Effect on Energy Savings and Reduction in CO_2 Emissions through Application of a High-Efficiency Centrifugal Chiller

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Air-conditioning accounts for a large portion of the energy consumed by industrial and commercial facilities. More specifically, according to the Energy Conservation Center, Japan (ECCJ), air-conditioning amounts to approximately 40% of the energy consumed in commercial buildings such as shopping malls. Energy-efficient air-conditioning should therefore make an important contribution to the reduction in CO_2 *emissions. In response to such needs, Mitsubishi Heavy Industries, Ltd. (MHI) provides energy-saving solutions based on centrifugal chillers that produce an excellent level of efficiency. At the core of these solutions is the achievement of complete optimization by providing consistent heat source solution services commensurate with the life cycle of products and systems to promote more effective energy-savings. Here we introduce MHI's involvement in this field.*

1. Features of centrifugal chillers with exceptional levels of efficiency[1]

The following section describes features of the latest centrifugal chiller models developed by MHI, which represent the key technology to energy-saving solutions. The refrigerant used in the chillers is HFC-134a, which does not destroy the ozone layer. Moreover, modifications and improvements to the compressors, heat exchangers, and other units achieve higher performance over the entire range of operation.

The centrifugal compressor is equipped with two-stage open impellers that allow high-precision machining and eliminate the breakaway and stagnation of refrigerant gas flow. The compressor is designed with flow analysis including static channels, and it is more efficient than earlier models. An additional capacity control mechanism installed at the inlet of the second stage impellers has improved the efficiency in low-load operations. Furthermore, high-capacity machines, with inverter specifications, are also available so that the entire series of products successfully achieves the optimal rotational speed control and expands the zones of operation based on the operating conditions. As a result, the load tracking control remains efficient even if the cooling water inlet temperature falls to 12°C, contributing to dramatically improving the partial load performance (coefficient of performance, COP) as shown in **Fig. 1**.

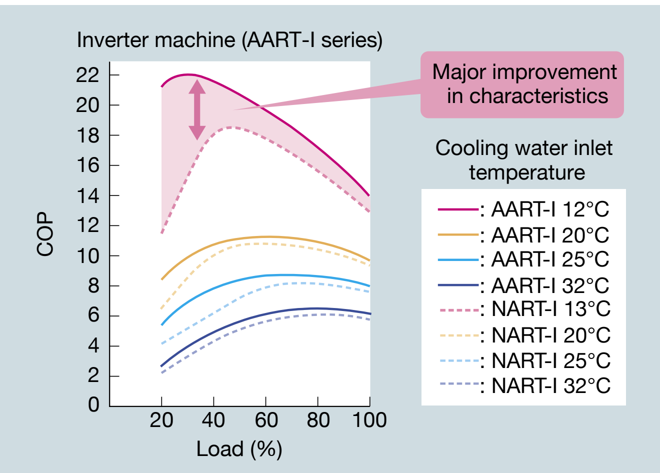

Fig. 1 Partial load characteristics of the variable speed drive centrifugal chiller (chilled water outlet temperature: 7°C)
The diagram shows a major improvement in the partial load characteristics. The coefficient of performance (COP) can be expressed by the following equation.
COP = output energy/input energy

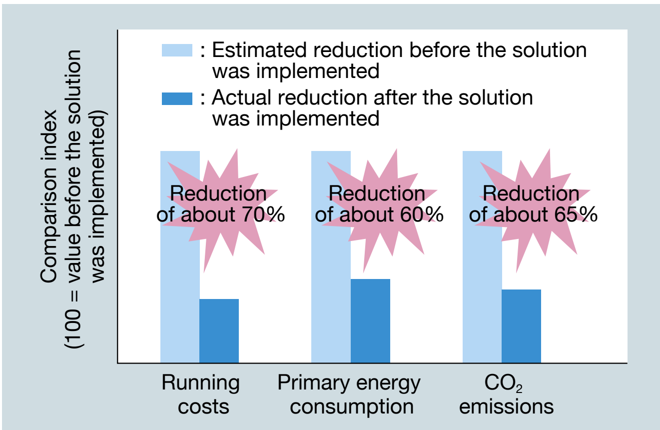

Fig. 2 Effects of reducing energy consumption and CO_2 emissions
The diagram shows that implementing the solution greatly reduces the yearly running costs and CO_2 emissions.

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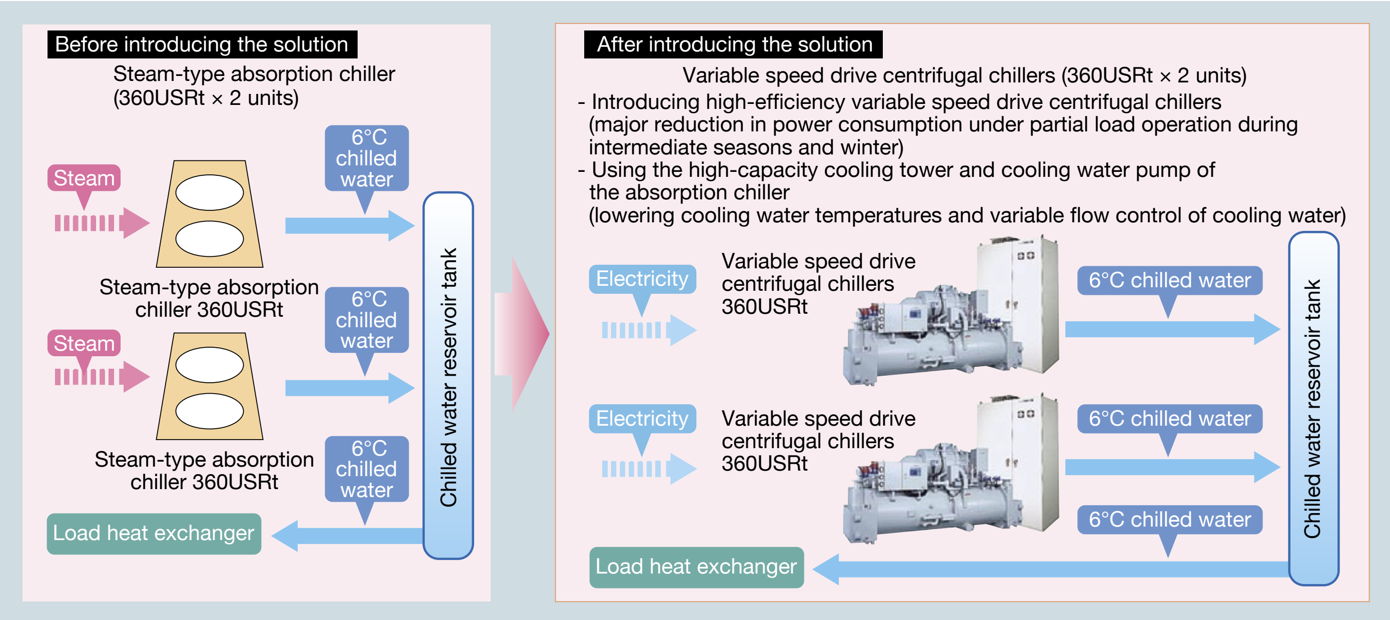

Fig. 3 Example of an introduced solution
An example in which the centrifugal chiller replaces the steam-type absorption chiller.

2. Case study of a solution for saving energy and reducing CO_2 emissions

This section introduces a solution proposed to the Takasago plant of Suntory Ltd. Heating and cooling take place at various temperatures in this food and beverage factory, which requires a heat source capable of coping with loads that vary considerably. The proposed energy-saving solution satisfied these requirements while achieving 60% or more in energy savings and reductions in CO_2 emissions (**Fig. 2**). **Figure 3** provides a schematic of the proposal. The main points of the proposal are as follows.

(1) A high-efficiency, variable speed drive centrifugal chiller has replaced the existing steam-type absorption chiller. This contributes to a major reduction in power consumption during partial load operations in the intermediate seasons and winter.

(2) By effectively using the existing high-capacity cooling tower and the cooling water pump of the steam-type absorption chiller, the resulting lower temperature cooling water and variable flow control of the cooling water help save more energy than was previously possible.

3. Solution proposal scheme

Figure 4 shows the schematic flow of events in the proposal in which the latest system technology improves the chiller, and its peripheral equipment and air conditioner reduce energy consumption. The flow of events is as follows.

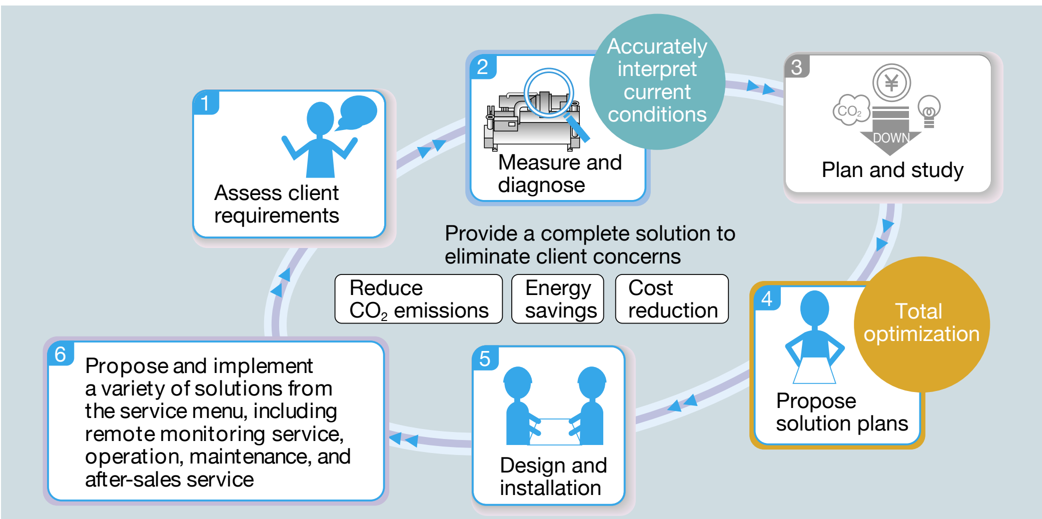

Fig. 4 Energy-saving solution proposal scheme showing the event flow of the solution proposal commensurate with the life cycle of products and systems

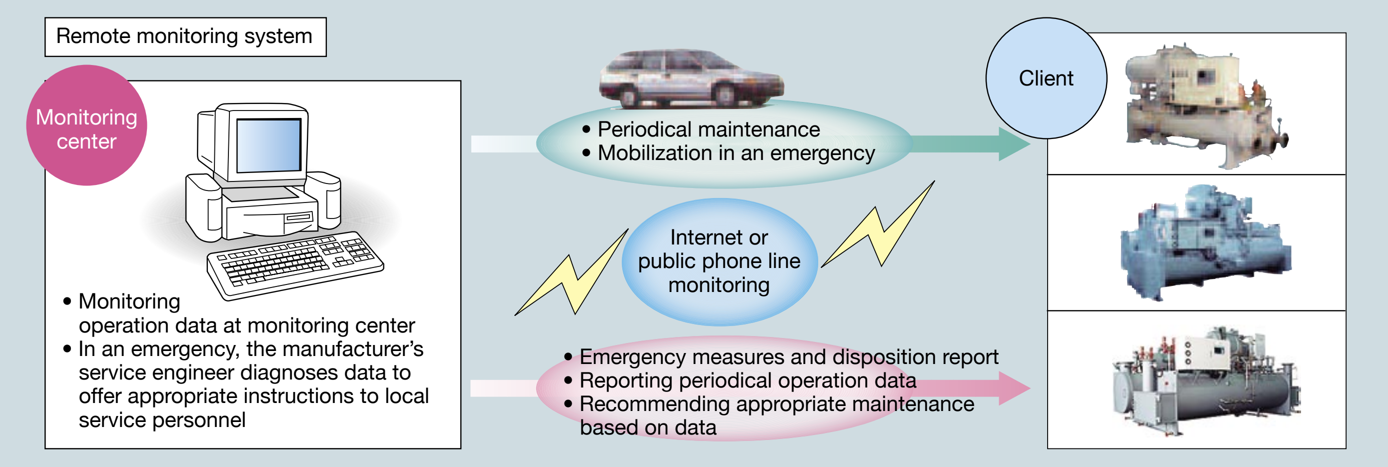

Fig. 5 Outline of the remote monitoring service

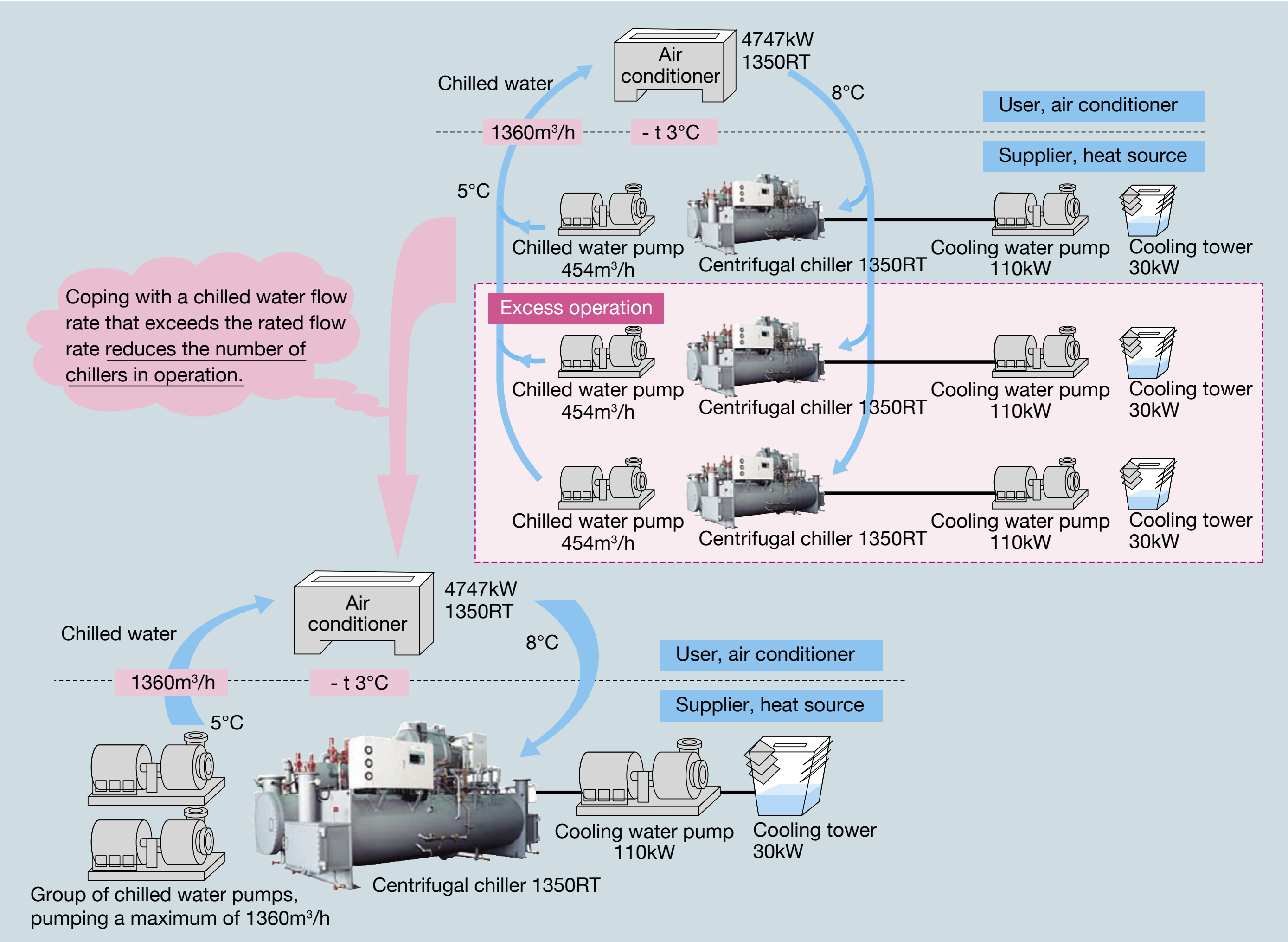

Fig. 6 Outline of the variable over water volume system (patented)
Coping with a chilled water flow rate that exceeds the rated flow rate reduces the number of chillers in operation, which in turn reduces energy consumption.

(1) Collect information from the client on the configuration of the facility and its operating conditions, energy consumption, and other details. (2) If necessary, measure the operation parameters of the facility and diagnose them to study the items requiring energy-saving. (3) Based on the study results, use simulation or another method to calculate the energy-saving effect. (4) At a stage when the effect is confirmed, compile the study results into a solution proposal for submission to the client. (5) Discuss the proposal with the client. Upon securing the client's

approval, begin detailed design and installation. (6) After installation, provide the client with solutions to the chiller operation, including support for energy-saving operations through remote monitoring and equipment diagnosis 24 hours a day, 365 days a year (**Fig. 5**) and 15-year operation support for functions, stable operation, and performance maintenance. Given this after-sales service menu, checking the operating conditions of the equipment and implementing appropriate maintenance enables the improvements to be evaluated and confirmed. This helps the client to better appreciate the major energy savings compared to a single-unit energy-saving proposal.

4. System examples applying chillers

The solution proposals involving the centrifugal chiller are divided into a variety of aspects covering the variable flow control of chilled water and cooling water, free cooling, and reuse of waste heat. The following sections introduce actual energy-saving proposals employing systems around chillers.

4.1 Variable over water volume system

Generally, thermal loads should be reduced in the intermediate seasons and winter. However, depending on the control on the load circuit, the heat exchanger characteristics, and other factors, the reduction in the thermal loads may not be proportional to the reduction in the flow. This makes the temperature difference smaller between the supply water temperature and return water temperature, and is more likely to lead to nonreduction of the load flow. In facilities where the system controls two or more chillers, more than the necessary number of chillers are likely to operate in many cases, which lowers the efficiency of the entire facility. To improve these situations, Mitsubishi Jisho Sekkei Inc. and MHI have codeveloped a Variable over water volume system. **Figure 6** shows an outline of this system. To reduce the number of chillers in operation, the system can handle the flow rate of chilled water that exceeds the rated flow rate, enabling the system to reduce energy consumption.

4.2 Stealth Turbo® system

Facilities equipped with two or more absorption chillers to cope with peak loads in summer must operate fewer chillers under partial load during the intermediate seasons and winter when the load is generally reduced. In many cases like this, the entire facility is likely to operate at low efficiency. We suggest that clients in this situation install a small-capacity centrifugal chiller, the Stealth Turbo®, to realize energy savings without investing money by increasing the contract power capacity. Mitsubishi Jisho Sekkei Inc., SANKI Engineering Co., LTD and MHI have codeveloped this system, which is outlined in **Fig. 7**.

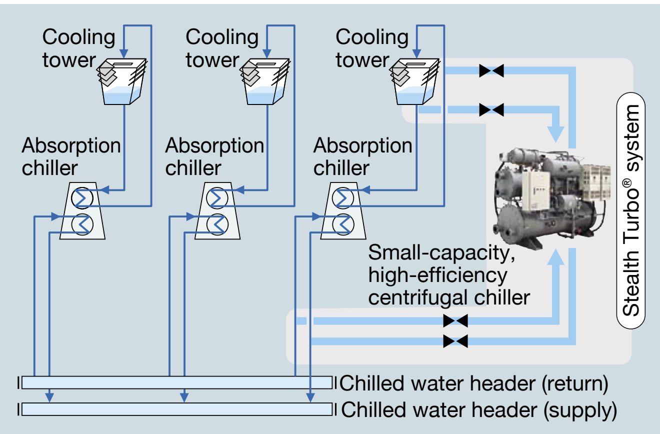

Fig. 7 Outline of the Stealth Turbo® system (patent pending)
A bypass circuit is hooked up to the existing chilled water and cooling water pipe lines to install a small-capacity, high-efficiency centrifugal chiller.

5. Conclusions

Reducing energy consumption and CO_2 emissions is one of the most critical issues facing the world. Given these circumstances, we have introduced MHI's involvement in providing consistent heat source solutions from facility investment planning and installation to after-sales service. These solutions optimize the air conditioners and heat source facility to effectively reduce energy consumption and CO_2 emissions. MHI's home page at the URL below provides valuable information for clients.
Air-Conditioning & Refrigeration Systems Headquarters
URL: http://www.mhi.co.jp/en/aircon/index.html

Reference

1. Seki, W. et al., New Model Turbo Chiller, AART Series, Contributes to the Reduction of Energy Consumption under Year-Round Operation, Mitsubishi Heavy Industries Technical Review Vol.43 No.2 (2006) p.41


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