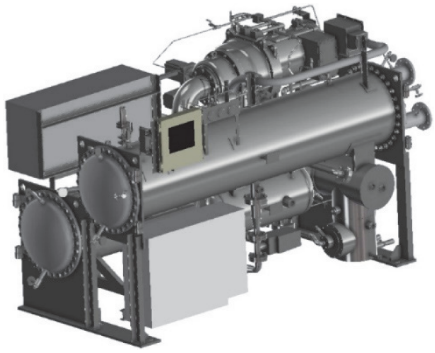
High-Efficiency Centrifugal Heat Pump Using Refrigerant with Global Warming Potential of 1



Mitsubishi Heavy Industries Thermal Systems, Ltd.
Sales Department

From the standpoint of CO_2 emissions reduction and energy conservation, demand for heat pumps that effectively use waste heat is growing. In Japan, a product designation system was introduced through the Act on Rational Use and Proper Management of Fluorocarbons. Accordingly, each centrifugal chiller shipped domestically from 2025 shall not exceed a global warming potential of 100 when calculated by average weight of the total number of units sold in each fiscal year. In response, Mitsubishi Heavy Industries Thermal Systems, Ltd. has been working to develop a high-temperature heat pump using a low-GWP refrigerant, HFO-1233zd(E). This heat pump is designed to supply hot water up to 90°C, and uses the waste heat over a wide range of temperatures (from as low as 10°C at the heat source water inlet). Product specifications and application examples of this heat pump are presented in this report.

1. Introduction

Cleaning with hot water is conducted in many production lines at various facilities such as food and machine factories. The hot water used is often produced by boilers using energy from fossil fuels. The wastewater after cleaning is directly discharged into the drainage system. Heat pumps can utilize such discharged wastewater as a heat source to supply hot water, thereby reducing CO_2 emissions.

In Japan, according to the product designation system established under the Fluorocarbon Emissions Control Act, limits have been placed on the production and shipment of centrifugal chillers with a high global warming potential (hereinafter referred to as GWP) refrigerant from fiscal 2025 onwards. Regarding centrifugal chillers for air conditioning, Mitsubishi Heavy Industries Thermal Systems, Ltd. (hereinafter referred to as MTH) launched the ETI-Z series that uses HFO-1233zd(E) with a GWP of 1 in 2015, and the JHT-Y series that uses HFO-1234yf with a GWP of <1 in 2022. Regarding heat pumps, however, only the ETW-L series using HFC-134a with a GWP of 1,430 is offered. A lineup of low GWP refrigerant products has not been available up to now.

In order to satisfy the growing demand for heat pumps and adopt a more suitable refrigerant, MTH has developed the new heat pump ETI-W15 that uses a low-GWP refrigerant, HFO-1233zd(E). MTH's air conditioning line-up, arranged according to the supply temperature and type of application, is shown in **Figure 1**. The heat pump in the ETI-Z series can achieve a hot water outlet temperature of up to 45°C, while the maximum temperature of the newly-developed model is 90°C. Thus, with this new addition, MTH's product line-up can cover the capacity band for industrial applications as well as the high-temperature range with the use of a low-GWP refrigerant.

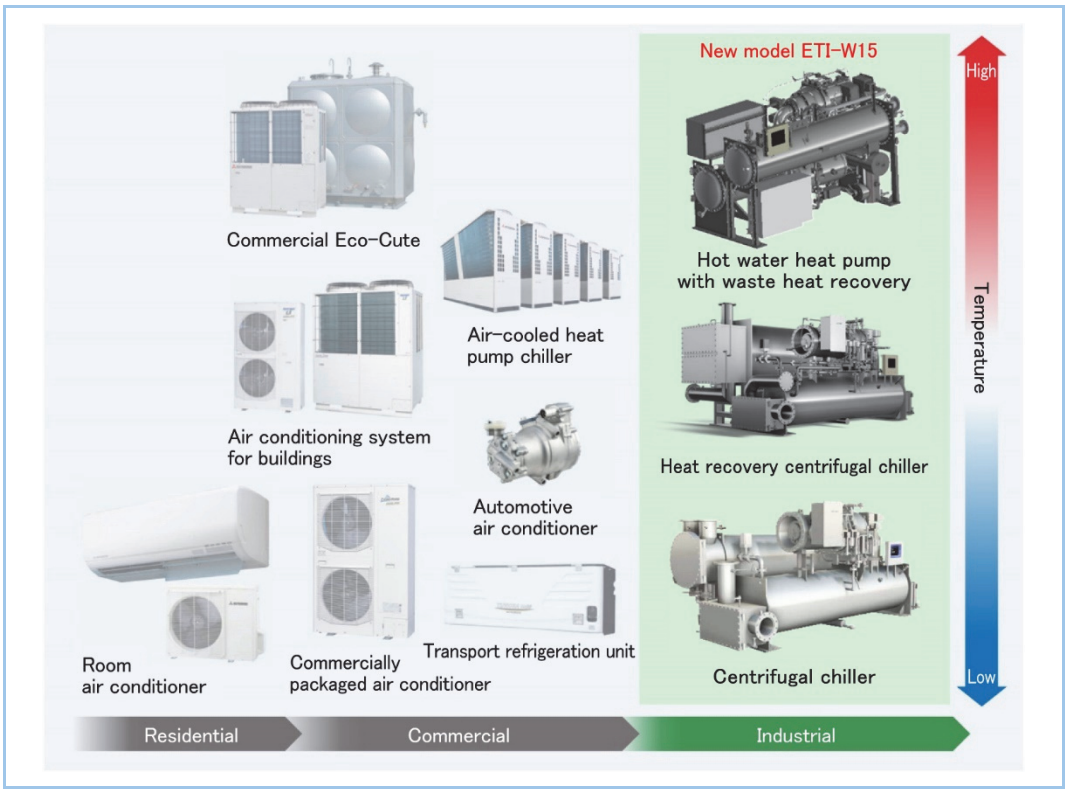


Figure 1 MTH product line-up according to supply temperature and application type

2. Specifications of the new model

2.1 Refrigerant selection

A comparison of refrigerants is shown in **Table 1**. Since their physical properties are relatively similar to the conventional HFC-134a refrigerant, HFO-1234yf and HFO-1234ze(E) are considered to be possible alternatives. However, as heat pumps are mainly used in factory processes, long-term reliability is required. For the new model, therefore, HFO-1233zd(E) was selected, because both design pressure and the number of compressor revolutions can be kept low in addition to the expected improvement in the performance due to the high theoretical COP.

Table 1 Refrigerant comparison

Refrigerant		HFC-134a	HFO-1234yf	HFO-1234ze(E)	HFO-1233zd(E)
GWP		1430	＜1	＜1	1
Refrigeration Safety Regulation under High-Pressure Gas Safety Act		Inert gas	Specified inert gas	Specified inert gas	Inert gas
Fluorocarbon Emissions Control Act		Applicable	N/A	N/A	N/A
Saturation pressure [MPa.G]	30℃	0.669	0.682	0.477	0.053
	90℃	3.143	2.979	2.374	0.732
Saturated gas density [kg/m^3]	30℃	37.5	43.7	30.5	8.5
	90℃	216.8	269.1	160.6	44.4
Theoretical COP [-]		2.799	2.366	2.797	3.341

	HFC-134a for air conditioning
7℃	0.273
37℃	0.836
7℃	18.3
37℃	46.0

*The theoretical COP is calculated with an evaporation temperature of 14°C, condensation temperature of 82°C, compressor efficiency of 80%, and a single-stage refrigeration cycle.

2.2 Product specifications

Specifications of the new model, along with those of the previous model, are shown in **Table 2**. Operable ranges are shown in **Figure 2**. Performance of the heat exchanger is improved by adopting a shell and tube system, resulting in a significant increase in COP of 20-40% over the previous model. The new model, based on the ETI-Z series, was designed to cover a high-temperature range, as described below.

- High-temperature resistant condenser

The condenser especially experiences high temperatures, and was designed in consideration of stress caused by thermal expansion. Since pressure exceeds 0.2 MPa(G) at 51°C or higher, HFO-1233zd(E) is subject to the Japanese High Pressure Gas Safety Act. The design of the equipment of the new model therefore satisfies the required strength calculations.

- Compressor design

In order to operate at a high compression ratio, the compressor adopts a structure in which a speed-increasing gear is used so the impeller can rotate at a higher speed than the electric motor. Based on the compressor of the ETI series where HFC-134a is used as a refrigerant, the new compressor that uses HFO-1233zd(E) has been designed so it can operate at a similar number of revolutions as past models with a proven achievement. Since its launch in 2009, the ETI series has been widely used for about 15 years, earning solid reliability on the market.

With the above design details, the new model has an operable range comparable to the previous ETW-L series, and can provide hot water at temperatures up to 90°C. The heat source water inlet temperature can be as low as 10°C, making it possible to utilize low temperature heat sources.

Table 2 Specifications of the new model

Item	Previous ETW-L series	New model
Refrigerant	HFC-134a	HFO-1233zd(E)
Applicable law	Refrigeration Safety Regulation under High-Pressure Gas Safety Act	Refrigeration Safety Regulation under High-Pressure Gas Safety Act
Temperature range	Hot water outlet: 50-90°C Heat source water inlet: 10-40°C	Hot water outlet: 50-90°C Heat source water inlet: 10-40°C
Heating capacity	About 200-600 kW	About 200-670 kW
Number of compressor revolutions	Up to ≈45,000 rpm	Up to ≈24,800 rpm
Cycle	Two-stage compression, single-stage expansion cycle	Two-stage compression, two-stage expansion subcooled cycle
Evaporator	Brazed plate type	Shell and tube type
Condenser	Brazed plate type	Shell and tube type
Economizer	Brazed plate type	Tank type
Subcooler	N/A	Shell and tube type
External dimensions	L 1.55 m × W 1.2 m × H 2.065 m	L 3.144 m × W 1.576 m × H 1.723 m (Ref. ETI-20) L 3.596 × W 1.520 × H 1.750

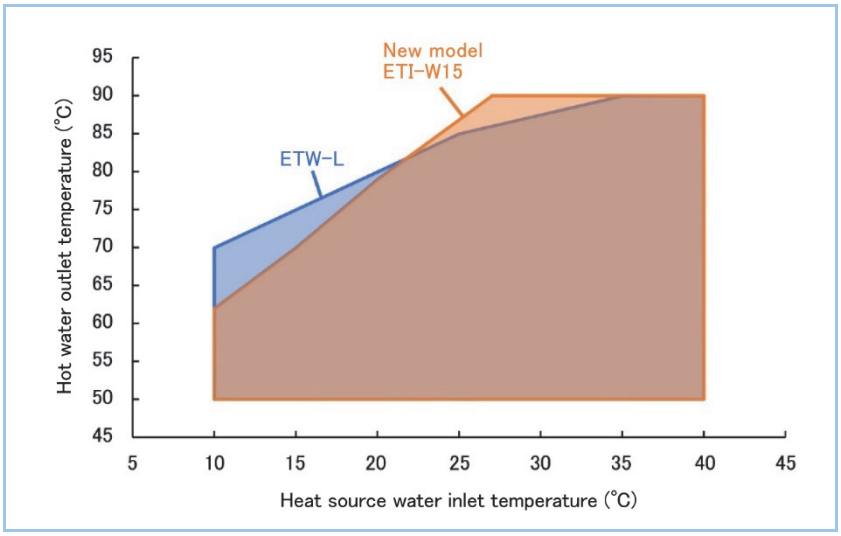


Figure 2 Operable temperature range

2.3 Product appearance

The new model has a compact design with the inverter installed on the evaporator, achieving integration with the main chiller body. Other containers and the control panel are located under the condenser. A view of the actual exterior of the new model (taken during the verification operation at a factory) is shown in **Figure 3**.

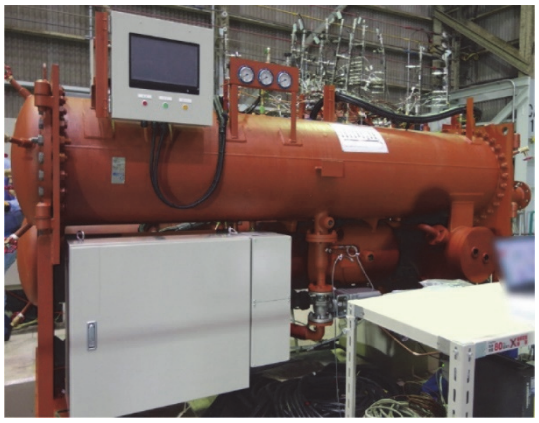


Figure 3 Exterior view (taken during verification operations at a factory)

3. Expected applications

A typical application example for this new model is shown in **Figure 4**. Hot water is required in the semiconductor production line. On the other hand, the centrifugal chiller is used for air conditioning to control a room's temperature (e.g. for a clean room). Waste heat in the cooling water is discharged from the cooling tower. In the example before introduction, the boiler is used to supply hot water, and waste heat from the air conditioning system is discarded. In the example after introduction, the boiler is replaced by the heat pump and a new system is set up so the cooling water from the chiller is effectively utilized as a heat source to produce hot water.

Hot water can also be supplied for purposes, such as coating/plating or sterilization in beverage factories, using other types of heat source water, including gray water and wastewater. In cases where hot water or steam is needed at temperatures 90°C or higher, a boiler can be used in combination. In other words, this heat pump can raise the temperature of boiler feed water to an appropriate level before superheating by the boiler, which can reduce CO_2 emissions and improve system efficiency.

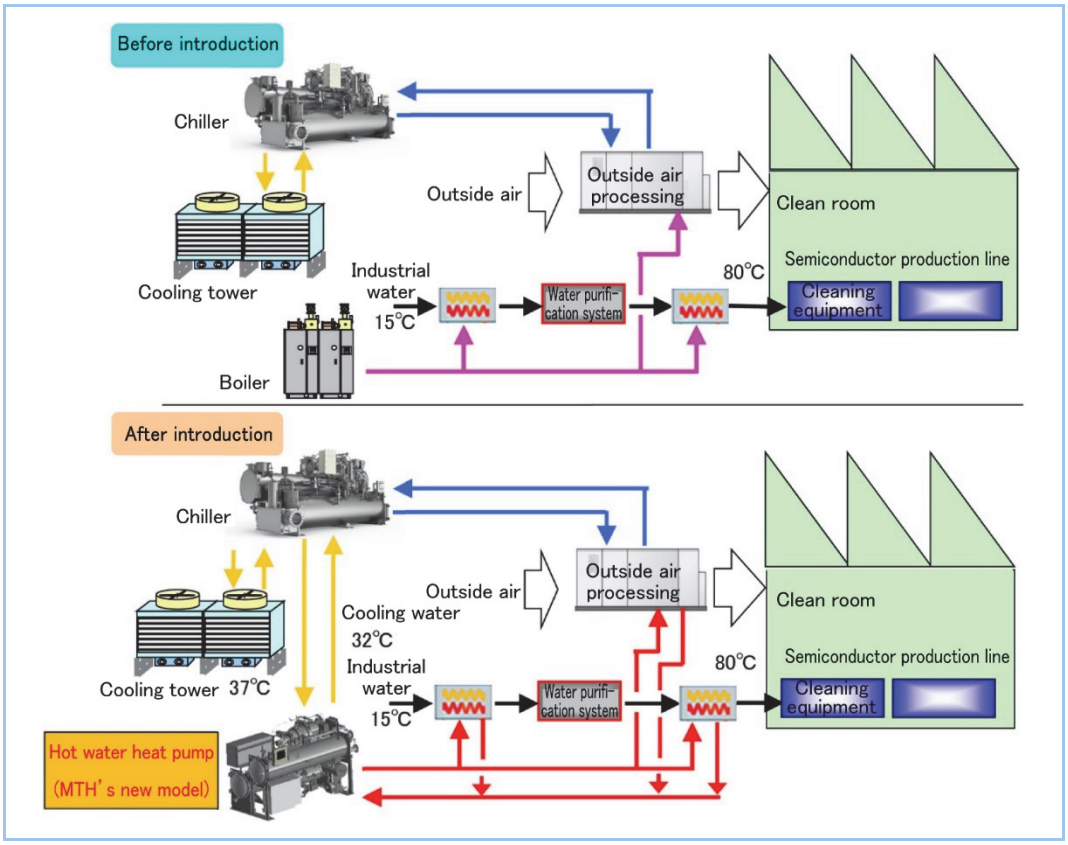


Figure 4 Application example

4. Future prospects

Heat pumps that use a low-GWP refrigerant can considerably contribute to reducing energy consumption and CO_2 emissions, and are expected to be in high demand on the market. Looking forward, MTH plans to utilize its expertise gained from its conventional ETW-L series to expand the options and provide a highly versatile new model.