High-pressure Metal Hydride Tank for Fuel Cell Vehicles

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Issues on FCV towards Market Introduction

Major Issues

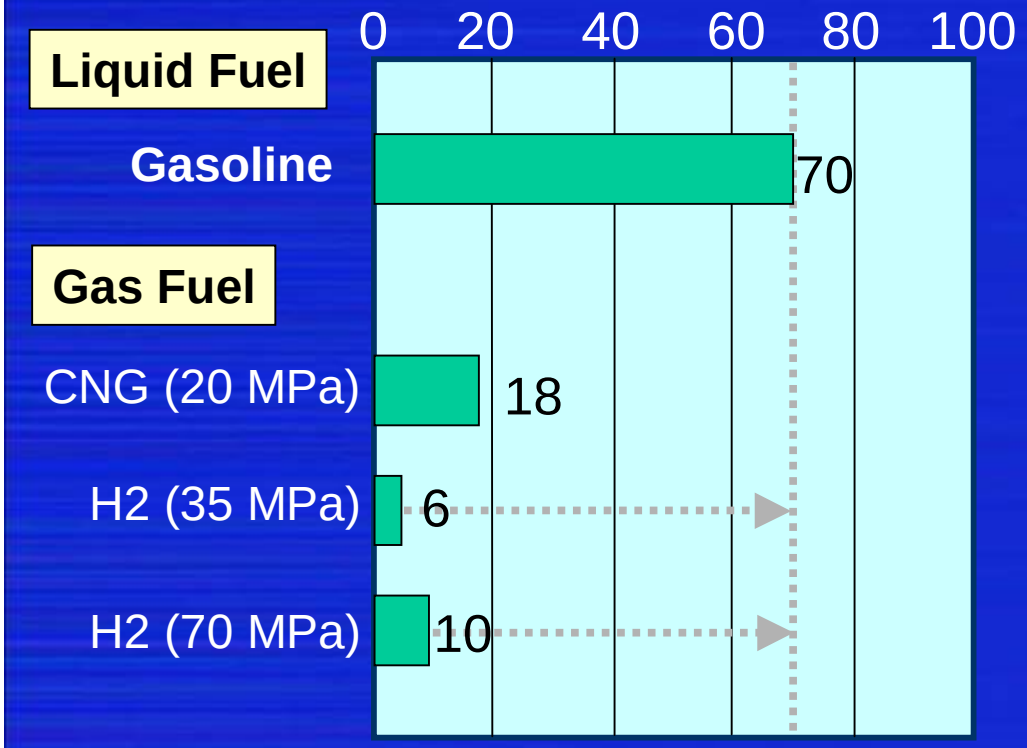
Items	Challenges	Responsibility
Technical	Low temperature, High temperature, High Efficiency･Size reduction, Reliability･Durability, Salt water, Dust, Volcanic gas (H_2S), High-altitude, electro-magnetic wave, etc.	Vehicle Manufacturers
Marketability	Driving range (Hydrogen storage), Cost (Vehicle cost)	
Environment	Recyclability, Life Cycle Assessment (LCA)	
Safety	Hydrogen, High voltage, Crash worthiness	
Infrastructure	Hydrogen production･transportation･storage, Infrastructure development, Hydrogen cost	Government, Energy Supplier

Cruising Range of High-pressure Storage

High-pressure storage is not sufficient to provide enough energy density

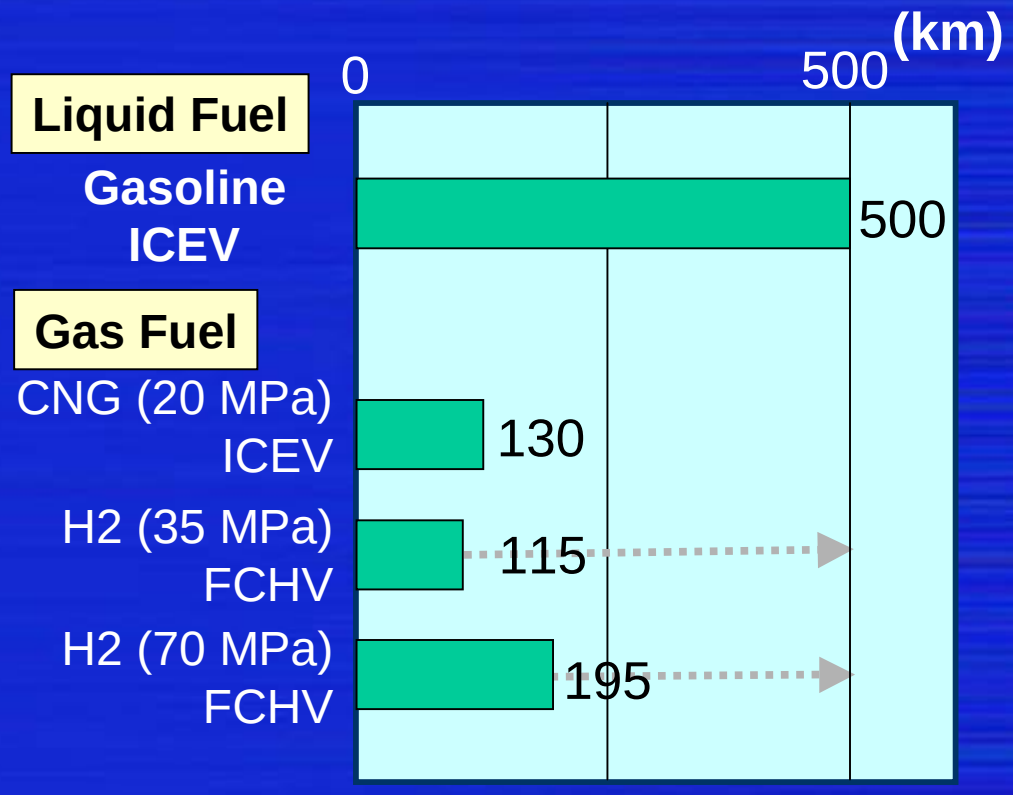
(1) Comparison of fuel amounts

(Tank capacity of 70L)



(2) Comparison of ranges

(Tank capacity of 70L)



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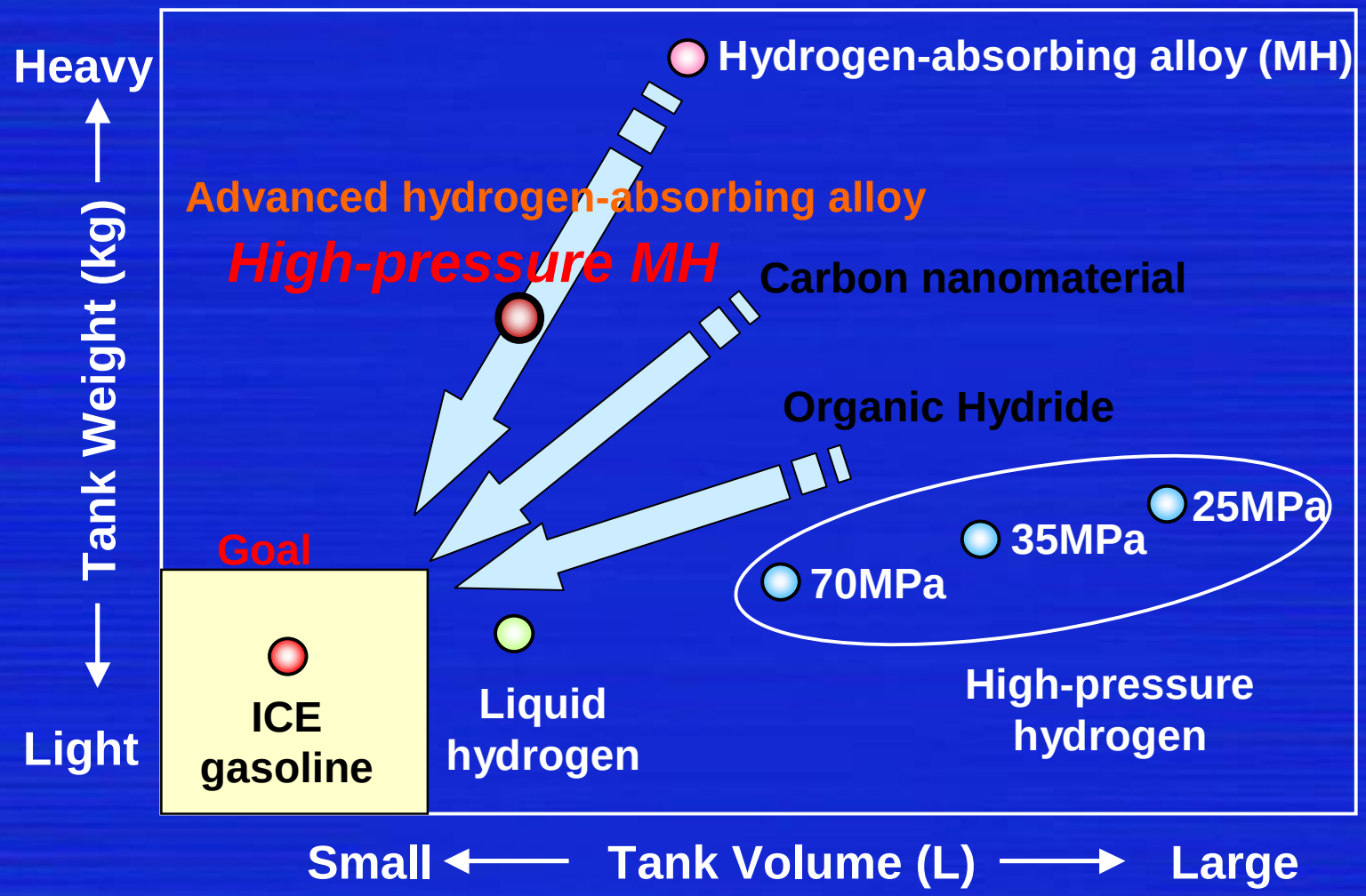
Hydrogen Storage Technology



Hydrogen Tank for FCHV

FCHV-3 (2001)

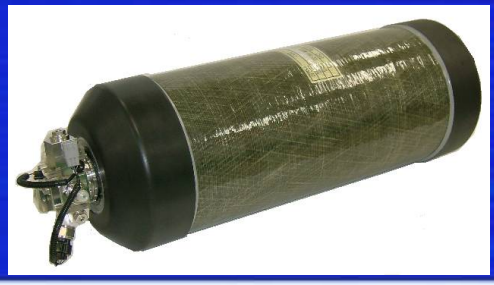
Metal Hydride Tank
(Low-pressure system with Ti-Cr-V alloy)

Toyota FCHV (2002)

35 MPa High-pressure Hydrogen Tank

70 MPa High-pressure Hydrogen Tank*
(Developed in Toyota)

35 MPa High-pressure Hydrogen Tank*
(Developed in Toyota)



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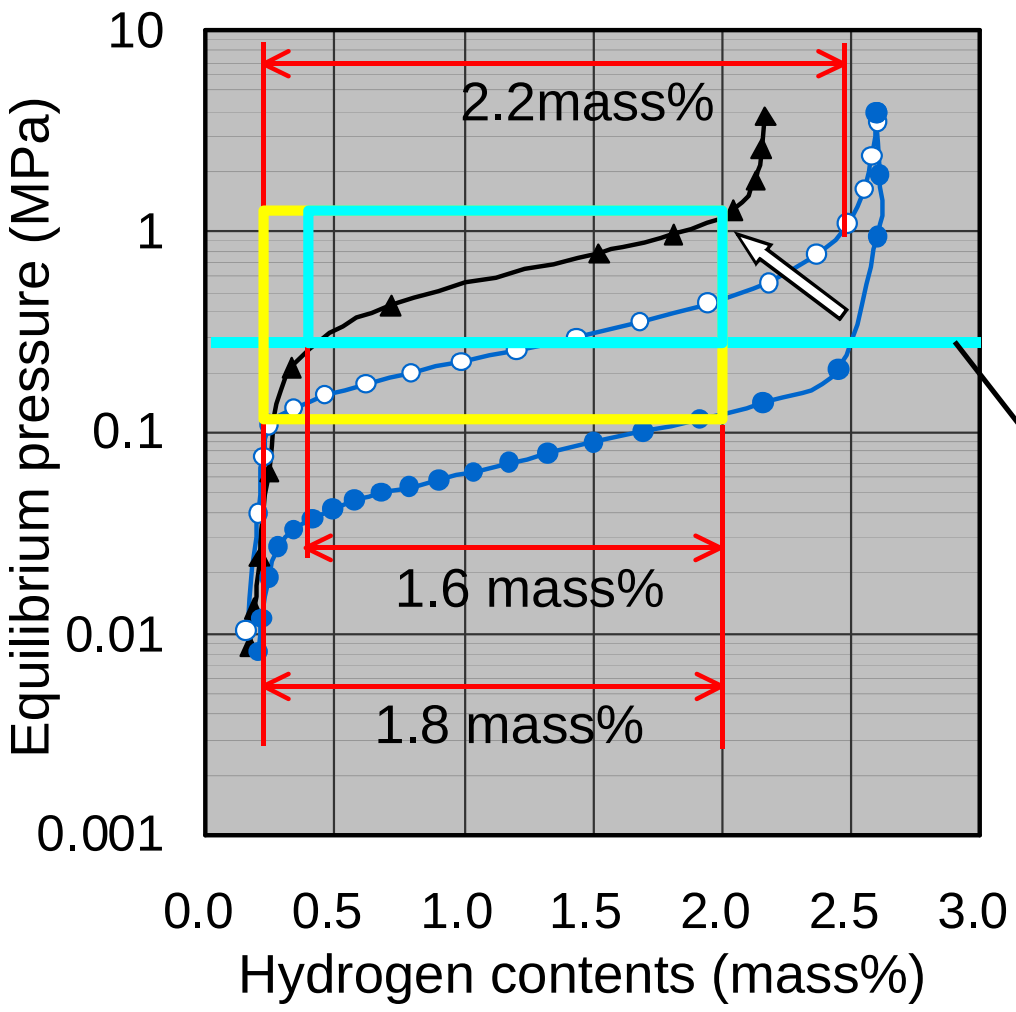
*Ref. M. Mizuno, et al., Toyota Motor Corp., Proceedings of the 2005 Spring Meeting of JSAE, EV・HEV・FCV Systems-Components/Evaluation

Issues of Low-pressure MH system



PCT diagram of Ti-Cr-V alloy

Available hydrogen storage capacity decreased by various restrictions.

- Restriction of temperature-pressure band
- Absorption→desorption hysteresis
- To keep system performance
- Low-temperature

Required pressure to supply H_2 for FC system

▲ desorption (308 K)
◯ absorption (268 K)
● desorption (268 K)

Performance of On-board Tank System

	Low-pressure MH tank Ti-Cr-V System	High-pressure tank
Hydrogen storage capacity	3.5 kg /tank 120 L	3 kg / tank 180 L
Tank weight	300 kg	< 100 kg
Hydrogen filling time	30 -60 min. With external cooling facility	5-10 min.
Hydrogen release at low temperature	Difficult under 308 K	Possible
Control ability	Difficult in acceleration	Good
Safety	Low pressure (<1 MPa)	High-pressure (35 MPa)

According to our experience…

External cooling during refueling
- Is not easy
- for example liquid connection

For on-board heating during release
- Only generated heat in FC stack is available

High-pressure MH Tank

- High pressure cylinder vessel with MH and built in heat exchanger

Metal hydride

Ti-Cr-Mn* (AB_2 laves phase)
Hydrogen amount: 1.9 mass%
$|\Delta H^0|$: 22kJ/molH_2
Desorbing pressure:
0.5MPa at 243K

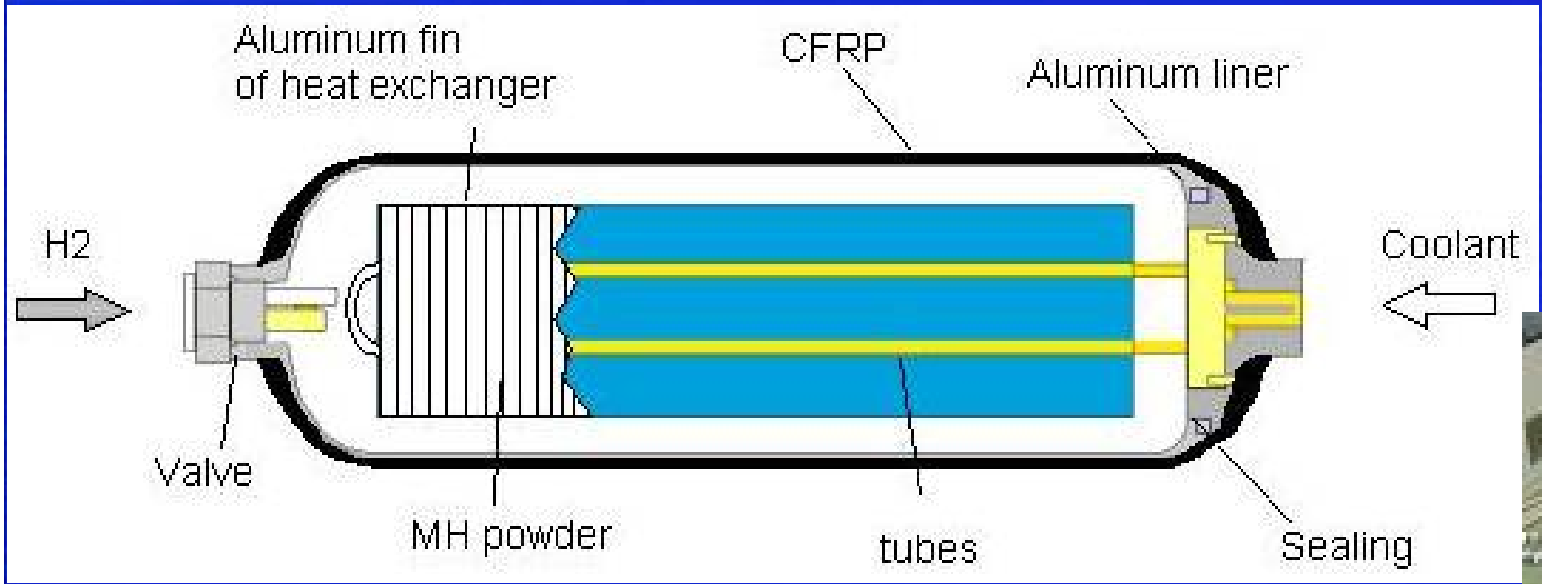


Fig. Schematic view of high-pressure MH tank

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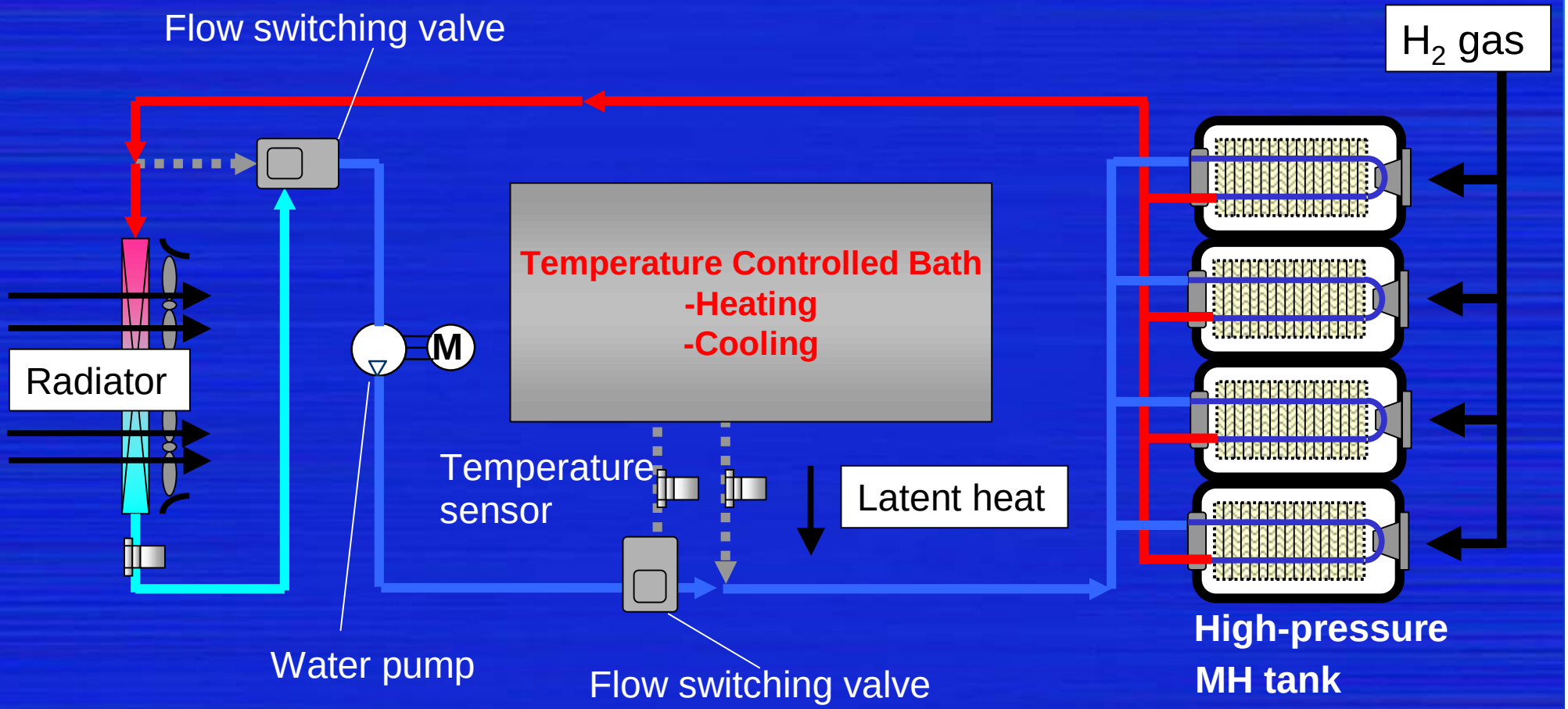
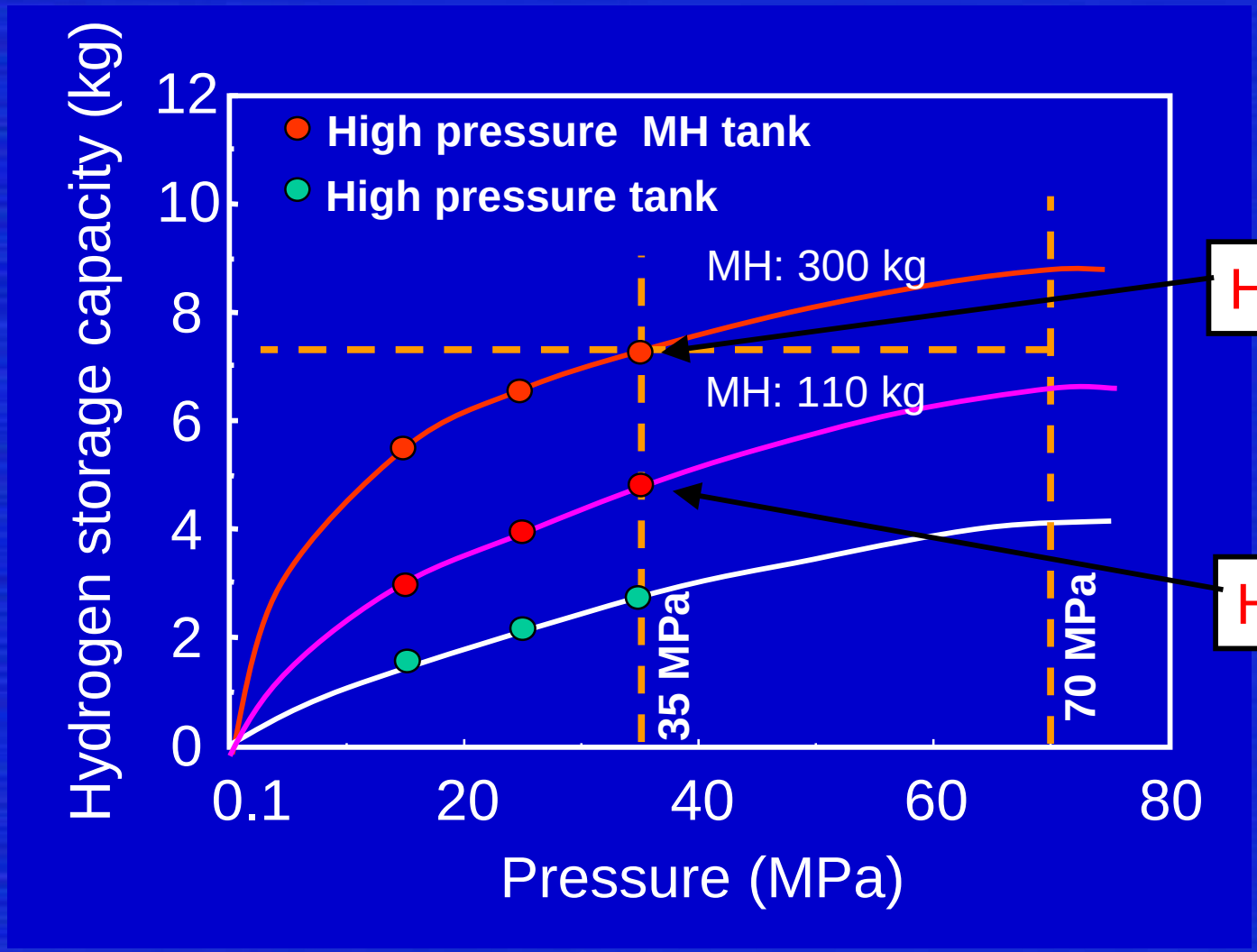
*Ref. Y. Kojima, Toyota Central R&D Labs., Inc., et al.
Collected Abstracts of the 2004 Autumn Meeting of the Japan Inst. Metals

Evaluation Method of Vehicle Scale Tank



- **Charge and discharge is mainly controlled by pressure**

Results: Hydrogen Storage Capacity

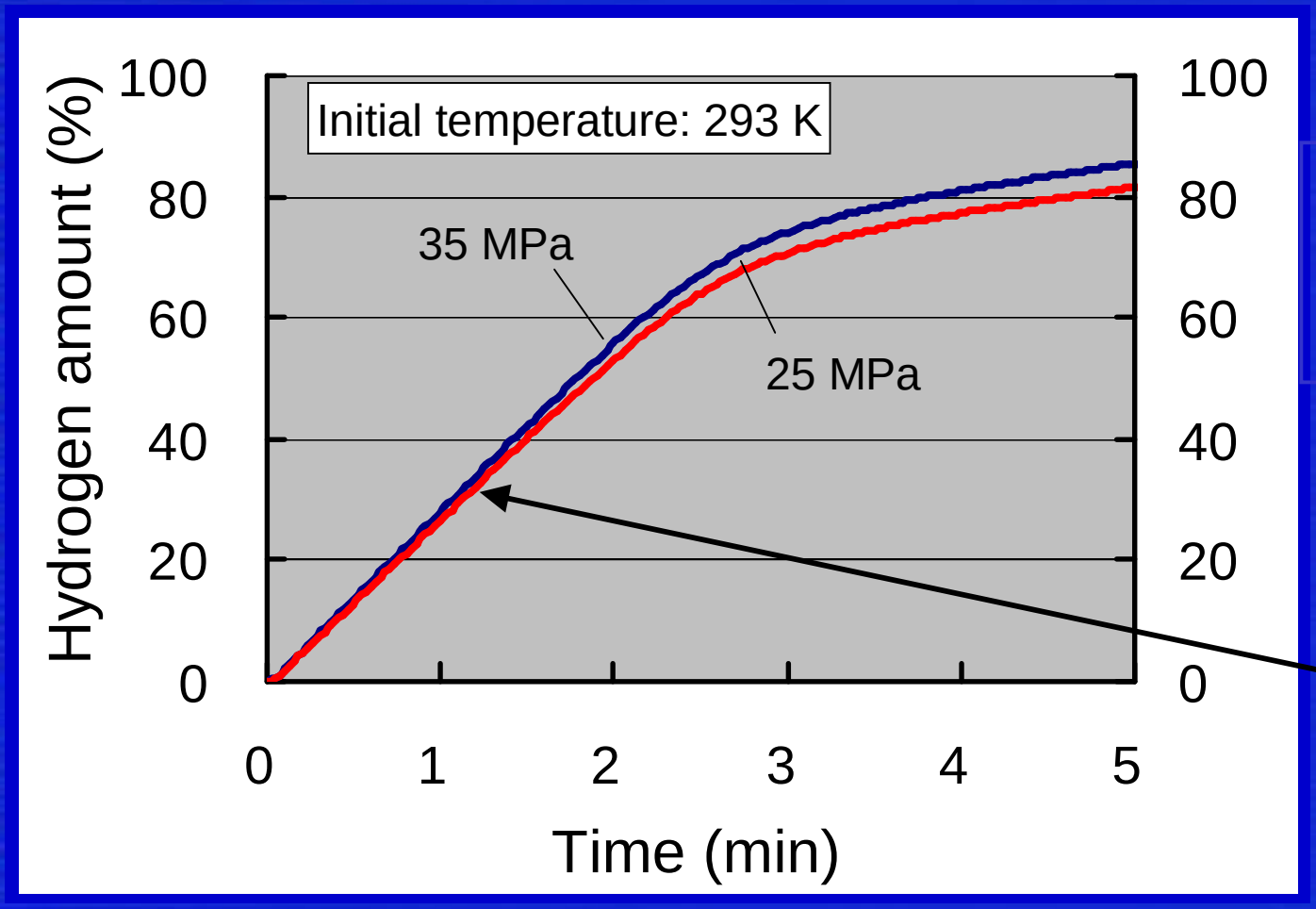


Temperature: 293 K
Tank volume: 180 L

H_2/MH =2.4 mass%

H_2/MH =4.5 mass%

High Speed Charge of Hydrogen



Tank number: 4
Volume: 180 L
Hydrogen: 5 kg
(at 35 MPa)

H_2 flow rate:
<11000 NL/min

Desorbing Ability at Low Temperature

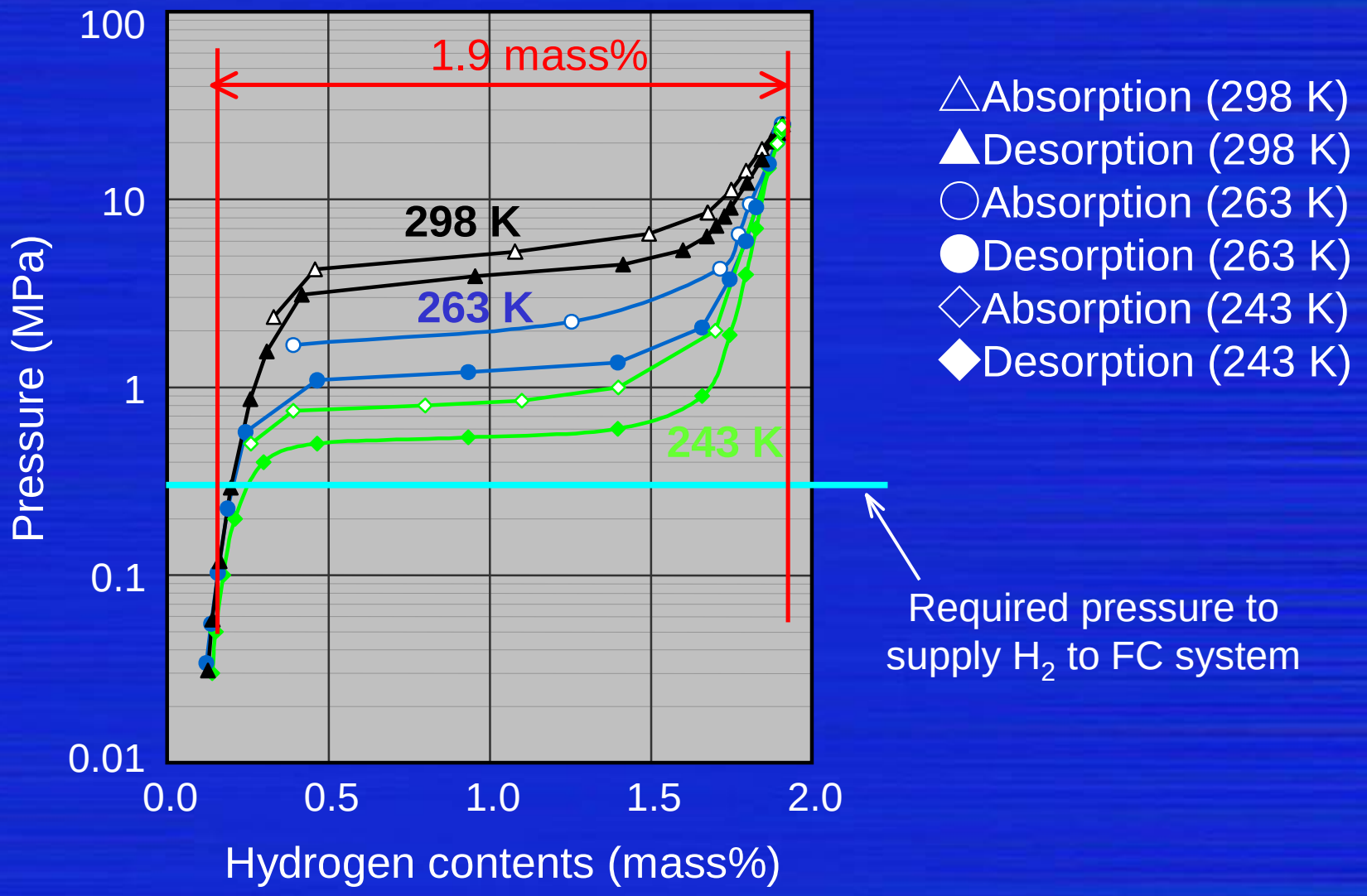


Fig. PCT diagram of Ti-Cr-Mn alloy

Performance of On-board Tank System

	Low-pressure MH tank Ti-Cr-V System	High-pressure tank	High-pressure MH tank Ti-Cr-Mn System
Hydrogen storage capacity	3.5 kg / tank 120 L	3 kg / tank 180 L	7.3 kg / tank 180 L
Tank weight	300 kg	< 100 kg	420 kg
Hydrogen filling time	30-60 min. With external cooling facility	5-10 min.	5 min. / 80 % Equal to high-pressure tank without cooling facility
Hydrogen release at low temperature	Difficult under 308 K	Possible	Possible even at 243K
Control ability	Difficult in acceleration	Good	Good Equal to high-pressure tank
Safety	Low pressure (< 1 MPa)	High-pressure (35 MPa)	High-pressure (35 MPa)

Target Performance for Metal Hydrides

Item	Specification	Note
1. Hydrogen storage density	Weight > 3-4 mass% Volume (V/V_0) > 1,800-2,400	V = stored hydrogen gas volume (273K, 1atm) V_0 = volume of MH
2. Enthalpy	$\lvert \Delta H \rvert$ < 20 kJ/molH_2	
3. Equilibrium pressure	> 1.0 MPa / 243 K (desorbing) < 35 MPa / 393 K (absorbing)	
4. Cyclic durability	Decrease of storage capacity < 10% / 1,000 cycles < 5% / 100 cycles	H_2 purity > 99.99 %

Recent Activities about Hydrogen Storage

1) D. Mori, N. Haraikawa, N. Kobayashi, T. Shinozawa, T. Matsunaga, H. Kubo, K. Toh and M. Tsuzuki, “High-pressure Metal Hydride Tank for Fuel Cell Vehicles”, 2005 MRS Spring Meeting

2) D. Mori, N. Kobayashi, T. Shinozawa, T. Matsunaga, H. Kubo, K. Toh and M. Tsuzuki, J. Japan Inst. Metals, 69, 308 (2005)

3) D. Mori, N. Kobayashi, T. Matsunaga, K. Toh and Y. Kojima, Materia Japan, 44, 257 (2005).

4) T. Matsunaga, T. Shinozawa, H. Suzuki and D. Mori, “High Desorption Pressure Metal Hydride for High-pressure MH Tank”, E-MRS 2005 SPRING MEETING

5) H. Suzuki, T. Mouri, K. Tange, Y. Kojima, “Development of Hydrogen Storage Materials for Fuel Cell Vehicle#, ICMAT & ICAM 2005, 3-8 July 2005, Singapore, SYPOSIA (P) Materials for Rechargeable Batteries, Hydrogen Storage and Fuel Cell

Summary

-Performance of High-pressure MH System

1.Hydrogen storage capacity
max.7.3kg / tank (volume 180L)

2.High speed charge
hydrogen charging rate is over 11,000NL/min
(same as 35MPa cylinder vessel)

3.Release H2 at low temperature from 243K

-High-pressure MH system shows a realistic way to obtain adequate cruising range over 700km.

-Large gap to target performance is still remained.
To realize hydrogen society, worldwide collaboration study is expected in this field.

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