Hydrogen Storage Technology

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Hydrogen = Element of Water

Wasserstoff

水素

Hydrogen for renewable energy and food

Hydrogen Technology using Metal Hydrides (MH) of Hydrogen Storage Alloys(HSA)

What can we do with MH ?

Hydrogen Technology

Two methods of application :

1. Consuming H_2 (H):

Combustion Engine, Fuel Cell etc

The H_2 production process and cost are factors to be considered.

2. Reversible use of H_2(H) without consuming :

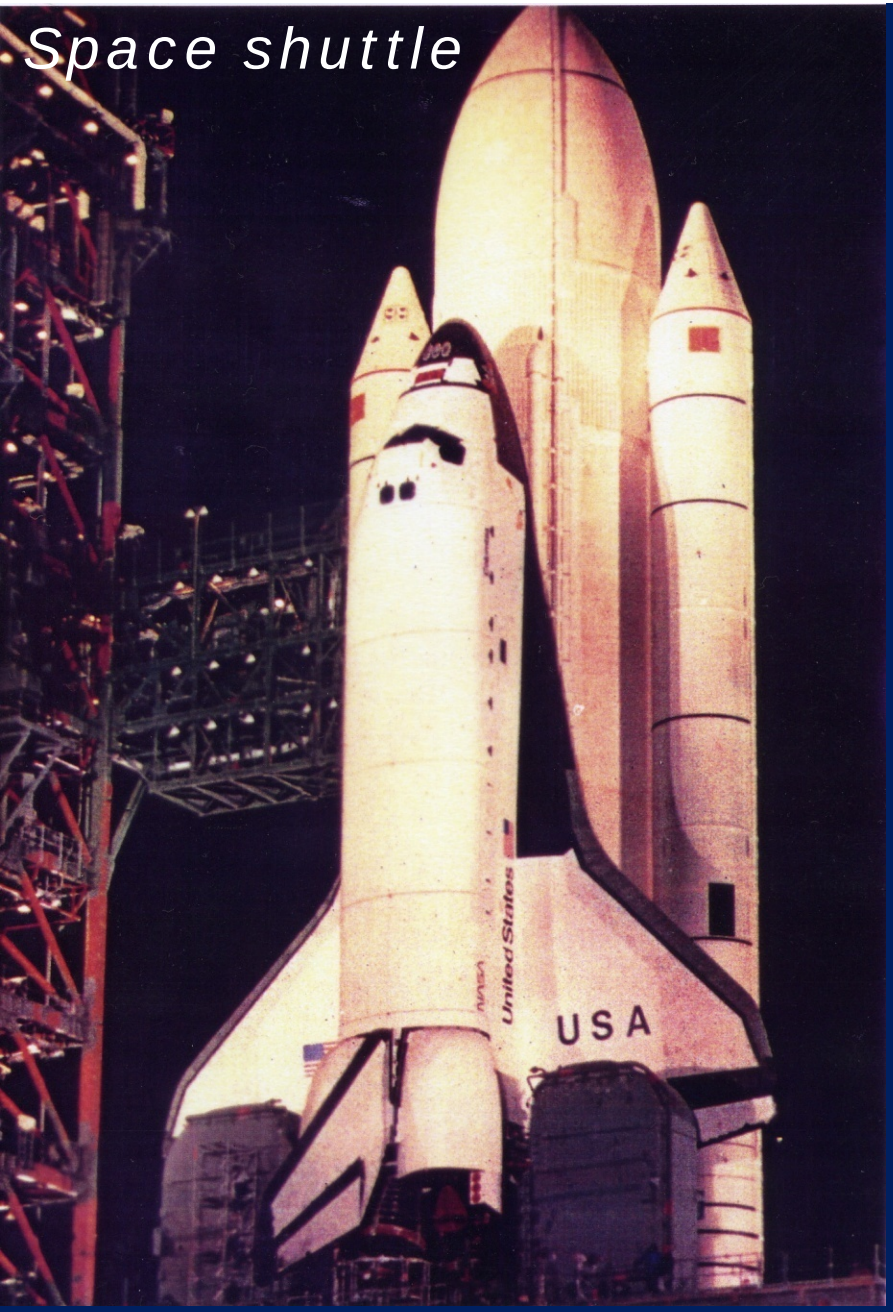
Ni-MH Battery, Heat Pump,

Vacuum Technology for Heat Insulation etc

- *Cyclic use of hydrogen using MH plays an essential role allowing the cost of H_2 production to be neglected.*
- *A high cyclic stability of MH is required.*
- *The cost of hydrogen storage alloys should be reduced.*

Hydrogen Technology
Systems Consuming Hydrogen

Space shuttle



MAZDA H_2 rotary engine

HONDA FC vehicle

Typical systems consuming hydrogen

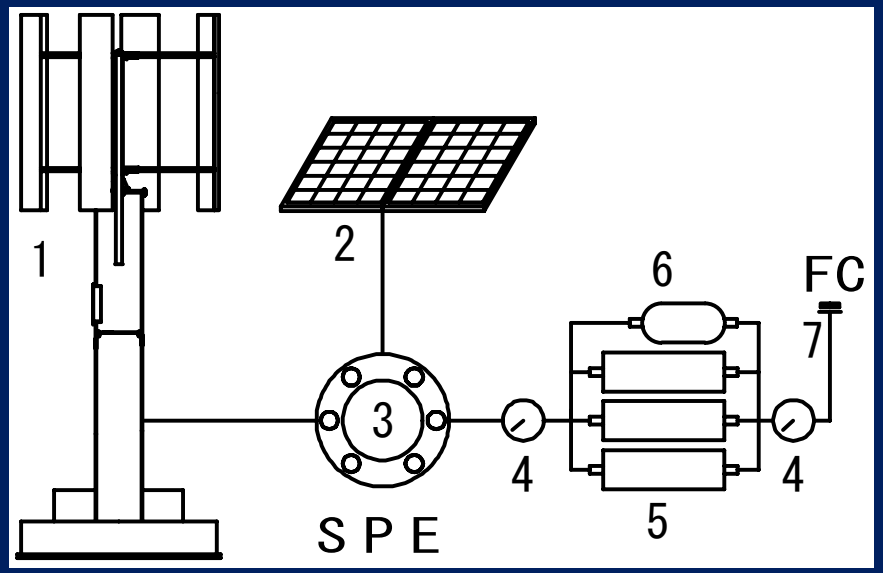
Debut of a new HONDA FC motorbike, February 2005

A wind & solar hybrid energy storage system with nano-FeTi alloy

Chiba Prefecture near Tokyo, Japan

A wind-solar hybrid energy storage system was constructed to store electricity from wind and solar energy as hydrogen.

A wind mill (1 kW) with a vertical axis system (Aura V, Tokai University type) and a solar photovoltaic array (1 kW) produce electricity to decompose water into oxygen and hydrogen gases using a solid polymer electrolyte (SPE). The produced hydrogen gas was stored in tanks containing a nano-structured TiFe hydrogen storage alloy produced by commercial ball-milling system. Hydrogen gas supplied to a fuel cell from TiFe tanks is used for LED light at night.



1. A Windmill (< 2kW)
2. Solar cells (1kW)
3. S.P.E (2.2kW)
4. Pressure gauge
5. MH tank
   1.0kg nano-FeTi ×3 tanks
6. Reservoir
7. Fuel cells (850W)

About 340 liter H_2 storage, corresponding to solar and wind energy input per day in January.

Hydrogen Storage system by Nano-FeTi under normal conditions

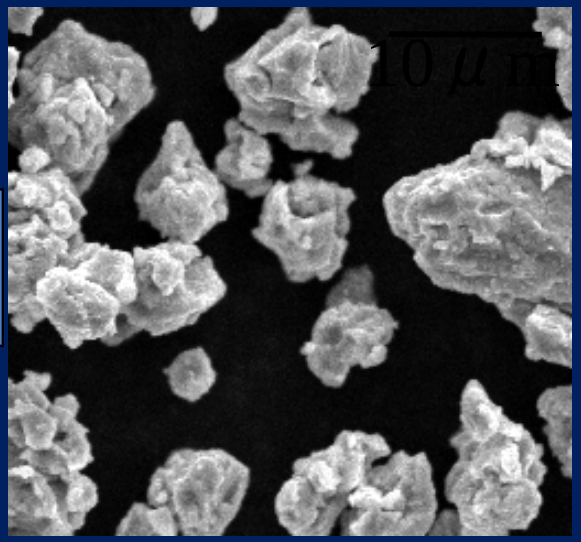
We have successfully synthesized nano-structured FeTi alloys by commercial ball-milling system. The produced alloys show ready initial activation and hydriding/dehydriding reversibly under normal conditions (at room temperature).

At present, we are proceeding with an experiment to store up hydrogen manufactured from sun and wind energy with this nano-FeTi alloy.

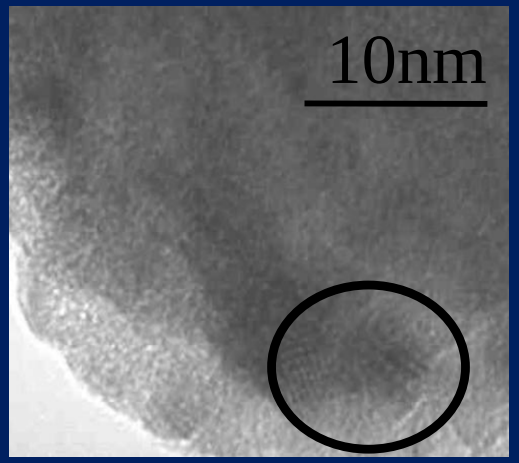
H2 purity : 99.99%
Dew point : < -60℃

at room temperature

MH tank (1.0kg nano-FeTi ×3)



SEM image of FeTi powders used for MH tank



TEM image of a FeTi particle with a nano structure

MH tank used nano-FeTi alloy produced by mechanical alloying for a mass production use.
Hydrogen Storage：About 1.2wt%(at 2MPaH_2)（ H_2 gas 125 litter ×3 ）

Wind power systems to produce hydrogen in the urban area

1. Aura V

Straight wing vertical axis wind turbine generation systems

Wings	5
Rotating Diam.	2.5 m
Min. Wind Vel.	3 m/s
Stand. Wind Vel.	10 m/s
Output	1kW

2. Aura 1000

Horizontal axis wind turbine (Propeller type)

Wings	5
Rotating Diam.	1 m
Min. Wind Vel.	3 m/s
Stand. Wind Vel.	10 m/s
Output	135W

Aura1000 wind power systems are utilized for lights or clocks in low wind areas (average wind speed is about 3m/sec)such as Tokyo.

Advantage of the two types Aura wind power systems

Aura V : Non-Directivity against Wind.

Aura 1000 : Good prompting for fluctuation.

Effective generation in low wind velocity conditions.

Low Rotating Noise.

Suitable for use in a city with fluctuating wind directivity

A micro wind & solar hybrid energy storage system with nano-FeTi alloy

We are executing an experiment to produce hydrogen gas by micro movable system in various parts of Tokyo. This system is composed of a micro wind & solar power generator, which produces H_2 gas through the electrolysis of water, and the nano FeTi alloy storage tank. We can produce and store hydrogen nearby even in a low energy area such as Tokyo.

Micro wind & solar hybrid energy system

FeTi MH tank（150g×2）

Removable Hydrogen storage tank

References

< Nano-structured FeTi >

1. T.Haraki, K.Oishi, H.Uchida, Y.Miyamoto, M.Abe, T.Kokaji, S.Uchida,
   " Properties of Hydrogen Absorption by Nano-Structured FeTi Alloys",
   Int. J. Materials Research 99(2008)507-512.

Hydrogen Technology Systems Without Consuming Hydrogen

- *Reversible hydrogen absorption and desorption reactions of hydrogen storage alloys are utilized for various applications*

POSSIBLE APPLICATIONS USING REVERSIBLE HYDROGEN REACTIONS WITH HSA

HYDRIDING / H_2 ABSORPTION

$M(HSA) + H_2 \rightarrow MH - \Delta H$: Exoth.

DEHYDRIDING / H_2 DESORPTION

$M(HSA) - H_2 \leftarrow MH + \Delta H$: Endoth.

WHAT CAN WE DO?

$$M + H_2 = MH + Q$$

H_2 -> PRESSURE CHANGE

-> ACTUATORS

VERTICAL MOTION OF A WHEEL CHAIR BY MH-ACTUATORS

(Japan Steel Works)

WHAT CAN WE DO?

$$M + H_2 = MH + Q$$

MH -> A HIGHER HYDROGEN STORAGE DENSITY OF MH THAN L-H_2

WHAT CAN WE DO?

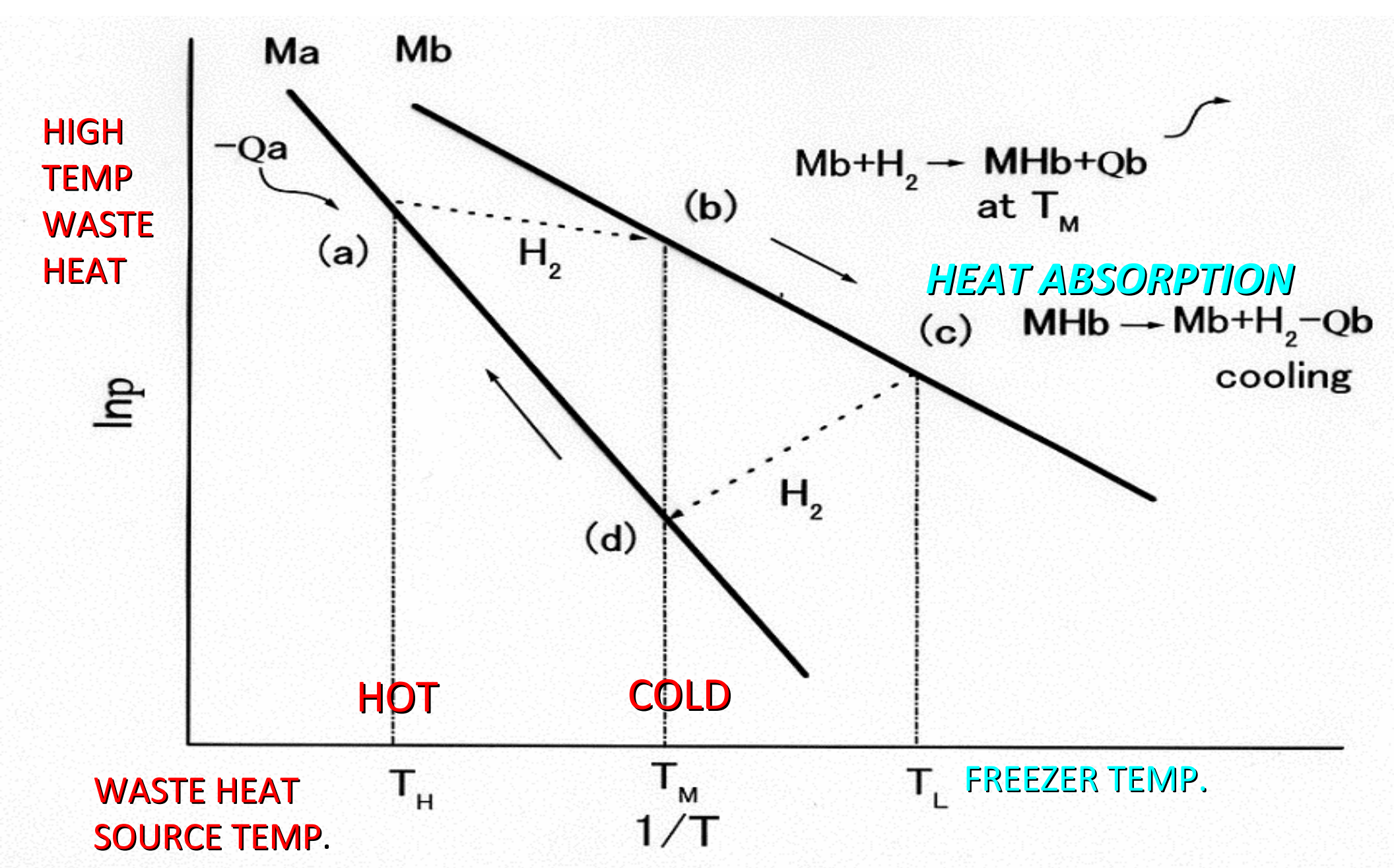
$$M + H_2 = MH + Q$$

Q -> REVERSIBLE HEAT REACTIONS

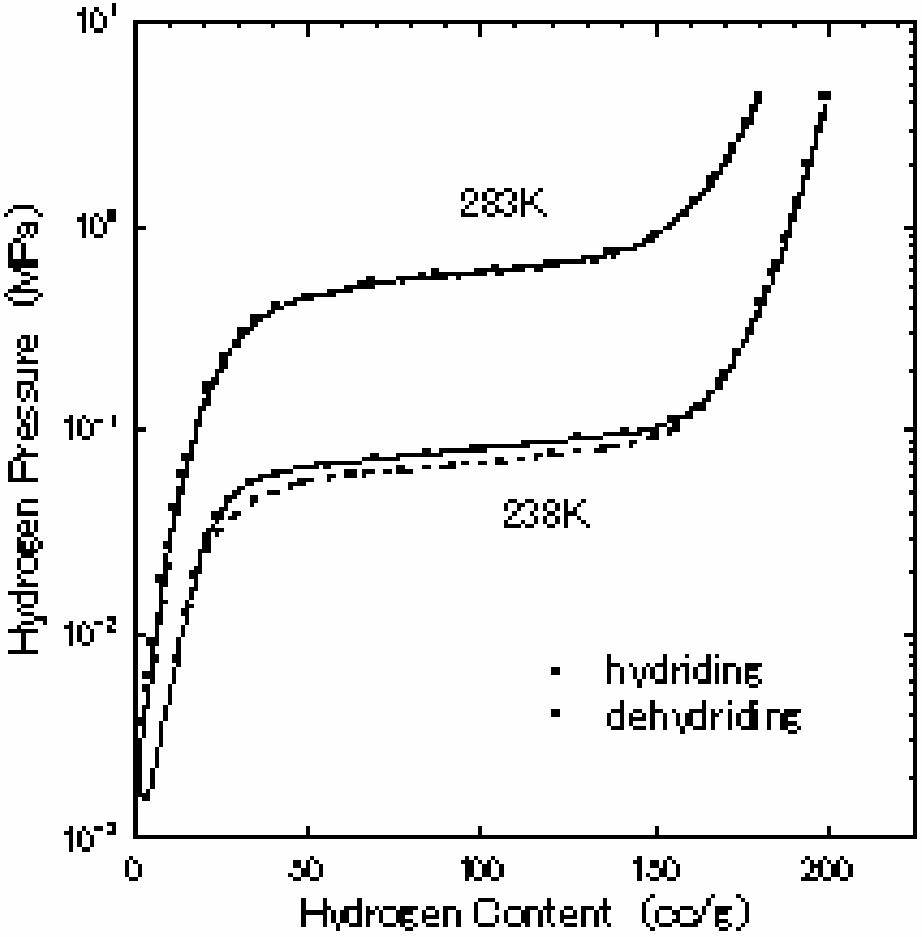
EXOTHERMIC H2 ABSORPTION
-> HEAT RELEASE -> HOT

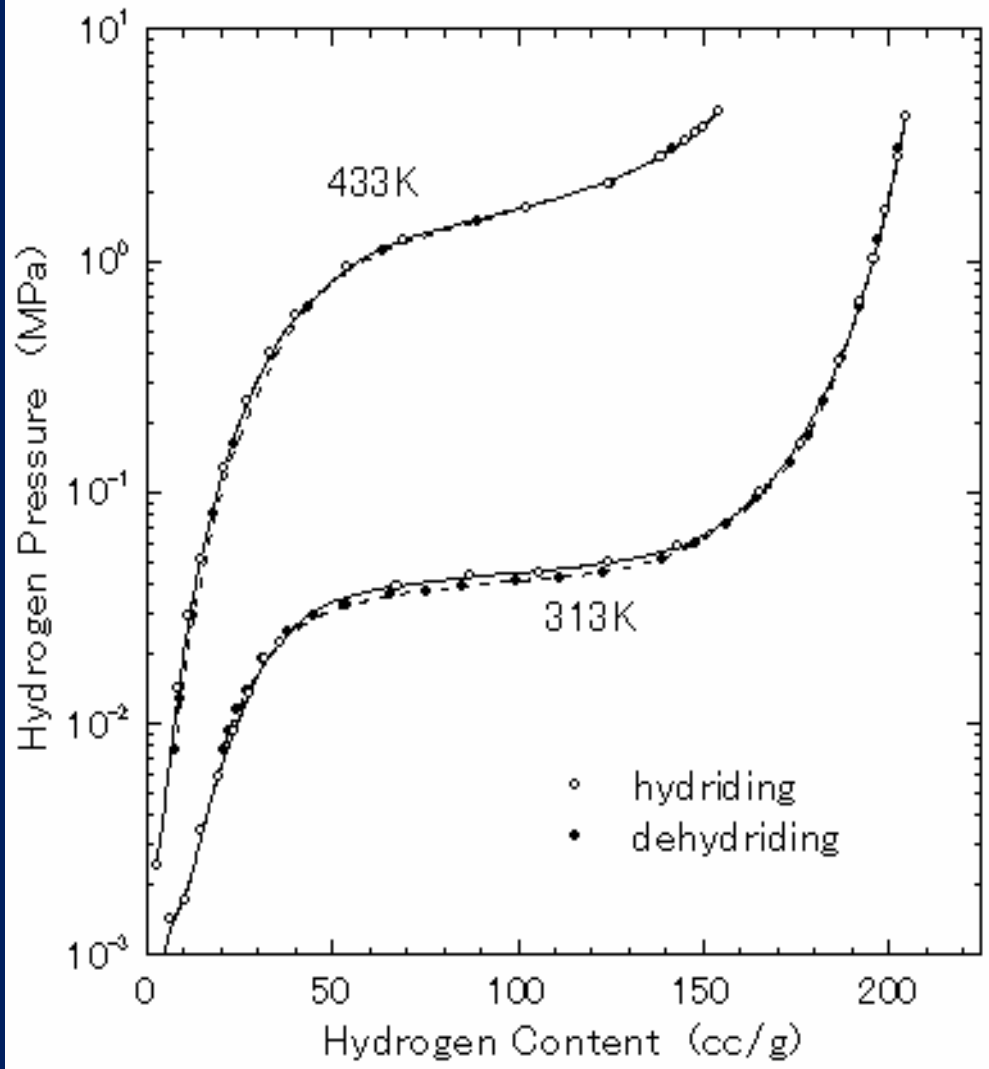
-> ENDOTHERMIC H2 DESORPTION
-> HEAT ABSORPTION -> COLD

-> HEAT PUMP



The principle of operation of a MH freezer





LOW TEMP. ALLOY Mb

Pressure-composition isotherms of a Ti-Zr-Cr-Fe-Ni-Mn-Cu alloy

Japan Steel Works

HIGH TEMP. ALLOY Ma

Pressure-composition isotherms of a Ti-Zr-Mn-V-Fe alloy

Japan Steel Works

Aqua-City SAIJO

The spring water quality of its fountain is one of the best 100 in Japan.

T =14-15 C constant
as a cold heat source for
a MH freezer

EXAMPLE OF
CITY SAIJO
METI PROJECT 2002

【Waste Heat of Plants, Incinerators etc】

Conventional
Output into Environment

Hydriding
(exothermic reaction)

Hydrogen
Storage Alloy

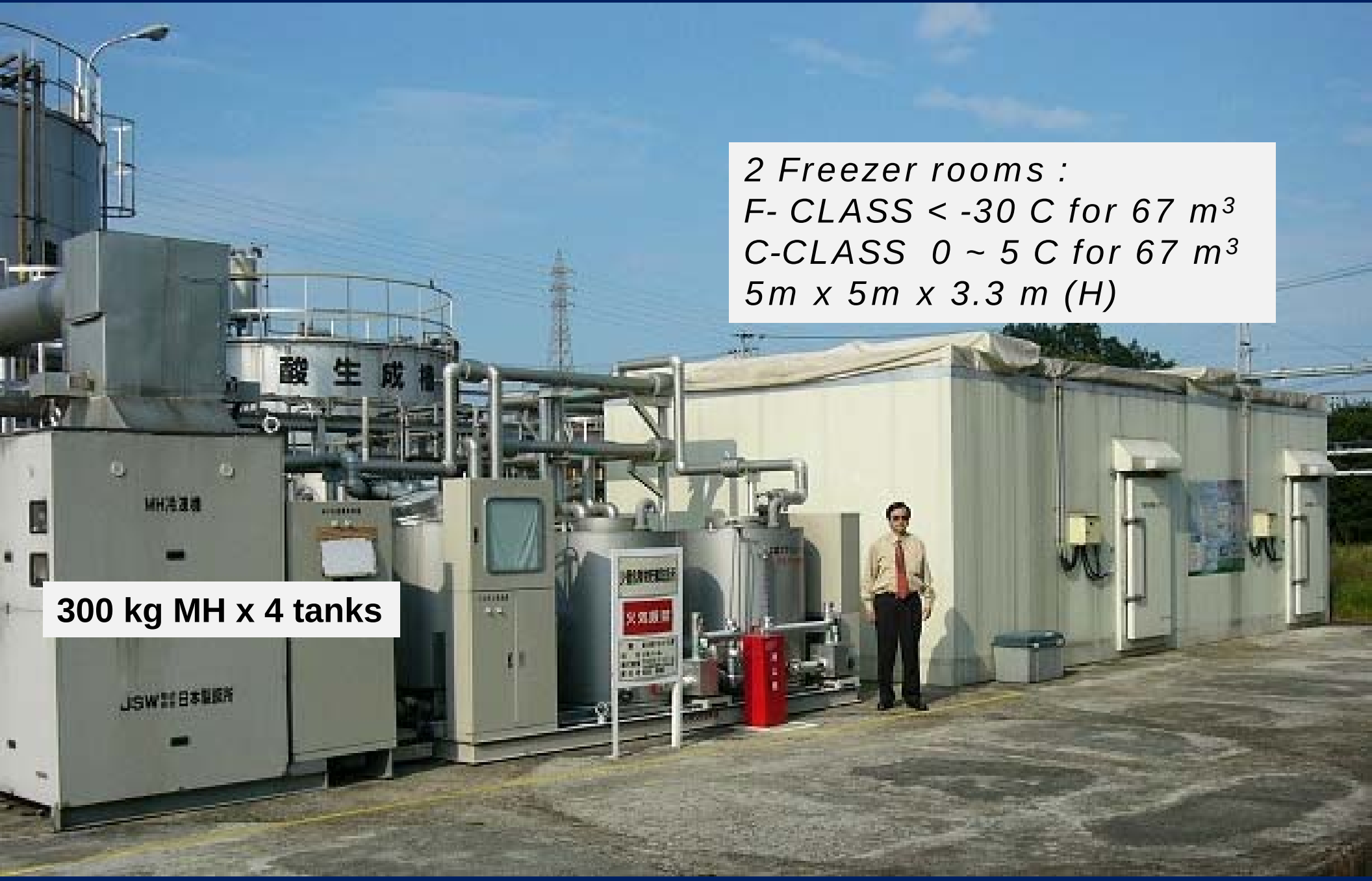
Dehydriding
(endothermic reaction)

253 K – 278 K
Refrigerator,
Freezer
and
Air Conditioner etc

Waste Heat Utility
50 % at 276 K
45 % at 253 K
(25 % at 253 K by a long heat transport)

【Ground Water, River, Sea etc】

The first MH freezer (in operation since 2001)



2 Freezer rooms :
F- CLASS < -30 C for 67 m³
C-CLASS 0 ~ 5 C for 67 m³
5m x 5m x 3.3 m (H)

300 kg MH x 4 tanks

HUGE EFFECTS IN ENERGY CONSERVATION & CO_2 REDUCTION

-30 ℃ **COOLING CAPACITY 7500 Kcal/h**

	< MH FREEZER >	< CFC GAS FREEZER >
DRIVING GAS :	**H_2**	**R22**
ENERGY CONSUMPTION :	**2.39 kW ← - 70 % !**	**8 kW**
CO_2 EMISSION :	**8.4 t-CO_2/y ← - 70 % !**	**28 t-CO_2/y**

Energy conservation effect is over 70% !!

Hydrogen Strawberry

Cultivation of SAIJO-Strawberry and Future Plans Using Hydrogen Energy in Saijo City, Ehime Prefecture, Japan

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Since 2001, Saijo City has been guided by Tokai University in establishing new technology which blends hydrogen energy and local resources. Through Industry-University Cooperation, the result, the MH freezer system, has become a core technology used in both preliminary and forefront industrial spheres.
Saijo City and the Saijo Industrial Information Support Center (Corp.) are supporting the first"LLP Tryout Ehime," infusing the local industrial sphere with unique, ground breaking technology. A test experiment cultivating strawberries with the MH freezer system was conducted in March, 2007.

Saijo City Augmented Food Distribution "Kombinat" Construction Project Team's Philosophy (abstract)

[International Issues]
- Reduce the stress on natural resources through eco-friendly ideas
- Development of peaceful industry ethics which the secure right to existence
- Increase food supply production to match world population growth

[Saijo City's Challenges]
- Apply local resources, topography, and intellect to eco-friendly industry and gov't
- Create local industry system through agriculture and commerce collaboration
- Increase self-sufficiency percentage through a preliminary agriculture initiative

Fig.1 The test facility for strawberries using the MH freezer system

Fig.2 SAIJO-Strawberry, cultivation by cooling water from the MH freezer system

Fig.3 Cooled water temperature gauge

Strawberry harvesting in Japan occurs from December until the following May, and is said to be impossible in the summer months due to high heat.
Strawberry producing farms generally depend on making 1/2 of their annual sales in December. Therefore, the success of this experiment and study, which aims for a low cost harvest starting in October, is a great contribution to the steady increase of production rates and the overall productivity of farms.

Strawberry Cultivation Experiment (Cooling Period : 2007/09/28~2007/11/01) ※Without pre-cooling measures

2007/06/14 Construction

06/28 Planting

09/28 MH Connection

10/09 First Flowering

11/09 Fertilizer Density

11/09 Blossoming

11/15 First Crop

11/30 Fruition

2008/03/17 Growth Process

04/24 Growth Process

05/02 Harvest Status

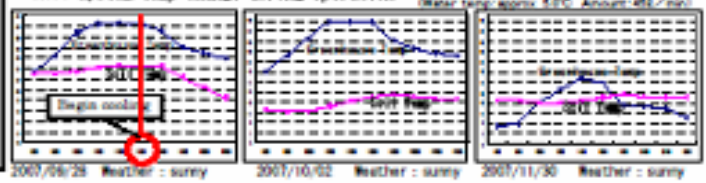
05/29 Growth Process

[House Area] 16.0mf (4.0m×4.0m)
[Cultivation Area] 2.22mf (7.4m×0.3m)
[Number of Plants] 88
[Fruit Produced] average 20g
[Fruit Sugar Content] avg. 13% (typical 10%)
[Fertilizer Density] 0.8mS/cm (typical 0.7~0.8mS/cm)

- A one-month harvest parallel to pre-cooled cultivation was achieved, despite the cooling of the soil delayed one month, and the harvest pushed back to mid-November.
- Due to an over-spec in the MH freezer system, the planting area was over-cooled from late Oct-Nov. Thus, temperature control remains an issue, but it was proven possible even under an increased planting area.
- Pest control and fertilizer regulation both proved to be effective. It is necessary to continue to clarify their value for future experiments.
- In 2008, by planting in mid-June we hope for an earlier harvest and further merit of pest control and fertilizer regulation, using a 5x larger planting area.

Vinyl Greenhouse
For new tests & study
[House Area] 81.0mf (9.0m×9.0m)
[Planting Area] 53.45mf
[Number of Plants] 600

MH system temp change during operation



[Future Goals]
In 2008, in order to evaluate water-based industries as supported by efficient energy use, preservation of the oceans, and stable manufacturing, the respective research bodies of Tokai University will propose the development of low-cost cultivation control through "High Efficiency Over-Ground Cultivation Systems."
We will endeavor whole-heartedly to make practical use of the success of these tests and experiments to increase overall food supply production, and in support of the grassroots realization of energy conservation and lowered environmental stress in our community and throughout the world.

The MH freezer NO.2 was manufactured as a small system with a volume of 12.8 m^3 to cool down to 273 K

The entire No.2 MH freezer system

MH freezer No.2
0.6 RT at 273 K
Alloys :
Ti-Zr-Mn-V-Fe-Al
36 kg x 2 for H.T.
30 kg x 2 for L.T.

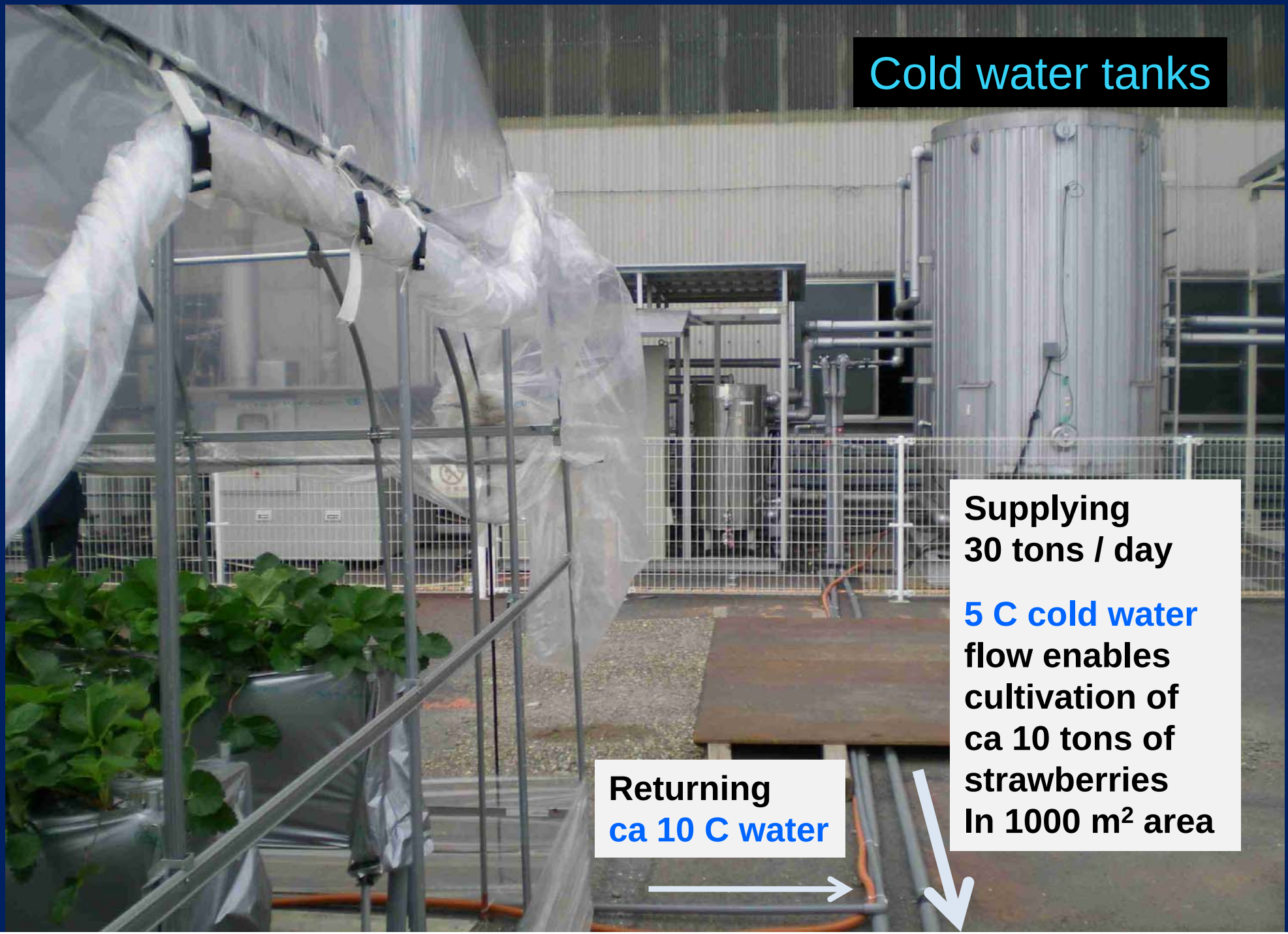
1 abs/des cycle : 7.5 h

Low temp（15 ℃）heat from ground water
and
High temp（200 ℃）heat from a steel factory

Visitors from abroad

The MH freezer system can be used for cold water production (0-5 C)

MH cold water lines to a strawberry house



A MH strawberry house

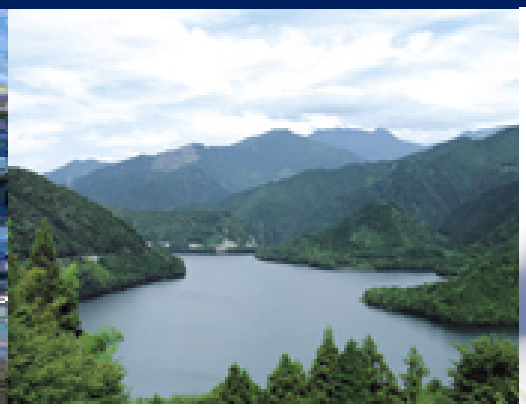
The MH cold water system enables strawberry cultivation through all four seasons in Japan

The MH freezer system is activating people and promoting business for sustainable development

The installation of a MH freezer system has brought these results:

1) New value added agricultural business started.
2) Small to medium size companies (SMC) in Saijo are organizing a new enterprise to manufacture small sized-MH freezer systems for multi-purposes use.
3) A big new project establishing a complex of foods storage, processing, and physical distribution using MH freezers is starting with the support of the Ministry of Economy, Trade and Industry (METI-Shikoku), and Ministry of Agriculture, Forestry, and Fisheries (MAFF-Shikoku), Japan.






MH freezer systems as sustainable energy use in a specific local area

- *Efficient use of waste heat in a local area*
- *High and low temperature heat sources are needed ->*

(Ex) Suitable for Iceland with abundant cold water from glacier, and hot heat source from geothermal ground



Concluding Remarks

- Hydrogen is suitable to store fluctuating wind or solar energy. Stored hydrogen can be used for local systems : fuel cell, combustion engines etc.
- Hydrogen storage alloys can be used for systems with reversible use of hydrogen :

  Ni-MH rechargeable battery, heat pumps,

  storage of renewable energy like solar, wind energy.