

The “eco Turbo ETI” Series of High-Performance Variable-Speed-Control Centrifugal Chillers



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1. Introduction

Due to the growing social concern related to energy conservation and reduction of CO₂ emissions, high-efficiency centrifugal chillers are now widely used, not only in industrial applications such as heat sources in factories, but also in air conditioning system of buildings. However, centrifugal chillers consume large amounts of energy because of the large-capacity heat pumps they contain. The reduction of CO₂ emissions is now an important consideration in the technical improvement and product development of this equipment. The development of user-friendly products that are easy to install has also become a vital issue because of the widespread application of high-efficiency centrifugal chillers in heat sources.

This paper describes recent trends and requirements for the main components in heat sources, and discusses the new “eco Turbo ETI” series of high-efficiency centrifugal chillers equipped with inverters as standard equipment, introduced in May 2008.

2. Centrifugal chiller market and product concept

Absorption chillers using oil and gas as fuel were generally used in large-capacity heat source equipment for air conditioning systems to help with summertime peak power reduction and electrical load leveling after the first spike in oil prices. However, calculations of the CO₂ emissions involved in producing the power required by these systems showed that the emissions due to absorption chillers were approximately 1.9 times^{note} that required by centrifugal chillers. It is thus imperative to review conventional approaches in terms of energy conservation and CO₂ emission reduction. Market studies reveal that sales of absorption chillers are declining even as domestic shipment of large-capacity chillers is leveling off, showing that the market is turning to high-efficiency centrifugal chillers that have found a new role as alternative heat sources.

Note: This calculation is based on the following assumptions: the COP of the centrifugal chiller is 6.4, the COP of the absorption chiller is 1.35, the generating efficiency is 41.9%, and electricity transmission loss is 4.7% based on the 2004 Tokyo Electric Power performance.

In other words, future centrifugal chillers will be primarily designed for, and integrated into, business-use air conditioning equipment with a refrigeration capacity of about 200 USRt. Reducing installation area and shipping weight has become increasingly important as the typical installation has changed from the factory compound to the general office building. Over the past several years, the approach to technical innovation has shifted from offering a certain coefficient of performance (COP) under rated conditions to providing year-round efficiency even under conditions of partial loading or low-temperature cooling water, which are more representative of how the chillers are actually used most of the time.

Mitsubishi Heavy Industries, Ltd., (MHI) has marketed a centrifugal chiller series using inverter-driven variable-speed controls since 2003. The present AART-I series effectively reduces annual energy consumption. Even so, MHI concluded that it was necessary to incorporate inverter-driven variable-speed controls into new centrifugal chiller models as standard equipment (**Figure 1**).

Based on market trends and user requirements, MHI developed new centrifugal chillers with the following product features:

- Smaller capacity (150–500 USRt)
- High performance (inverters included as standard equipment)
- Easy introduction (compact and lightweight)

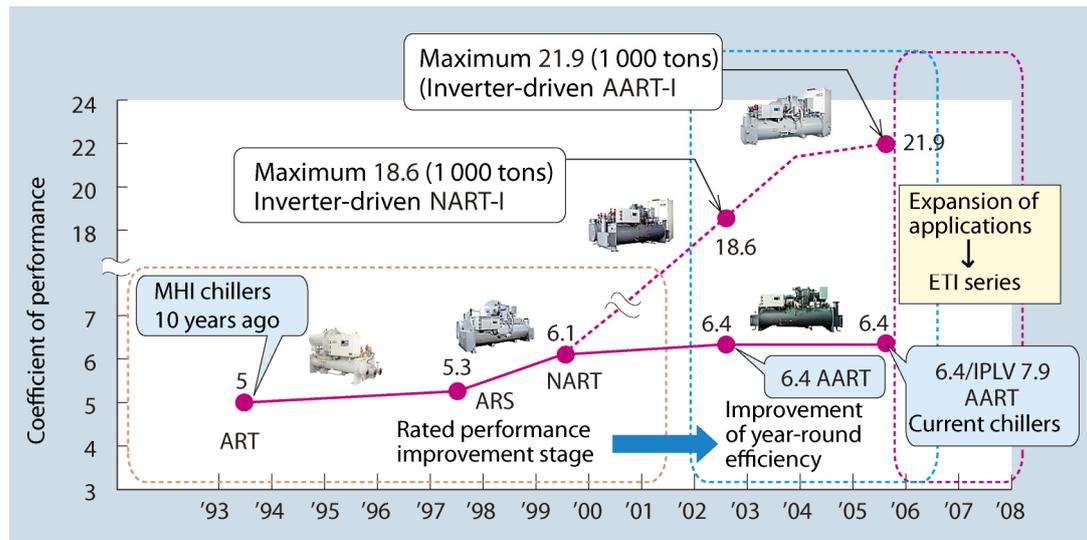


Figure 1 Centrifugal chiller transition

3. Detailed configuration of the ETI series

3.1 High-performance design

We started with the features of large centrifugal chillers that had actually proven achievement in high efficiency, and downsized and increased the performance of the chiller by carefully examining each feature. Typical features in this process included the following:

- Two-stage compression, two-stage expansion sub-cooling cycle
- High-precision machined impeller
- Low-loss gears and bearings
- First- and second-stage inlet guide vane control
- Load and cooling-water temperature follow-up controls using six-element mathematical operational control
- Inverter-driven compressor variable speed control
- Optional correspondence to just almost nonloading control with a capacity of less than 10%

The performance of a chiller declines as the size decreases due to the relative decrease in part and assembly accuracy. However, we minimized the performance reduction through the following technical approaches:

- Reevaluation of machining accuracy, reexamination of tolerances, and review of surface roughness criteria for each aerodynamic component
- Reexamination of standard tolerances during parts assembly
- Reexamination of specifications and auxiliary capacity.

Table 1 lists the specifications of the ETI-20 (title photograph) and the ETI-40 (**Figure 2**).

Table 1 Specifications of the ETI-20 and ETI-40

| Model | | ETI-20 | ETI-40 |
|--|--------|--------------------------------|--------------------------------|
| Refrigerating capacity | (USRt) | 200 | 400 |
| | (kW) | 703 | 1407 |
| Chilled-water temperature (°C) | | 12 in/7 out | 12 in/7 out |
| Chilled-water flow rate (m ³ /hr) | | 120.7 | 241.3 |
| Cooling-water temperature (°C) | | 32 in/37 out | 32 in/37 out |
| Cooling-water flow rate (m ³ /hr) | | 142.6 | 285.2 |
| Power consumption (kW) | | 116.6 | 233.7 |
| Statutory refrigeration ton | | 87.3 | 174.6 |
| COP | | 6.0 | 6.0 |
| Size (m) | | 3.7 long × 1.5 wide × 1.8 high | 4.5 long × 2.0 wide × 2.2 high |
| Refrigerant | | HFC-134a | |

Rated COP is calculated based on power consumption summing inverter input power, oil pump, and the control power source. A COP of 6 is the best performance of any comparable 200-USRt-class product. The year-round efficiency, an important factor in annual power consumption, is very high, resulting in an integrated part-load value (IPLV) of 10.2, and a maximum COP of 19.1 under partial loading. Both the IPLV and COP are high level for evaluating year-round cooling and heating applications (Figure 3).



Figure 2 ETI-40 exterior

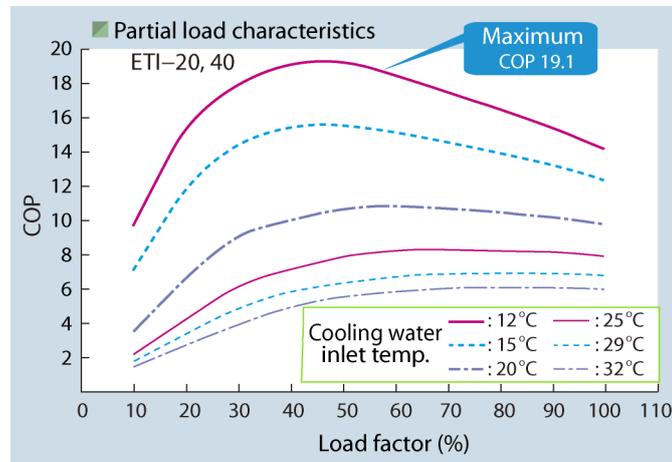


Figure 3 Partial load characteristics of the ETI-20 and -40

3.2 Compact and lightweight design

Models ETI-15, -20, and -25 are single-compressor units with different configurations to provide various capacities in the range 150–250 URSt. Models ETI-30, -40, and -50 are two-compressor units that cover the range 300–500 URSt. We managed to reduce the size by using the same compressor for both series.

- (1) Compact and lightweight compressor
 - We reduced the size of the motors and gears by using dedicated high-speed motors for the inverter.
 - We reduced the compressor weight and volume by separating the oil tank and oil pump from the compressor itself.
- (2) Compact and lightweight unit
 - We incorporated an inverter into the chiller body and eliminated the need for a separate inverter panel.
 - We located components such as subcooler, economizer and oil tank under the condenser.
 - We designed a heat exchanger optimized for the 250- and 500-USRt small-capacity class.

By optimizing the items described above, we were able to reduce the installation area for the ETI-20 and ETI-40 by approximately 40% and 20%, and the equipment weight by 49% and 27%, respectively, compared to our conventional models with the same capacity. This makes installation of new centrifugal chillers much easier.

3.3 Improvement of controllability and operability

We used the latest developments control panel technology for the ETI series of centrifugal chillers to improve operability and visibility, and provide enhanced basic functions.

- (1) Improvement of operability and visibility
 - We used a 10.4-inch color liquid crystal display to improve the visibility with a bright clear digital display and large characters.
 - We provided a dedicated CPU to enhance the display and reduce operator stress during the operation of the equipment.
 - The display backlight turns itself off after a period of inactivity. We also provided a detection sensor to turn the display lighting on again without the operator having to touch the panel. This reduces the possibility of error and decreases operator stress.
- (2) Enhancement of basic functions
 - We were able to increase the speed and capacity of the main control CPU by transferring control of the liquid crystal display to a dedicated CPU.
 - Made up of lead-free components, the operation panel is RoHS-compliant.

4. Evaluation of reduction of cost and CO₂ emissions

Figure 4 compares the CO₂ emissions of the ETI series, current fixed-speed AART series, and the ART series that dates from approximately 10 years ago. A preliminary calculation shows that the cost and CO₂ emissions of the ETI series are reduced by 62% compared to those of the existing ART series under air-conditioning loading. What is remarkable here is that the year-round power cost for the ETI series falls far below than that of current high-performance AART series for air-conditioning loading. This shows the value of the inverters.

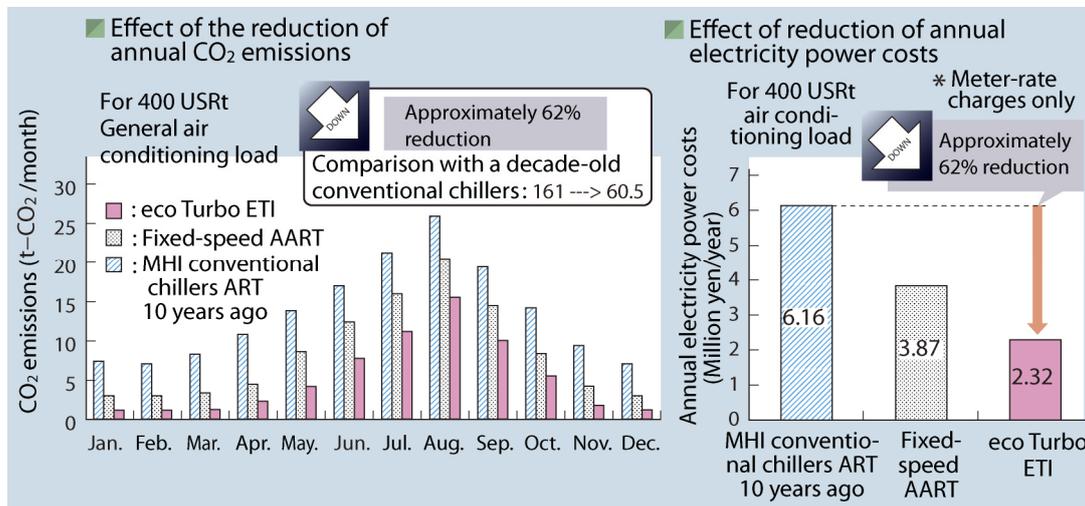


Figure 4 Reduction of cost and CO₂ emissions

5. Conclusion

The ETI series of high-performance compact small-capacity centrifugal chillers reflects market demands. The series has achieved reliable performance using a balance of new concepts, time-tested technology, and a design optimized for small-capacity applications. The performance characteristics are the same as or better than those of large-capacity high-performance centrifugal chillers. In addition to their use in air conditioning systems for conventional industrial or large-capacity commercial applications, the ETI series now offers substantial energy savings and reduction of CO₂ emissions to customers with small air conditioning systems or who need small-capacity equipment.

Inverter-driven centrifugal chillers will be the basis for other models that can be used for many new applications. The ETI chillers are the first step in a series that responds to customer needs, and we will continue our efforts to develop further products to cater to market demands.

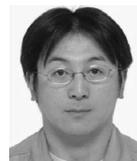
References

1. Wajima, K. et al., Centrifugal Chiller Maximizing Year-round Efficiency, pp.35-39, Mitsubishi Heavy Industries Technical Review Vol. 45 No. 2 (2008)

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