Heat Application Technology by Centrifugal Heat Pump ETW Series for Hot Water - Continuous Supply of Hot Water at temperature of 90°C -

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From the perspective of reducing CO_2 emissions and saving energy, heat pumps, which make the best use of waste heat, are attracting attention and are beginning to enter into industrial use. Mitsubishi Heavy Industries, Ltd. (MHI) began to sell the centrifugal heat pump ETW-L model last year, which extended the application range of heat source water to the low temperature range (10°C to 50°C) and can still handle hot water up to a maximum temperature of 90°C. This paper introduces the specifications and features of our heat pump products and heat recovery technologies together with specific application examples and also describes the effects of CO_2 emissions and running cost reduction through the adoption of a heat pump.

1. Introduction

Applications of heat and high temperature water for heating, disinfection and washing can be widely found in factories, plants, etc. Although the combustion of fossil fuels including heavy oil, natural gas, etc., has been used for these heat applications until now, from the perspective of saving energy and reducing CO_2 emissions, heat pumps, which make the best use of waste heat, are attracting attention and are beginning to enter into industrial use in applications such as heating and washing in processes, air conditioning and other uses. This technology extracts heat from the atmosphere and thermal effluent and generates hot water, making effective use of heat.

MHI first developed a centrifugal-type compressor type heat pump (MHI product model: ETW-H) that allowed hot water of up to 80°C to be continuously supplied by recovering the heat that is emitted from the cooling water tower of a factory to the atmosphere, as well as the waste heat that is cooled to 35-50°C and discharged to the sewer system, etc., after being discarded in processes and other purposes. The company then developed and began to sell a new heat pump (MHI product model: ETW-L) in July 2010 that is useful for factory processes and that enables hot water of up to 90°C to be continuously supplied by extending the application range of the heat source as low as 10°C.

The features and performance of the centrifugal heat pump ETW-L, as well as various specific application examples, are introduced herein. We also introduce the effects of reducing CO_2 emissions and running costs through the adoption of the ETW-L as an example.

2. Features and performance of the centrifugal heat pump ETW-L

2.1 Basic principle

The basic principle of the centrifugal heat pump ETW-L is shown in **Figure 1**. The heat pump has a centrifugal-type compressor and adopts a two-stage compressor and a single-stage economizer cycle. In the vaporizer, which is a plate-type heat exchanger, the temperature of the heat source water flowing inside it is higher than that of the surrounding refrigerant flowing in between the plates, so that the quantity of heat Q1 is transferred from the heat source water to the refrigerant.

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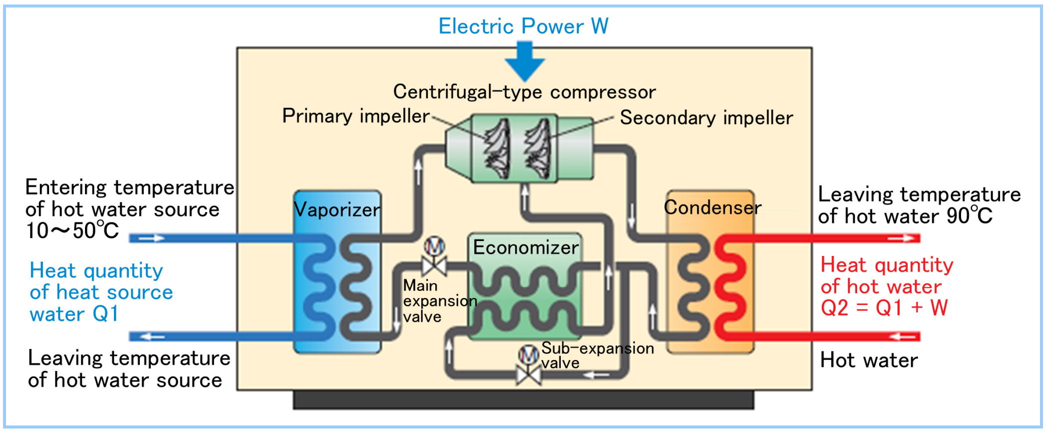

Figure 1 Basic principle of centrifugal heat pump ETW-L

The refrigerant is vaporized at a temperature corresponding to the saturated vapor pressure within the vaporizer, and then suctioned into the centrifugal-type compressor to be compressed by the primary impeller, which rotates at high speed. After being cooled down by the refrigerant from the economizer, it is further compressed by the secondary impeller to be sent to the condenser. Then electric power W, which is input into the centrifugal-type compressor, becomes heat energy to be transferred to the refrigerant, which is warmed up and pressurized to be sent to the condenser (the heat exchanger).The hot water flowing between the plates, the temperature of which is lower than that of the refrigerant gas, removes the heat from the refrigerant gas within the condenser. It is then condensed at a temperature corresponding to the saturated vapor pressure within the condenser. At that time, the hot water is warmed up by the refrigerant with the quantity of heat Q2 = Q1 + W; the heat from the heat source water is transferred to the hot water. In addition, the condensed refrigerant liquid is sent to the economizer, and after being cooled down by the refrigerant that was decompressed by a sub-expansion valve, it is further decompressed by the main expansion valve into the vaporizer to be vaporized again.

The refrigerant that was decompressed by the sub-expansion valve becomes a gas and is suctioned into the secondary impeller and thereby one cycle is completed. The same process is continuously repeated, so that heat is continuously transferred from the heat source water to the hot water.

2.2 Features

2.2.1 Comparison with the ETW-H

The ETW-L has some advantages compared with the ETW-H, which preceded it on the market. Notable items are described below.

(1) Adoption of high head type impeller

The ETW-L adopts a high head type impeller, which is based on the impeller of the ETW-H and is adaptable for low temperature heat sources and can handle high pressure differences.

(2) Adaptable for a wide temperature range of heat source water and practicable to provide hot water of up to 90°C.

Figure 2 shows the application range of the ETW-H and ETW-L.

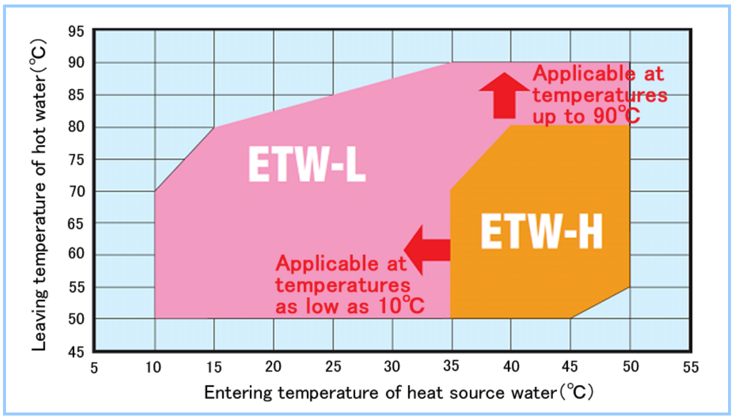

Figure 2 Application range of centrifugal heat pump ETW

The application range of the ETW-L is greater than that of the ETW-H; the entering temperature of the heat source water ranges from 10-50°C and the leaving temperature of the hot water ranges from 50-90°C. Extending the entering temperature of the heat source water as low as 10°C enables chilled water for air conditioning use to be supplied at the same time as hot water.

In addition, because the ETW-L adopts a high head type impeller and while the application range of the ETW-L covers that of the ETW-H, the ETW-H has an advantage in terms of heating capacity and COP, over the ETW-L in the application range of the ETW-H.

(3) Selectable hot water leaving temperature control or heat source water (chilled water) leaving temperature control

The leaving temperatures of the hot water and heat source water (chilled water) can be chosen and controlled within a certain range, but the leaving temperature not selected becomes uncontrolled.

2.2.2 Modifications from conventional heat pump

Modifications from the specifications of a conventional heat pump are mainly conducted as follows:

(1) Reduction of size and weight

Table 1 shows the major items of the specifications. The size has been reduced by shrinking the components, changing the cycle, reviewing the piping layout and through other measures, resulting in an approximately 30% reduction of the installation area and a roughly 24% drop in weight compared with a conventional heat pump, making the system the equivalent size of a small once-through boiler.

Table 1 ETW-L specifications

Item	Specification	Item	Specification
Heating capacity	547 kW	Legal refrigeration ton	109
Temperature of hot water	80°C in/90°C out	COP	3.7
Flow rate of hot water	48.3 m^3/h	L x W x H	1.55 m x 1.2 m x 2.0 m (2.2 m x 1.2 m x 2.1 m)
Temperature of heat source water	50°C in/45°C out	Basic machine mass	2,400 kg (3,150 kg)
Flow rate of heat source water	70.9 m^3/h	Operating mass	2,700 kg (3,610 kg)
Electric power consumption	147.6 kW	Refrigerant	HFC-134a

(2) Facilitating close installation

By modifying the layout of the interior equipment so as to provide access for maintenance from the control panel and nozzle side, making it unnecessary to access the equipment from the side, close installation of multiple ETW-Ls with no space between them is possible, with the aim of reducing the installation area (**Figure 3**).

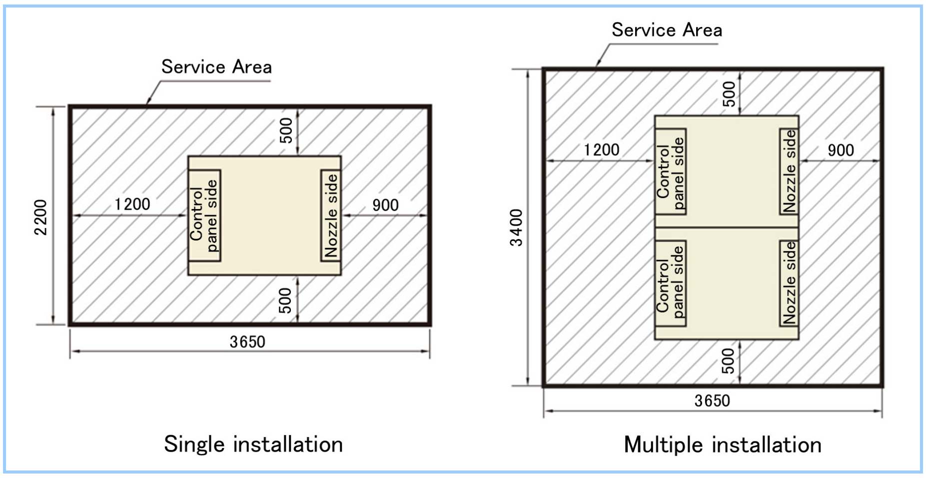

Figure 3 Equipment layout

(3) Unification of power source

Although a conventional heat pump needs a 400V class power source as the main supply in addition to a 200V class power source for the control system, the ETW-L can be operated just with a 400V class power source by mounting a transformer therein.

2.3 Performance

The centrifugal heat pump ETW-L has a coefficient of performance (COP) of 3.7, based on inverter input power under the conditions where the leaving temperature of the hot water is 90°C and the entering temperature of the heat source water is 50°C, in addition to including the power consumption of the oil pump and control system. As a result, when replacing a boiler, a substantial reduction of CO_2 emissions and significant energy savings can be realized.

Figure 4 shows a map of heating capacity. While the application range of the entering temperature of the heat source water is 10-50°C, with the entering temperature being more than 35°C, hot water of 90°C can be output. When the entering temperature of the heat source water is 10°C, the leaving temperature of the hot water can be up to 70°C. In addition, when the leaving temperature of the hot water is constant, the higher the entering temperature of the heat source water, the larger the heating capacity.

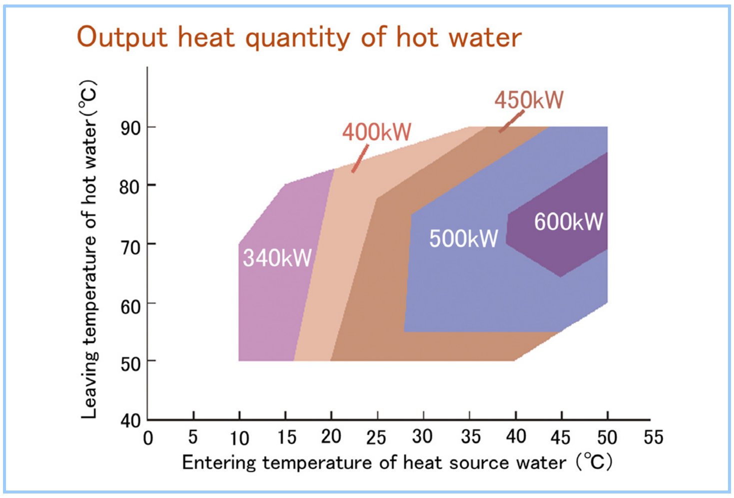

Figure 4 Heating capacity map of ETW-L

Figure 5 shows a map of the COP. The higher the entering temperature of the heat source water and the lower the leaving temperature of the hot water, the higher the COP. A heating COP of up to 7.0 can be output, as can a combined COP of up to 13.0 that takes cooling capacity into account.

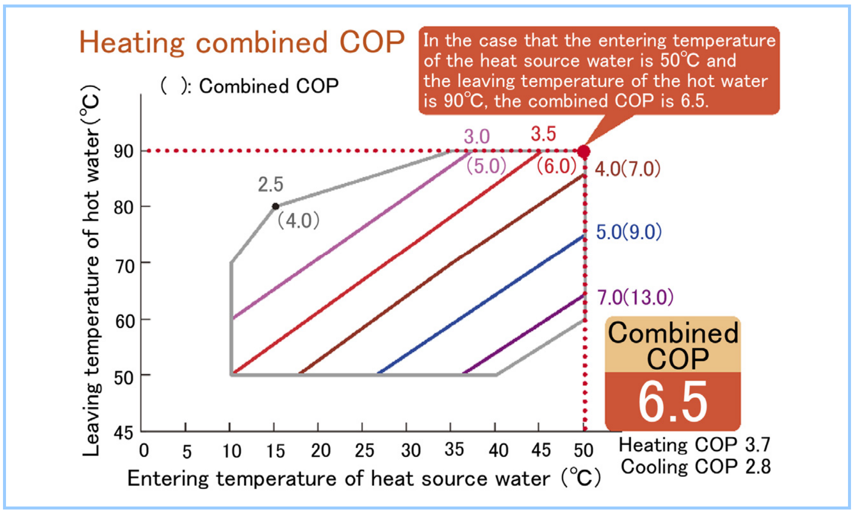

Figure 5 COP map of ETW-L

3. Application Example

3.1 Application example at a beverage factory

Figure 6 shows an application example of the centrifugal heat pump ETW.

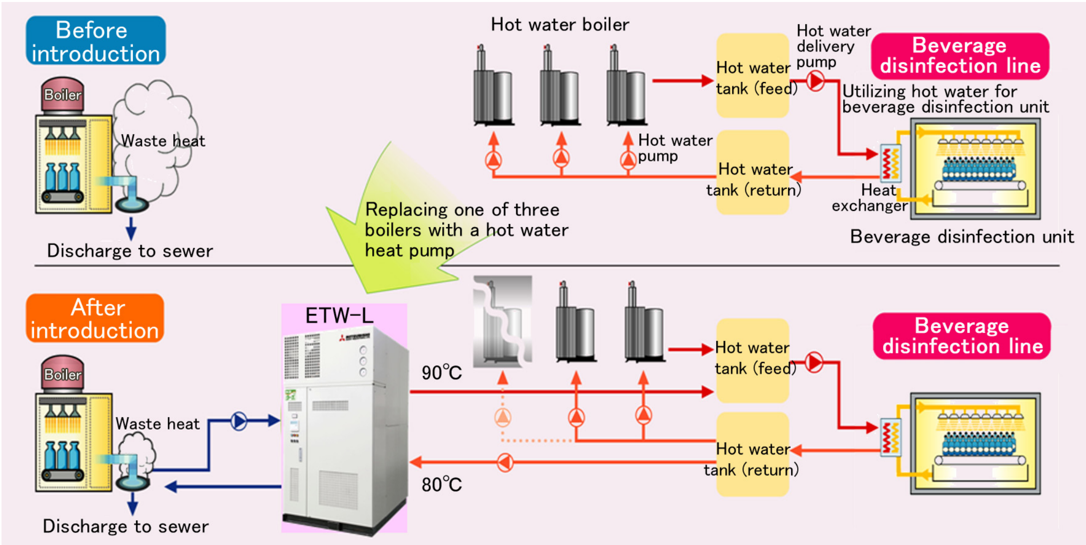

Figure 6 Example of system

In a beverage factory, hot water produced by a boiler is used in large quantities for warming, disinfection, etc. On the other hand, in the case that hot waste water is produced simultaneously and the plant simply drains the hot waste water into the drainage system, introducing the centrifugal heat pump ETW into the waste water system allows hot waste water to be effectively employed as heat source water, enabling the installation of a system producing hot water of up to 90°C.

3.2 Application example for desiccant air conditioning

For industrial air conditioning use such as in a food factory or battery factory, etc., desiccant air conditioning is typically seen. In addition, for general air conditioning use, the energy saving feature of desiccant air conditioning is attracting attention, such that desiccant air conditioning is being introduced in recent years. On the other hand, because a heat source for regeneration is necessary for desiccant air conditioning, a boiler is mainly adopted particularly in industrial use when there is no hot waste heat available. **Figure 7** shows an example of the system.

Figure 7(a) shows a conventional desiccant air conditioning system in which hot water generated by a boiler is used as a heat source for regeneration. In addition, the cooling of intake air including pre-cooling is in this case conducted by a centrifugal chiller. On the contrary, Figure 7(b) shows an example of the ETW system in which the centrifugal heat pump ETW is used for the regeneration heat source instead of a boiler. The cooling water of a centrifugal chiller is used for the heat source water for the ETW. Furthermore, to cope with the imbalance between the thermal load and the cold energy load, a cooling tower is installed in the heat source water line.

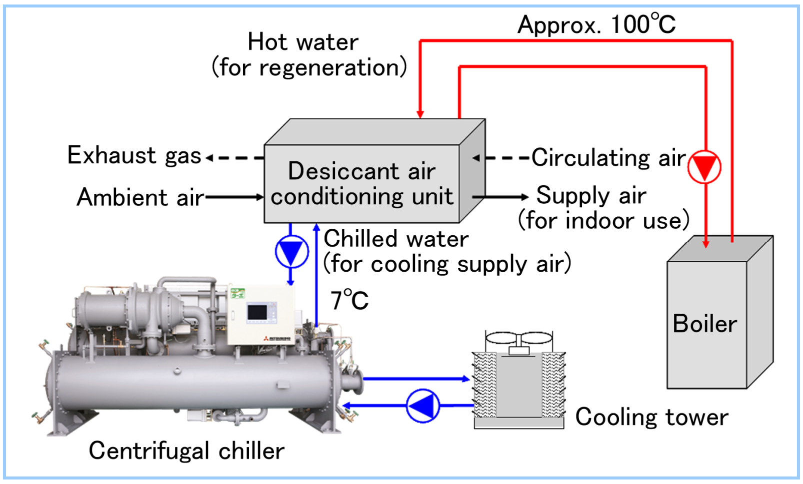

Figure 7 (a) Example of desiccant system using a boiler

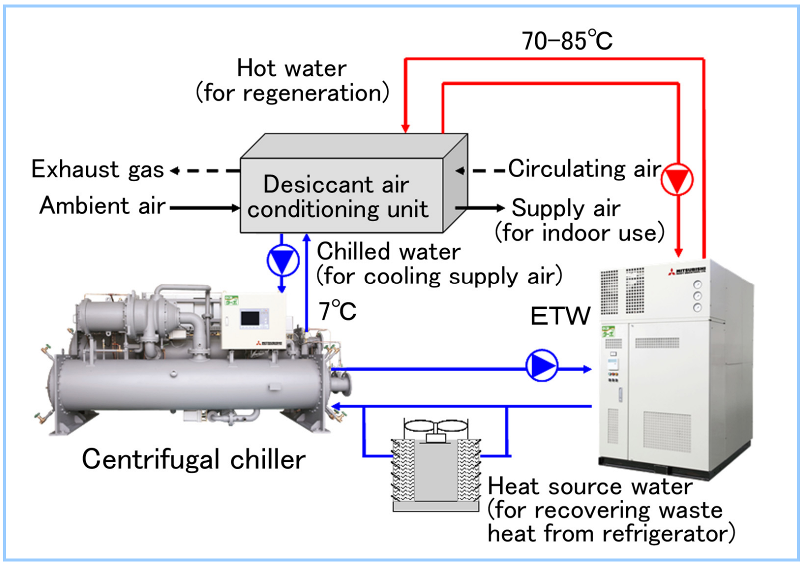

Figure 7 (b) Example of desiccant system using ETW

3.3 Other application examples

(1) Washing unit

Many production lines, such as in food factories or machine shops, etc., contain washing steps using hot water. By utilizing the heat from various cooling water and waste water processes after washing for the centrifugal heat pump ETW, the improvement of production line system efficiency can be expected.

(2) Application for coating and metal plating

In pre- and post-coating and metal plating processes such as degreasing, washing, drying, etc., the need for heat can be expected. The centrifugal heat pump ETW can provide a wide range of hot water temperatures that can cope with processes that require various temperatures depending on the material and use.

(3) Preheating of boiler feedwater

When hot water or steam of more than 90°C is required, boiler feedwater can first be warmed up by the centrifugal heat pump ETW before being heated to the target temperature by the boiler. This can contribute to a reduction of fossil fuel consumption and improve overall efficiency in harmony with a boiler.

(4) Hot water supply and heating

By employing heat from hot spring waste hot water and cooling water from refrigerators as a heat source, hot water and heating can be provided for lodging and bath facilities. For example, an efficient system in combination with a hot water storage tank can be constructed and used in hot spring facilities in applications such as additional heating for cold springs.

(5) Applications of river water or seawater

Through indirect heat exchangers, depending on the water quality conditions, the use of a heat source from river water or seawater is also possible, meaning that applications to large-scale systems such as district heating can be anticipated.

(6) Utilization of terrestrial heat

Because the temperature of the heat source can be as low as 10°C, terrestrial heat such as the heat of underground water, which is generally said to be around the annual average temperature of the area, can be used as a heat source to construct a heat pump system.

(7) Utilization of heat from sewage

When the utilization of urban waste heat is considered, as a means to bridge the physical distance between waste heat from air conditioning facilities through the year and the need for heat source water such as hot water and heating, a method of employing the sewer system, which is existing infrastructure, as a heat highway can be conceived. Since the temperature of sewage is stable in the range of 10-30°C throughout the year, heat exchange between physically separated locations can have the flexibility, for instance, to release waste heat at one location and utilize sewage as a heat source at another. This is a useful application for the future.

4. Effect of CO_2 emissions reduction and economic benefits

We make a comparison between CO_2 emissions reduction and economic benefits using the above example of a desiccant air conditioning system. Data used in the calculation of economic benefits are shown in **Table 2**, under the conditions of being operated 24 hours a day, 365 days a year and a boiler efficiency of 0.85. In this calculation, the energy consumption volume of the air conditioner, heat source equipment and auxiliary equipment (pump, etc.) that makeup the system are calculated for both a boiler system and the ETW application system, and then the amount of CO_2 emissions and running cost are determined using the unit CO_2 emissions volume and unit cost from Table 2.

Table 2 Basic data

Item	Unit CO_2 emissions rate	Unit cost	Calorific value
Electricity	0.324 kg-CO_2/kWh [1]	12.9 yen/kWh [2]	-
Town Gas (13A)	2.19 kg-CO_2/Nm^3 [3]	58.71 yen/Nm^3 [4]	40.6 MJ/Nm^3 [5]

Figure 8 shows the calculated amount of annual CO_2 emissions. The ETW application system can reduce CO_2 emissions by roughly another 32% annually compared with a boiler-used system, and in a running cost comparison with the same conditions, can also reduce running cost by about 11% annually (**Figure 9**). In the annual running cost calculation, only the energy consumption of each equipment configuration is considered, but water cost is not taken into account because the heat source water of the ETW is used in a centrifugal chiller as cooling water, so water cost can also be reduced.

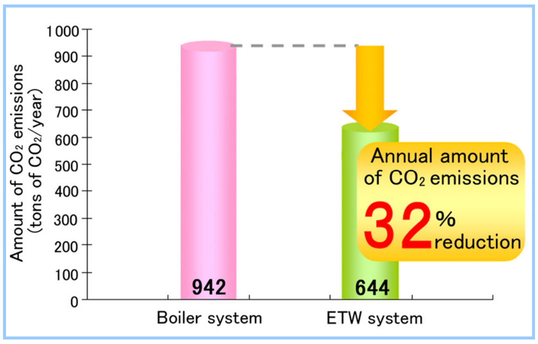

Figure 8 Comparison of annual amount of CO_2 emissions

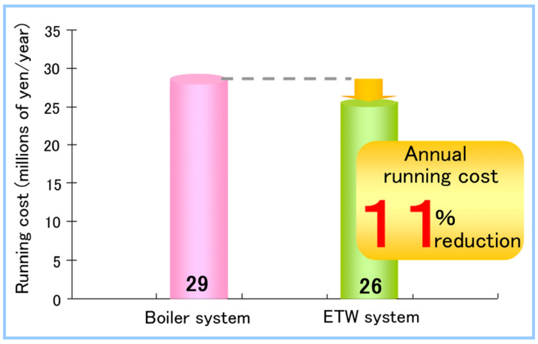

Figure 9 Comparison of annual running cost

5. Conclusion

The centrifugal heat pump ETW series has been developed based on the technologies that have been accumulated in MHI centrifugal chillers. The centrifugal heat pump ETW-H that is already on the market has a good reputation in various plants as a product that can efficiently utilize the waste heat of a factory and effectively provide hot water. With the addition of the ETW-L to the MHI lineup, hot water can cover high temperature ranges up to 90°C. Furthermore, the extension of the range of heat source water to temperatures as low as 10°C widens the range of the utilization of waste heat. As a result, applications to not only heating use for processes or air conditioning, but also cold energy use for various locations, can be expected.

As was described above, by widely meeting user needs in various applications through the use and enhancement of the ETW series, we will continue to develop an even better product and present a new system that can contribute to energy and cost savings.

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