METAL HYDRIDE AIR-CONDITIONING

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Contents

Summary

Reasearch and development (R&D) of Metal Hydride (MH) heat pump have been carried out in a number of countries and advanced to a remarkably high level. However, owing to a recent drop in the crude oil price and expensive system costs, its priority in room cooling/heating device is declining. Nevertheless, the need for the development of refrigerating systems based on hydrogen and metal hydride as a promising substitute for flon in the field of refrigeration is rising driven by demands for the total abolition of use of flon, which is suspected of destroying the ozone layer and causing global warming, in response to the growing concern in the global environmental issues. It is expected the future trend in the development of MH refrigerating system will be focused in boosting the system efficiency by incorporating exhaust heat of various origins to the heat source for driving the system.

1. Alloys Used for Metal Hydride Air-Conditioning (heat pump, heat storage)

In the heat pump based on hydrogen absorbing alloy, the most important factor to determine the heat pump performance is the hydriding characteristics of the alloy. In order to construct a heat pump of better performance, the alloys are required to meet the following requirements:

- Rechargeable hydrogen storage capacity per unit mass of alloy is larger.

- Rate of reaction is high.
- Values of hysteresis and plateau slope are small.
- Equilibrium desorption pressure is to be adjusted freely depending upon the heat source temperatures.
- Durability is excellent: the performance is not deteriorated after required operation cycles of hydrogen absorption/desorption.
- Alloys are of reasonable price.

Recently, hydrogen absorbing alloys have been developed which show good durability in temperature ranges as high as 433 K and as low as 213 K (refrigerating range). By utilizing these alloys, it has become possible to develop MH refrigerating systems which can be operated not only in the room-cooling and heating ranges but also in the refrigerating range.

1.1 Metal Hydride Heat Pump

There are two ways of operating a metal hydride heat pump: (1) heat-driven MH heat pump, to utilize heat energy released by the migration of hydrogen, and (2) compression-type MH heat pump, to utilize mechanical energy.

The heat driven heat pump draws up heat by using two different alloys and a heat source of large capacity, such as exhaust heat, while the compression-type heat pump takes up heat by using a single alloy, a heat source of relatively smaller capacity and mechanical energy of a compressor.

1.1.1 Heat-Driven Type MH Heat Pump

1.1.1.1 Single-stage type heat pump

Principle. The heat-driven single-stage MH heat pump is operated in either of two modes: heating cycle and cooling cycle (refrigeration/heat augmenting), depending upon the heat migration associated with absorption/desorption of hydrogen gas, as shown in Figure 1, Figure 2(a) and Figure 2(b). In both modes two alloys of different absorption/desorption characteristics are combined for the operation.

In the heating cycle operation, heat (QI) is supplied from an external heating source (ex. exhaust gas) to the lower temperature side alloy (MH-B) to make the alloy release hydrogen, which is absorbed in the higher temperature side alloy (MH-A). Heat produced (Q2) by the exothermic reaction in this process is to be used as heat supply, as shown if Figure 1. In the cooling cycle operation, the higher temperature side alloy (MH-A) is cooled to let the alloy absorb hydrogen gas and to reduce the hydrogen pressure within the system, to make the lower temperature side ally (MH-B) to desorb hydrogen, as shown in Figure 2(a). The heat of endothermic reaction in this process is to be used for room cooling or refrigeration. In the heat-augmenting operation, heat produced by the exothermic reaction is to be utilized in an intermediate temperature range at limits of which the lower temperature side alloy (MH-B) and the higher temperature side alloy (MH-A) absorb hydrogen, respectively in Figure 2(b).

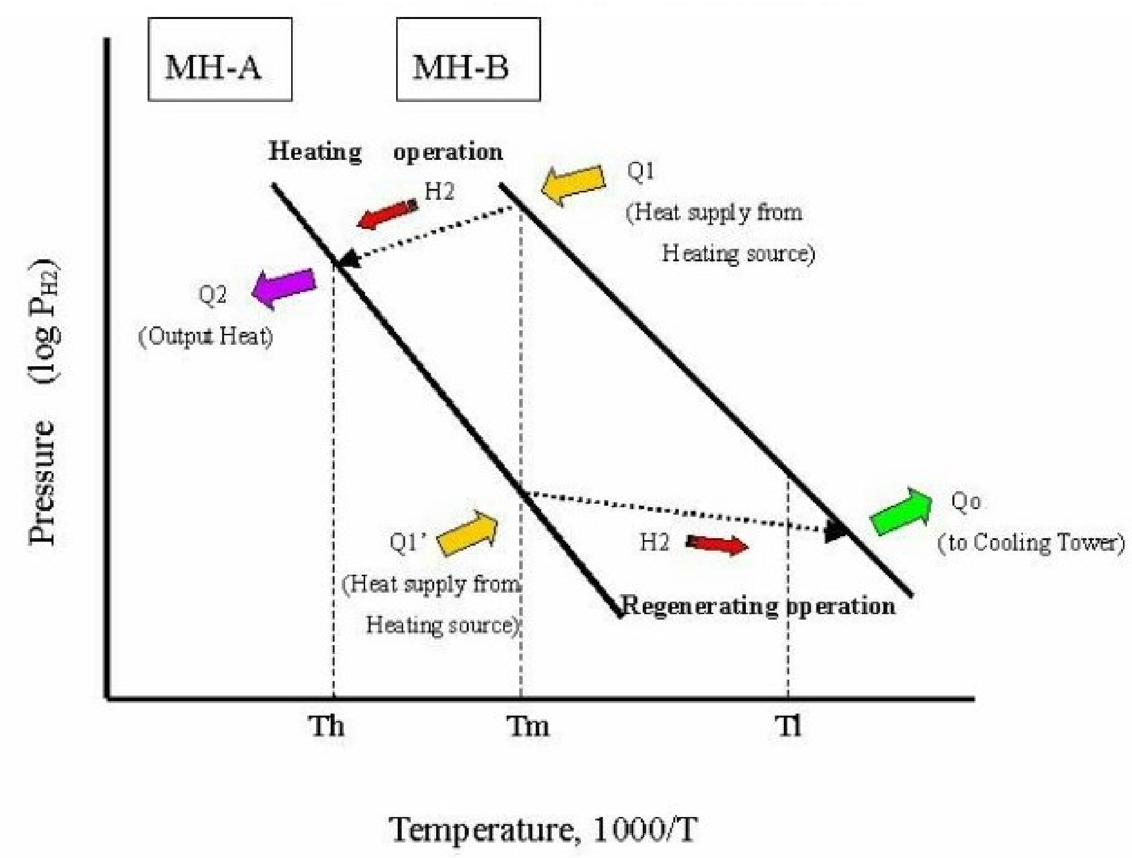
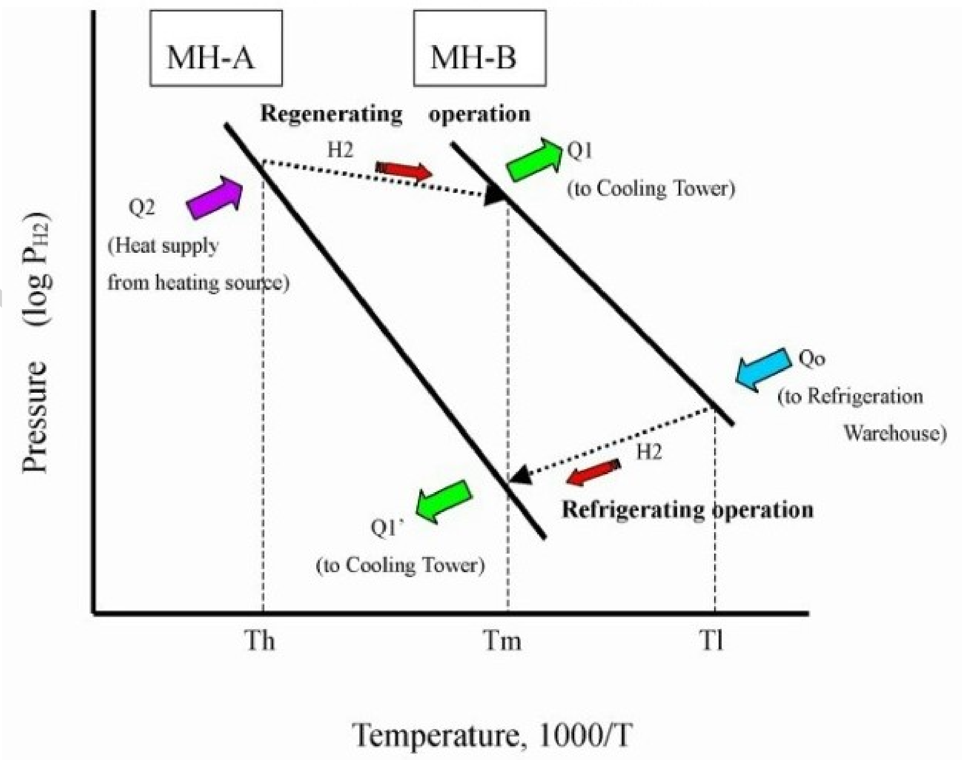


Figure 1.Heat pump P-T diagram
(Heating Cycle)



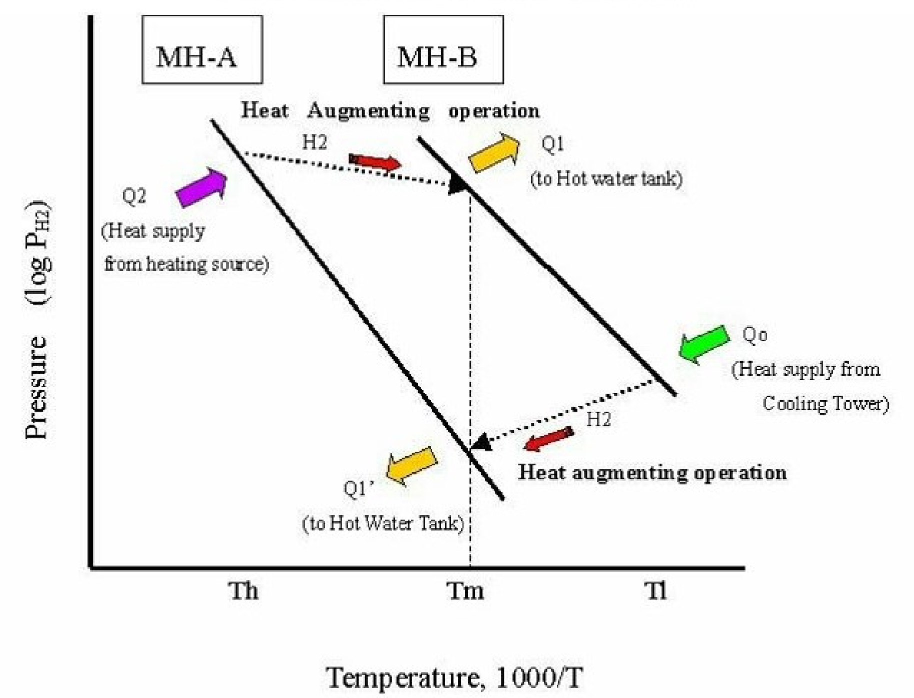


Figure 2. (a) Heat pump P-T diagram (Refrigeration Cycle) (b) Heat pump P-T diagram (Heat Augmentating Cycle)

The coefficient of performance (COP). The COP for a heat-drive pump is given by a ratio of input heat to output heat:

(i) Heating mode: COP = Q2/(Q1+Q1')
(ii) Cooling/Refrigerating mode: COP = Q0/Q2
(iii) Heat-augmenting mode: COP = (Q1+Q1')/Q2

1.1.1.2 Dual-Effect type MH Pump

Principle. In the dual-effect heat pump, two cycles operation using three different alloys are combined as shown in Figure 3, for the purpose of improving COP of the MH heat pump: MH-A, MH-B and MH-C mean metal hydrides are useful for a high temperature range, a middle temperature range a lower temperature range respectively. Heat produced (Q3') by exothermic reaction of MH-A in the first operation cycle combining MH-A and MH-C is to be used as heat source of hydrogen desorption process of MH-B in the second operation cycle combining MH-B and MH-C. And so the high temperature waste heat can be utilized effectively, improving COP. However, the heat source to drive the system requires higher temperature than that to drive the single-stage heat pump.

(i) The coefficient of performance (COP): Theoretical calculation of the coefficient of performance (COP) for a dual-effect heat pump is generally given by a ratio of input heat to output heat.
(ii) Heating mode: COP = (2Q1+Q1')/Q2
(iii) Cooling/Refrigerating mode: COP = 2Q0/Q2

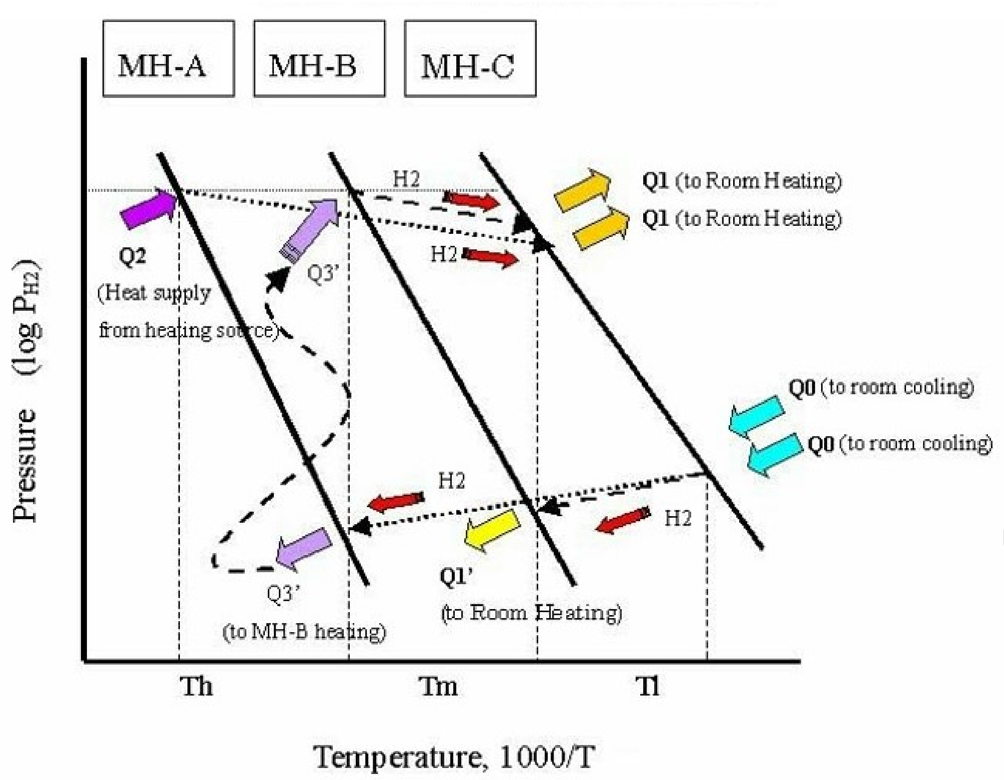


Figure 3. Heat Pump PT Diagram (Dual Effect Cycle).

1.1.1.3 Multi-Stage type MH Heat Pump

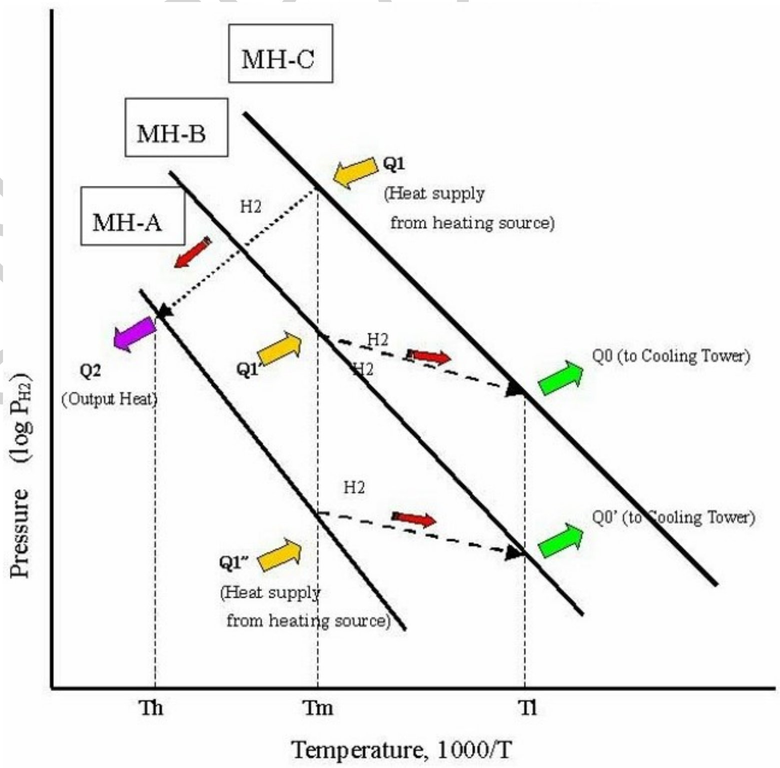


Figure 4. Heat Pump PT Diagram (Double Stage Heating Cycle: high temperature)

Principle. The operating conditions of a heat pump can be made more flexible by combining three different alloys and changing the migration route of hydrogen, to enhance COP, lower heat source temperature or elevate output temperature. Figure 4 shows typical cycle in the double-stage MH heat pump.

The driving condition. It is inevitable that the pressure to drive the system is higher than the single-stage heat pump.

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Biographical Sketches

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