of Advanced Industrial Science and Technology

research collaboration agreements (1 May 2006)

KYUSHU UNIVERSITY

Fukuoka

Tsukuba

HYDROGENIUS (1 July. 2006)

Fundamental Research Project on Advanced Hydrogen Science

NEDO → *Funding* → HYDROGENIUS Hydrogen saves the Earth

New Energy and Industrial Technology Development Organization

Yukitaka Murakami Dr.Eng., Ph.D.

Director, HYDROGENIUS AIST
Vice President, I^2CNER, Kyushu University

Relation between AIST and Kyushu University

1st stage: 2006-2013

Research Center for Hydrogen Industrial Use and Storage (HYDROGENIUS)

Kyushu Univ. Ito campus

- Hydrogen Thermo Physical Team
- Hydrogen Fatigue and Fracture Team
- Hydrogen Polymers Team
- Hydrogen Tribology Team

AIST Tsukuba

- Hydrogen Dynamics in Metals Research Team

2nd stage: 2013-

Kyushu Univ.

HYDROGENIUS

AIST

Energy Technology Research Institute

- Hydrogen Industrial Use and Storage Group

Research Institute of Science for Safety and Sustainability

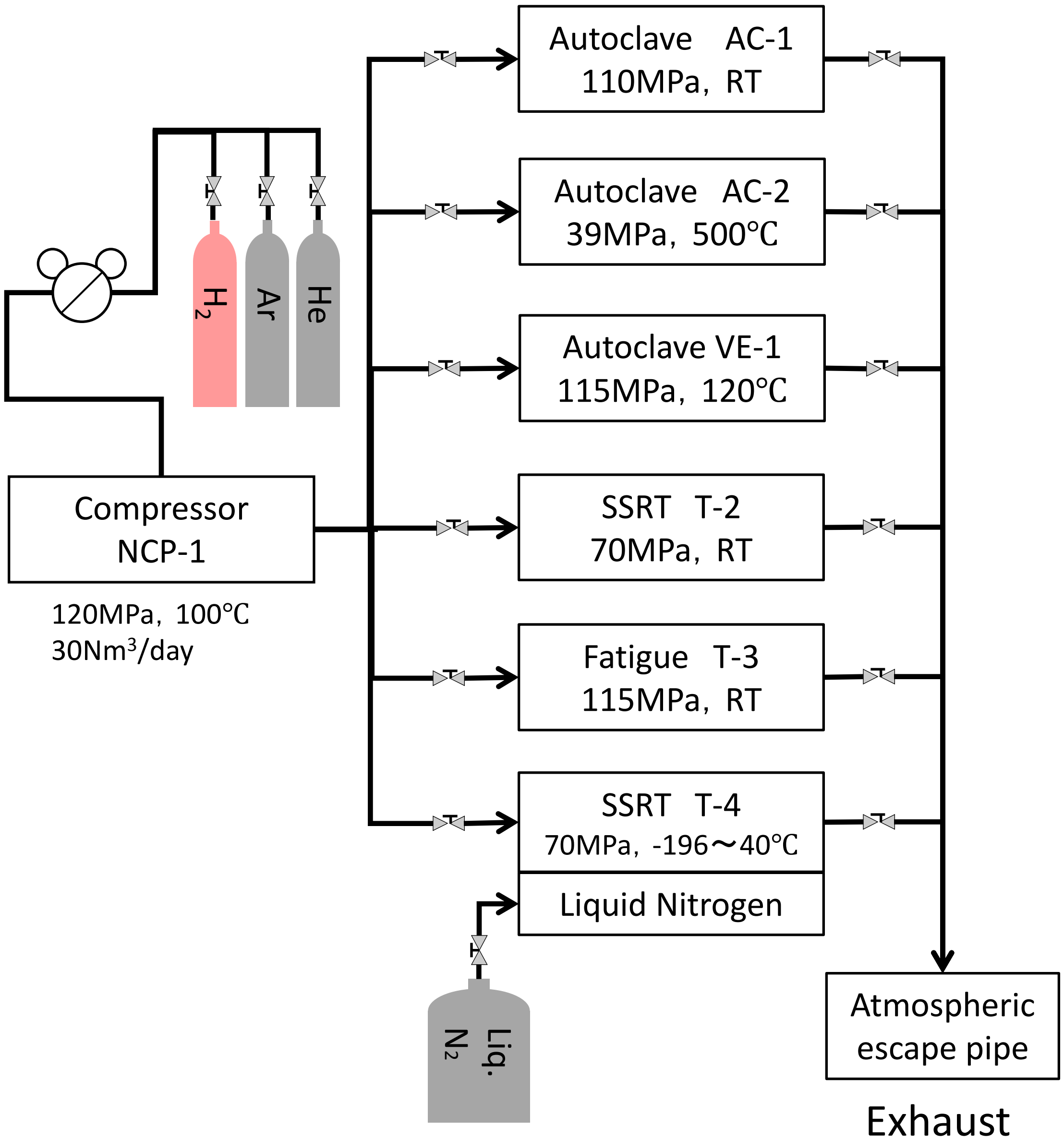
- Industrial Safety and Physical Risk Analysis Group

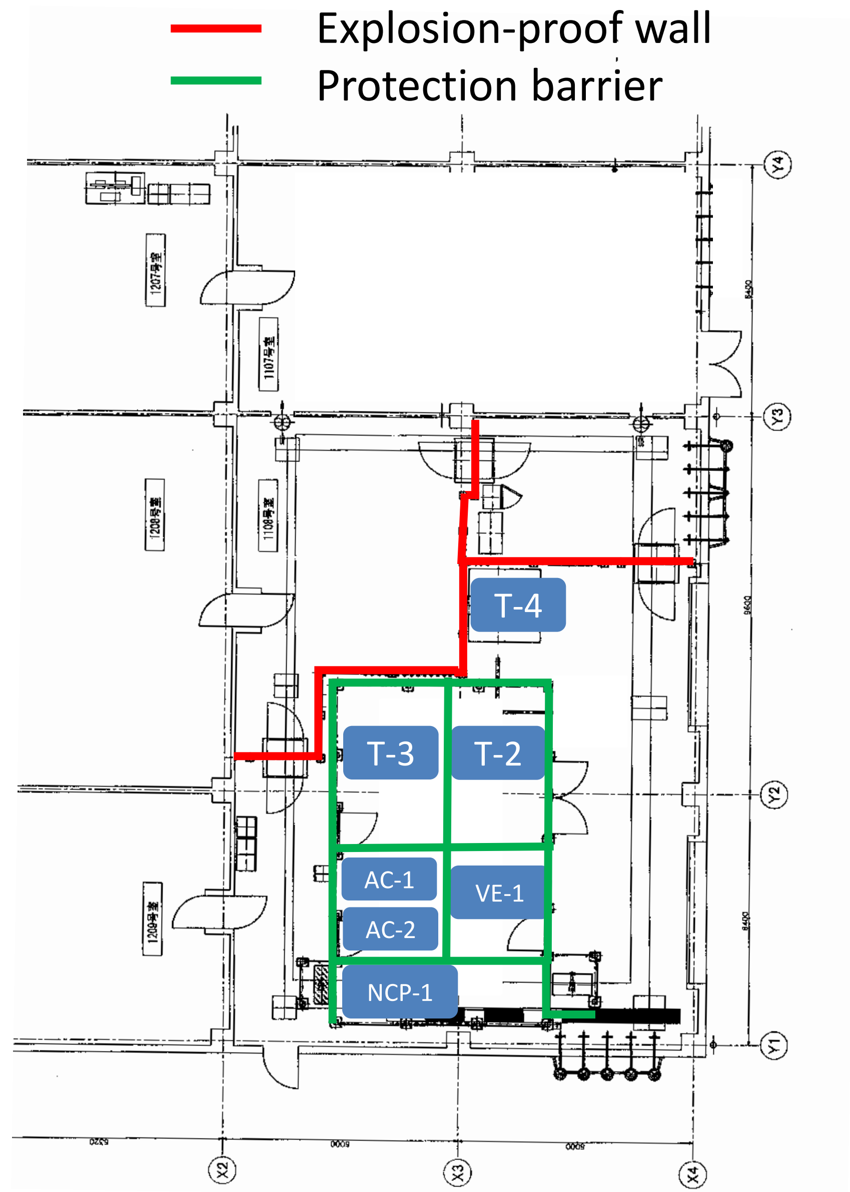
Collaborative Research Team for Hydrogen Industrial Use and Storage

AIST Hydrogen facility in Tsukuba

1. **Material Test system**
   - ➢ Fatigue test : RT, 115MPa
   - ➢ SSRT
     - RT, 70MPa
     - -190^{o}C - RT, 70MPa
2. **Autoclave:** Static exposure system
   - 500^{o}C, 40MPa
   - 120^{o}C, 115MPa
   - RT, 110MPa

AIST Hydrogen facility in Tsukuba





AIST Hydrogen facility in Tsukuba

Materials test system at room temperature

SSRT

70MPa

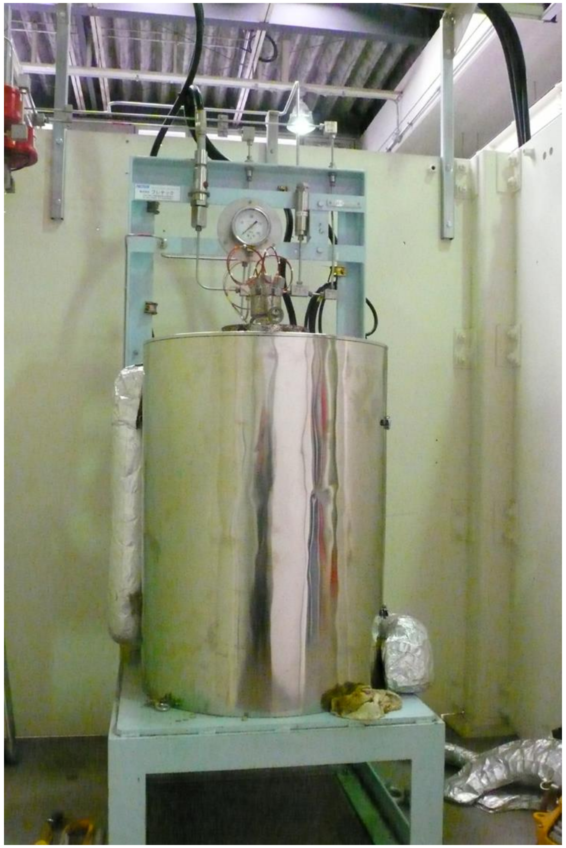
Fatigue test

115MPa

AIST Hydrogen facility in Tsukuba

Static exposure system (Hydrogen charge test)

500℃ 40MPa



100℃ 115MPa

AIST Hydrogen facility in Tsukuba

120MPa compressor

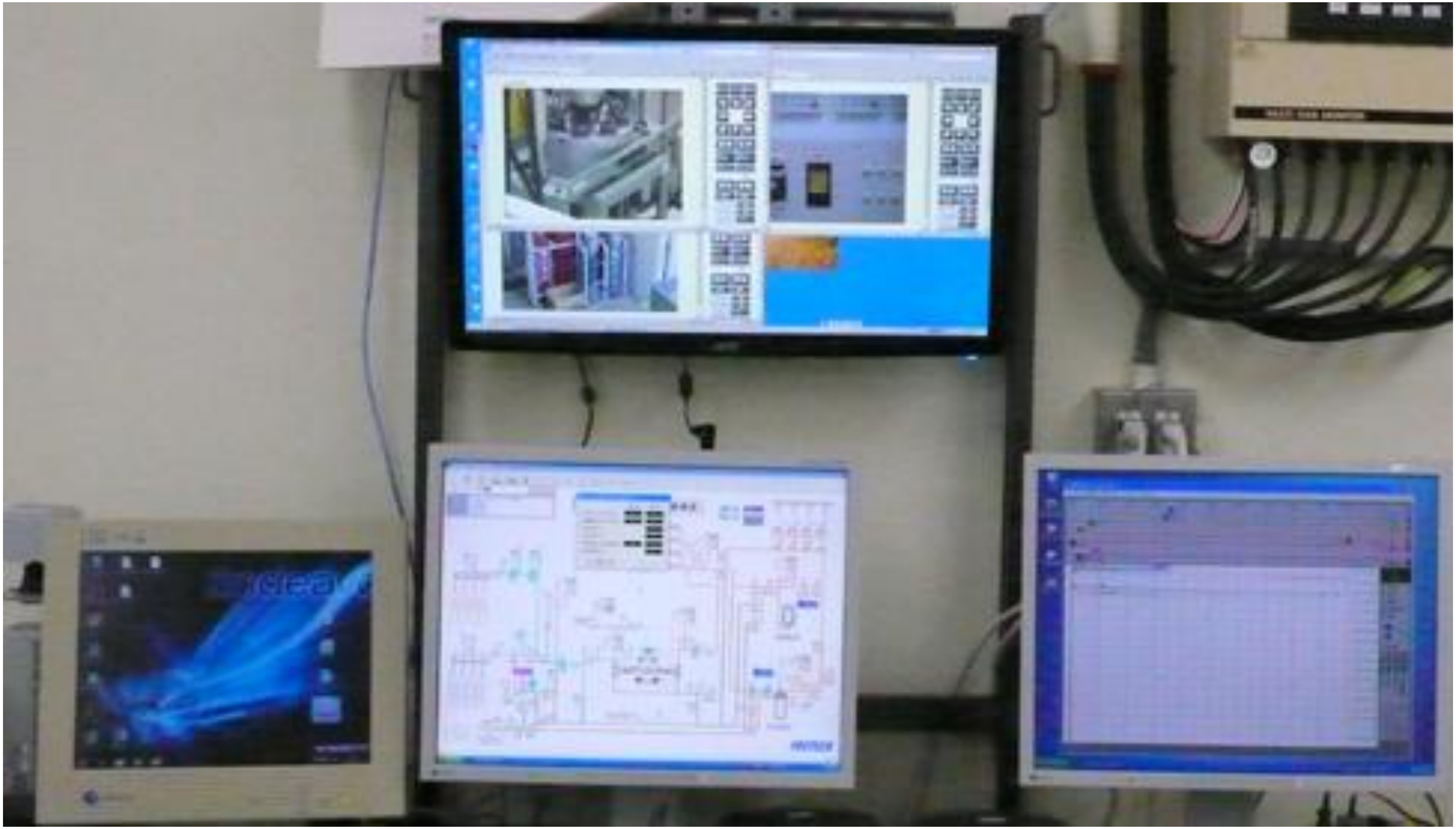
Protection barrier

AIST Hydrogen facility in Tsukuba

- Control facilities
- Explosion-proof wall

- PC control gas operating system
- PC control material test system
- Monitoring camera system

AIST Hydrogen facility in Tsukuba

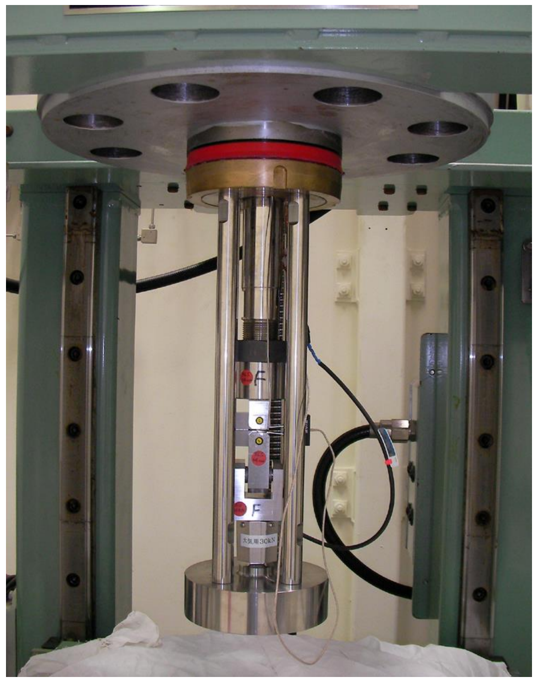


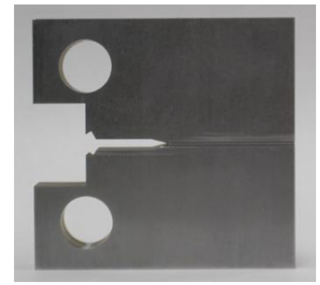
AIST Hydrogen facility in Tsukuba

Materials test system at room temperature

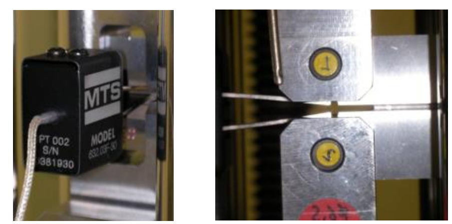
1.Rising-displacement fracture threshold test

Fracture test : 0.1～115MPa in H_2



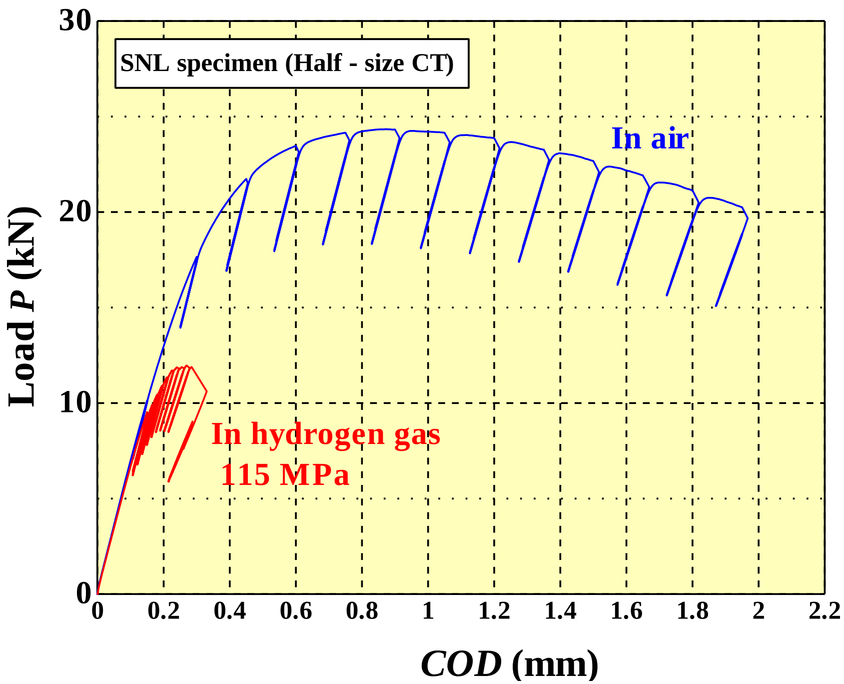


CT Specimens



Sample set up

Rising-displacement fracture threshold test



Unloading elastic compliance method

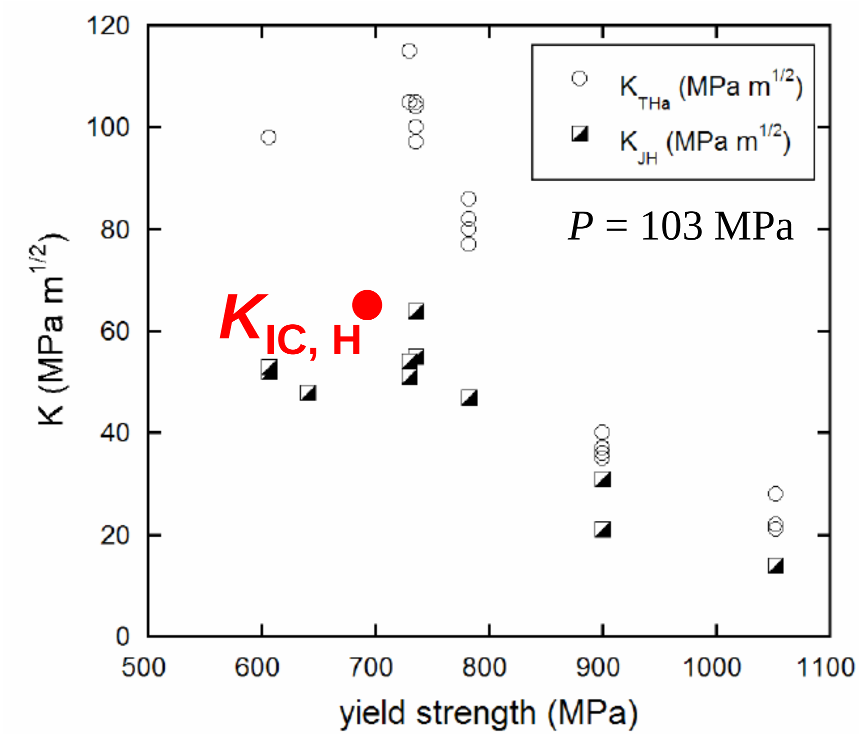


Fig. Crack arrest thresholds from constant displacement (K_{THa}) and crack initiation thresholds from rising displacement tests (K_{JH}) plotted as a function of yield strength in 103 MPa hydrogen gas*1

*1 Kevin A. Nibur et al. SANDIA REPORT(2010)

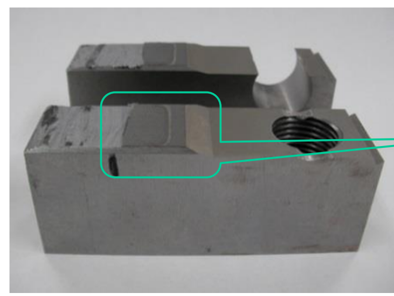
● SCM435: σ_{ys}=700, K=62.9

Materials test system at room temperature

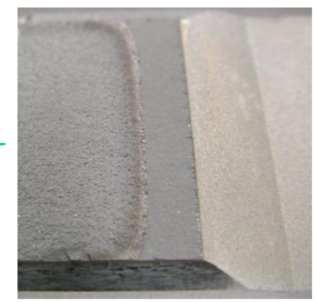
2. Crack-arrest threshold under static loading test

Fracture test : 0.1～115MPa in H_2

Sample



Fractured sample

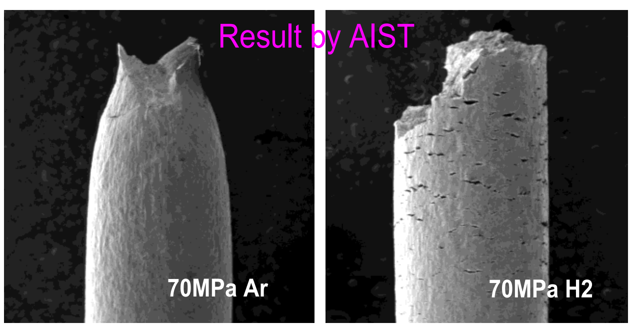


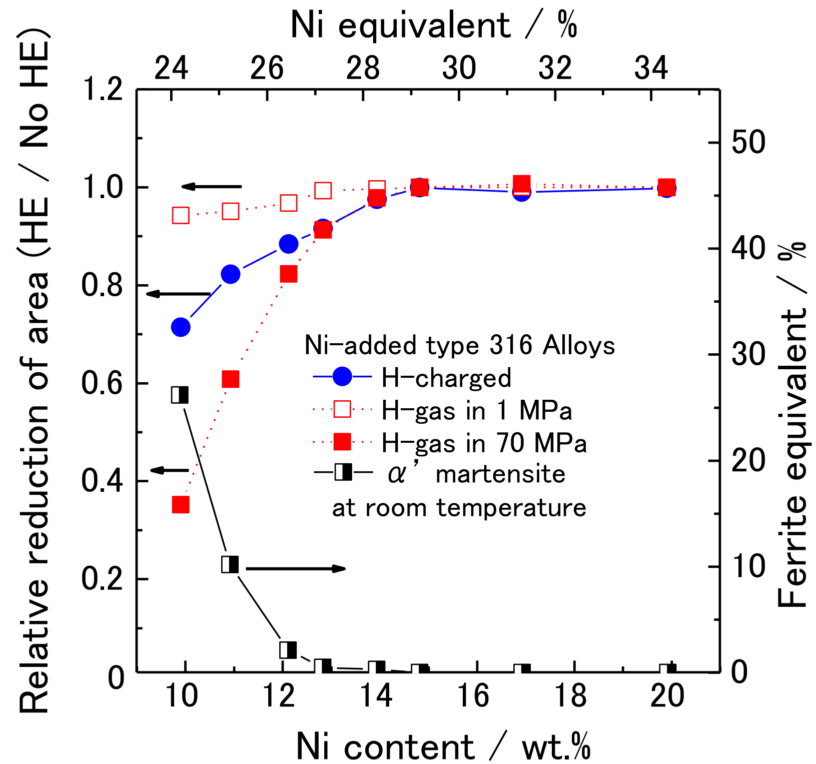
Fractured surface

AIST Hydrogen facility in Tsukuba

Materials test system at room temperature

3. SSRT test : 70MPa in H_2





Effect of Ni content on HE and IRHE of Ni-added type 316 stainless steel at room temperature.

AIST Hydrogen facility in Tsukuba

AIST Tsukuba facilities

1. **Material Test system**
   - ➢ Fatigue test : Rising-displacement fracture threshold test
   - ➢ SSRT
     - RT
     - Low temperature
2. **Autoclave**
   - ➢ Static exposure system (Hydrogen charge)
   - ➢ Crack-arrest threshold under static loading test

SNL – AIST collaborative project

"Collaborative work with SNL for technical evaluations and standards of hydrogen storage tank and vessel"

Objective

To promote FCV, develop the evaluation method of the materials for the hydrogen storage tank and vessel, and clarify the mechanism of hydrogen embrittlement.

Final goal

Contribute the revision of international standards like ASTM or ISO in collaboration with Japan and US.

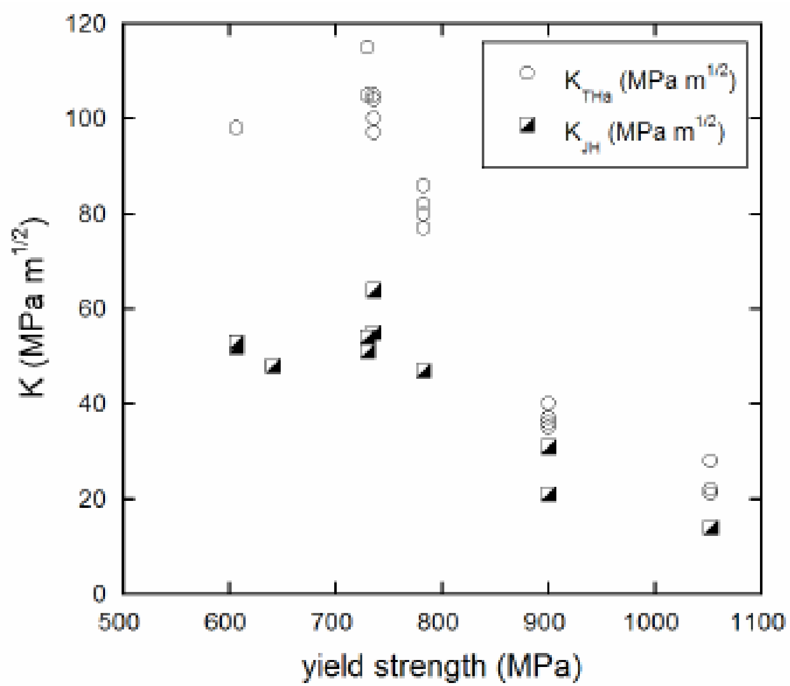
Background

The engineering analysis method for calculating the design life of steel hydrogen pressure vessels, ASME KD-10 (Boiler and Pressure Vessel Code) requires measurement of two fracture properties for the steel containment materials in hydrogen gas.

1. The crack-arrest threshold under static loading (K_{THa})
2. The fatigue crack growth relationship (da/dN vs. ΔK) under cyclic loading

Recent testing at Sandia to measure the fracture thresholds of ferritic steels in hydrogen gas demonstrated that the crack-arrest threshold under static loading (K_{THa}) was higher than the crack-initiation threshold under rising-displacement loading (K_{THi}) for lower-strength ferritic steels.

SNL – AIST collaborative project



SANDIA REPORT
SAND2010-4633
Unlimited Release
Printed July 2010

Figure 19 Crack arrest thresholds from constant displacement tests (K_{THa}) and crack initiation thresholds from rising displacement tests (K_{JH}) plotted as a function of yield strength.

The rising-displacement fracture threshold may be a more conservative value to use in the life prediction analysis.

However, the rising-displacement fracture threshold is not commonly measured, so more testing directed at developing proper methods is needed

SNL – AIST collaborative project

Outline of the project

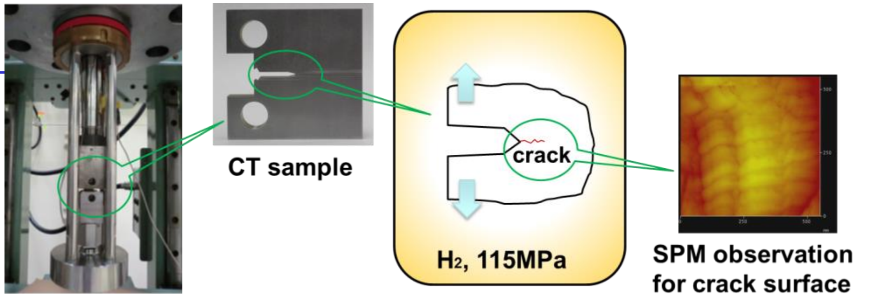
1.Measurement of Ferritic Steel Fracture Properties in Hydrogen Gas

Measure the rising-displacement fracture thresholds (K_{THi}) for the same steels under identical mechanical loading and environmental conditions at AIST and Sandia.

- Sandia supply machined CT specimens from the SA372 Grade J steel to AIST.
- AIST supply machined CT specimens from the SCM435 steel to Sandia.
- The testing results from AIST and Sandia will be directly compared.

2. Identifying the Mechanisms for Hydrogen-Assisted Fracture in Stainless Steels

Carry out an experiment to clarify the nanoscale structures of the hydrogen-assisted fracture surfaces and crack profiles for the typical materials by using SPM techniques.



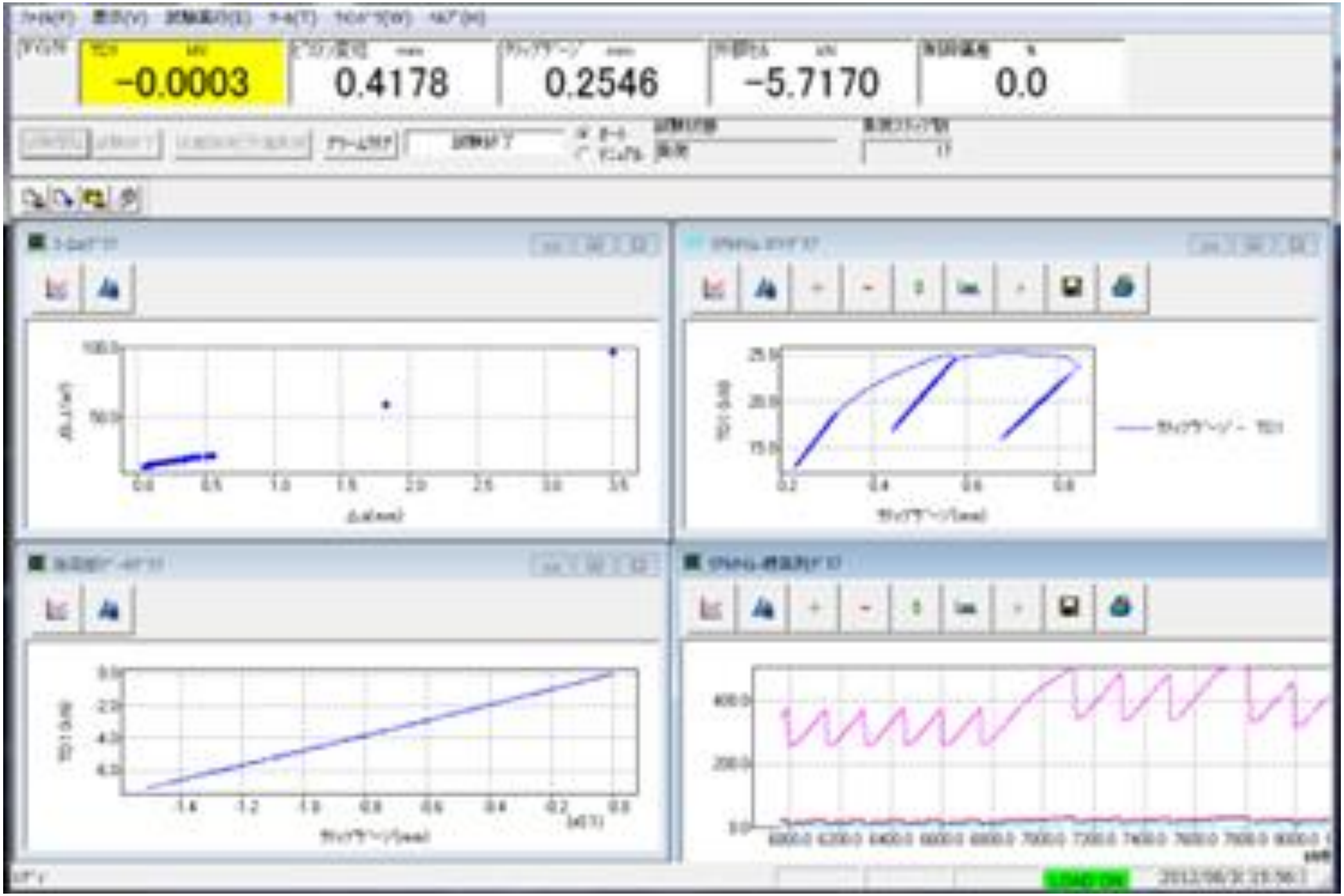

-0.0003
0.4178
0.2546
-5.7170
0.0

Table 1. Proposed test matrix for measuring rising-displacement fracture thresholds of Cr-Mo steels in high-pressure hydrogen gas.

Steel	H_2 pressure (MPa)	Load-line displacement rate (mm/s)
SCM435	10	$2x10^{-3}$ (2-3 hours)
SCM435	40	$2x10^{-3}$
SCM435	115	$2x10^{-3}$
SCM435	10	$2x10^{-4}$
SCM435	40	$2x10^{-4}$
SCM435	115	$2x10^{-4}$
SCM435	10	$2x10^{-5}$ (300 hours)
SCM435	40	$2x10^{-5}$
SCM435	115	$2x10^{-5}$
SA372 Grade J	10	$2x10^{-3}$
SA372 Grade J	40	$2x10^{-3}$
SA372 Grade J	115	$2x10^{-3}$
SA372 Grade J	10	$2x10^{-4}$
SA372 Grade J	40	$2x10^{-4}$
SA372 Grade J	115	$2x10^{-4}$
SA372 Grade J	10	$2x10^{-5}$
SA372 Grade J	40	$2x10^{-5}$
SA372 Grade J	115	$2x10^{-5}$