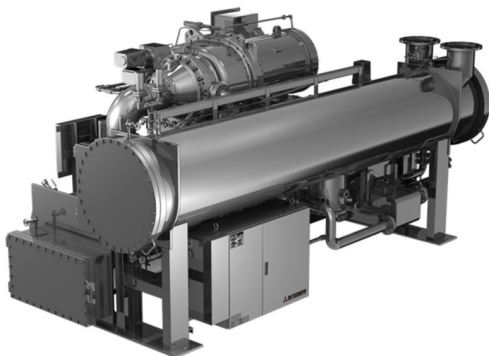


# “GART Series” Large Capacity Centrifugal Chillers Achieved High Efficiency, Downsizing



KAZUKI WAJIMA\*1

YASUSHI HASEGAWA\*2

OSAMU HASEGAWA\*3

JUN KOGA\*3

NAOKI YAWATA\*2

Recently, domestic demand in terms of both total capacity and number of shipments of centrifugal chillers has been declining because of factors such as the trend of customers shifting production facilities to overseas locations. Therefore, to motivate customers to select the centrifugal chillers of Mitsubishi Heavy Industries Ltd. (MHI), products with functions and specifications that satisfy customer requests for heat source equipment, including demands for a reduction of electricity consumption and saving of installation volume space, are needed. The GART series of large capacity centrifugal chillers achieves both high efficiency and a smaller size in response to the requests of customers. By not only improving the performance and compactness of its components such as the compressor and the heat exchanger, but also by using the space effectively, the layout of the GART series has been optimized so that the space volume ratio is enhanced. As a result, a rated COP (Coefficient Of Performance) of 6.5, a 6% increase of IPLV (Integrated Part Load Value) compared with existing models and a 40% reduction of the space volume of the machine compared with existing models have been attained.

## 1. Introduction

Although demand for centrifugal chillers has been growing overseas mainly in emerging countries, domestic demand has been declining since its peak in 2007. Domestic demand for centrifugal chillers in 2012 in terms of total capacity as well as number of shipments has decreased to half. This is because of a reduction in the construction of new domestic heat source facilities due to factors such as the trend of customers shifting production facilities to overseas locations since the Lehman crisis in 2008. Because of this background, when customers renovate existing heat source facilities or build new models, they require efficient planning and operation of heat source equipment and request higher functionality for the centrifugal chiller to be used.

The main role of a centrifugal chiller is to create chilled water for cooling, but the creation of the necessary quantity of chilled water is a matter of course. What is important when a customer selects a centrifugal chiller is the characteristics of the product, including its capabilities to reduce electricity consumption in operation and the saving of necessary installation space. Therefore chillers with high efficiency that can reduce electricity consumption and compactness that enables space-saving will be selected by customers.

This paper presents the GART series of large-capacity centrifugal chillers that attain both high efficiency and compactness to address those requests of customers.

## 2. Background of development of GART series

Since 2000, the high-capacity centrifugal chillers that MHI produces have specialized in products that use R134a, an ozone-friendly refrigerant. In 2000, MHI brought the NART series of high-performance models to the market. Since then, MHI has released the AART series with the

\*1 Chief Staff Manager, Chiller & Heat Pump Engineering Department, Air-Conditioning & Refrigeration Division  
Machinery, Equipment & Infrastructure

\*2 Chiller & Heat Pump Engineering Department, Air-Conditioning & Refrigeration Division, Machinery, Equipment & Infrastructure

\*3 Chief Staff Manager, Takasago Research & Development Center, Technology & Innovation Headquarters

industry's highest level of rated COP of 6.4 in 2003, and chiller models that attain high efficiency in the entire practical operating range including partial load operation due to the employment of an inverter and the improvement of the control mechanism in 2006. The improvement of COP has a direct effect on the economic aspect of the operation of the heat source facilities of customers, and also contributes to environmental conservation through benefits such as a reduction of CO<sub>2</sub> emissions. MHI has been researching performance enhancements and the optimum control of the compressor and heat exchanger in order to improve the performance of centrifugal chillers. However, the insatiable pursuit of performance improvement without being content with the current situation is still required.

On the other hand, the layout design has not been changed significantly since the launch of the NART series, and the space volume, which is the product of the overall length, width and height of the machine, has remained unchanged since then. The reduction of the space volume of a chiller enables the improvement of refrigerating capability without extending the machine room. In addition, in the case of replacements where the space volume of the machine room is limited, a machine with larger dimensions cannot be installed even if it has higher efficiency. Reduction of the space volume of a centrifugal chiller enhances the flexibility of the customer's facility plan and enables the selection of the model that suits their needs.

Accordingly, just providing high efficiency or compactness cannot meet the needs of customers, and only a chiller offering both will be selected. MHI has developed the GART series under the concept of the simultaneous pursuit of high efficiency and compactness, while aiming to improve COP from 6.4 to 6.5, reduce space volume by up to 30% and attain the smallest size in the market.

### 3. Technologies for simultaneous pursuit of high efficiency and compactness

The main technologies for high efficiency and compactness of the GART series, as well as their simultaneous pursuit, are described below.

#### 3.1 Higher efficiency and compactness of compressor

The compressor is an important component that defines the performance of the centrifugal chiller. For high efficiency and the compactness of the compressor, the technologies described in (1) and (2) below are used (Figure 1).

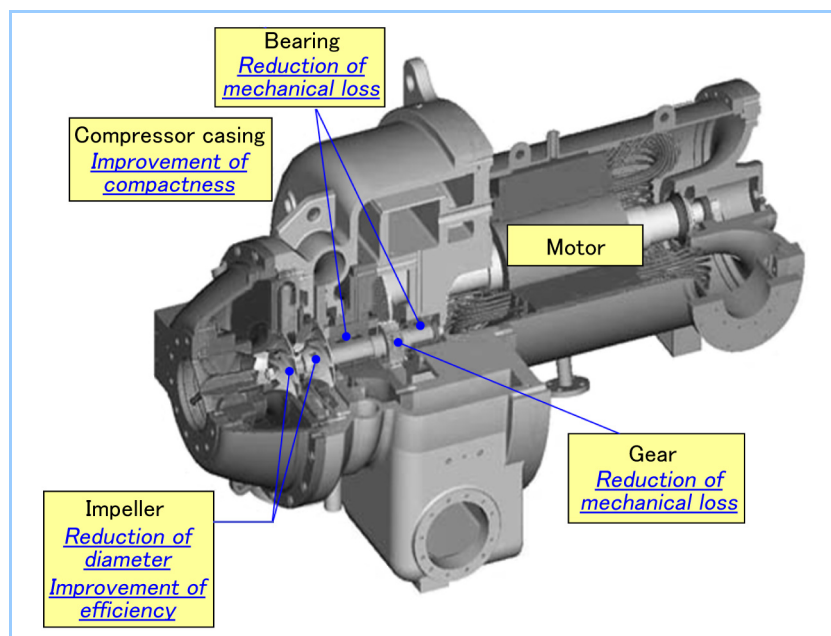


Figure 1 Improvement of compressor

##### (1) Aerodynamic design capable of high efficiency and compactness

To enhance the performance and compactness of a compressor, the improvement of the aerodynamic characteristics of the impeller is indispensable. The developed impeller has a revised blade shape and aerodynamic characteristics with increased gas flow quantity. In

addition, through the improvement of the shape of the anterior edge of the impeller blade and the variable guide vane at the inlet of the impeller, higher efficiency than existing models is attained even with a smaller impeller diameter.

(2) Reduction of mechanical loss due to downsizing

A compressor uses speed increasing gears to accelerate from the rotation speed of the motor. On the developed compressor, the distance between the shaft centers of the motor and the compressor is shortened and the circumferential velocity of the gears is lessened due to a reduction of the impeller diameter. As a result, the mechanical loss at the gears is lowered. In addition, the diameter of the compressor shaft itself is reduced in order to lessen the mechanical loss at the bearing. Consequently, a reduction in mechanical loss of up to 25% is attained in comparison with existing models with the same cooling capacity.

Due to the use of these technologies, the compressor attains both high efficiency and compactness. The volume and the weight of the compressor are reduced by up to 30% and 35%, respectively.

### 3.2 Compactness of heat exchanger

The heat exchanger is designed so that its size is reduced while retaining the current level of performance.

(1) Evaporator and condenser

The shell and tube type evaporator and condenser use high-performance thin heat transfer tubes. The combination of number, length, and diameter of the heat transfer tubes is readjusted to minimize the heat transfer area. As a result, the number of heat transfer tubes can be reduced, resulting in a smaller diameter of the cylindrical shell compared with that of existing heat exchangers.

(2) Plate heat exchanger

The sub cooler and economizer employ a high-performance brazed plate heat exchanger. In particular, due to the change from an adiabatic expansion flush tank type to a plate heat exchanger type, the economizer attains a volume reduction of 50% or more and therefore a significant saving of the refrigerant used.

### 3.3 Separation of operating part from controlling part

The operating part is what the customer uses for the operation of the chiller, and needs to be placed where the customer can use it easily regardless of the size of the machine. Operating panels that include both the operating part and the controlling part tend to be larger, and must be placed at the outermost position regardless of the efficient layout design of the machine in order to ensure operability. In some cases the operating panel interferes in the carrying-in of the machine and needs to be removed in advance.

Therefore the GART series employs an operating part separated from the large-sized controlling part, which is fixed because the user need not access it frequently. The operating part is downsized so that it can be placed freely according to the customer's request without having an effect on the external dimensions of the machine (**Figure 2**).



**Figure 2** Comparison of operating panels

### 3.4 Improvement of space occupation rate of main components to unit layout

In addition to improvement in the compactness of the components, the layout is designed so that the space occupation rate of the main components (the rate of the spatial volume of the main components to the occupation volume of the entire chiller) is improved through effective space usage in the placement of components. With the conventional layout design, the evaporator and the condenser were placed at the lower part, the compressor was placed above the condenser and the sub cooler, the economizer and the operating panel were placed overhanging the evaporator and the condenser, and therefore the rate of the occupation volume of the main components to the entire space volume of the chiller was approximately 28%. In contrast, the space occupation rate of the main components is enhanced to approximately 35% by placing the compressor above the evaporator, the condenser beside the compressor and the sub cooler, the economizer and the controlling part below the condenser. As a result, the volume reduction rate is improved from 25% in total for components to up to approximately 40% for the entire chiller (Figure 3 and Table 1).

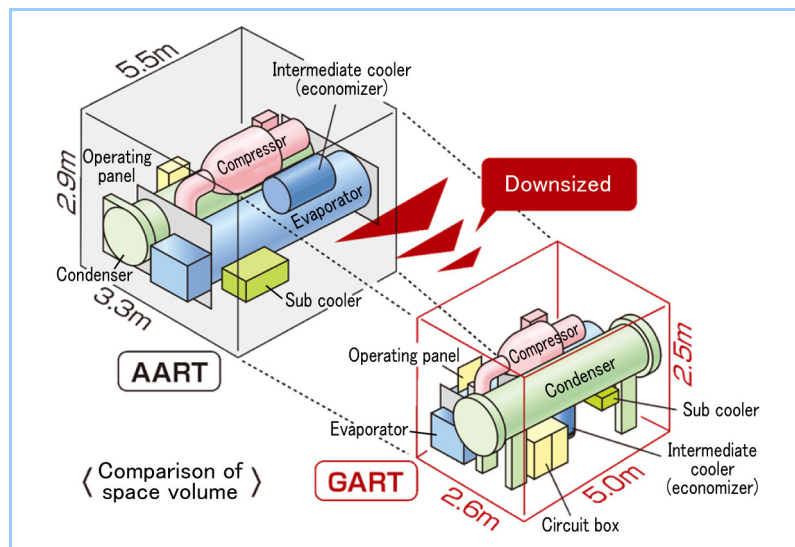


Figure 3 Effective space usage in placement of components

Table 1 Comparison of space volume to existing models

	AART-90	GART-110	Reduction rate
Total space volume of main components (m <sup>3</sup> )	14.8	11.1	25%
Space volume of entire chiller (m <sup>3</sup> )	52.6	31.3	41%
Space occupation rate	28.1%	35.6%	—

## 4. Features of GART series

Due to the use of these technologies, the GART series attains both high efficiency and compactness. The features of each attainment are described below.

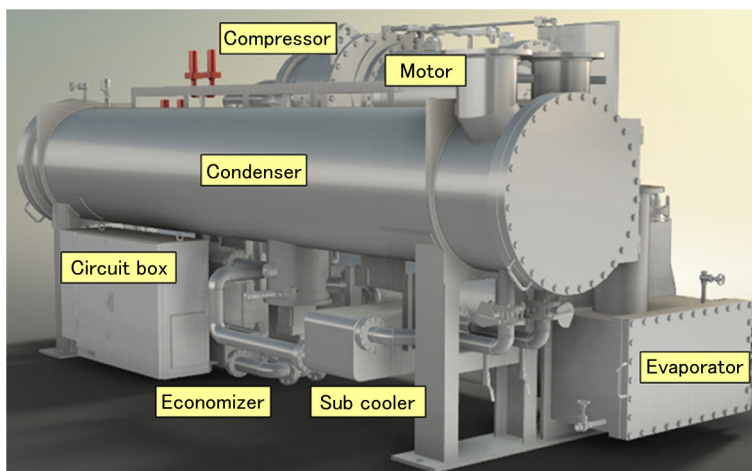
### 4.1 Higher efficiency

The centrifugal chiller machine models of the GART series with cooling capacity of 1100 USRt, 1600 USRt and 2200 USRt attain the target of the development, which is a rated COP of 6.5 or higher under the JIS conditions (chilled water entering temperature 12°C and leaving temperature 7°C, cooling water entering temperature 32°C and leaving temperature 37°C at the outlet), in contrast to 6.4 or lower for existing models. In addition, the partial load performance is improved to IPLV 7.24 of fixed speed machines and IPLV 9.29 of inverter machines. This is a performance improvement of approximately 6% compared with existing models. The IPLV is a further practical performance evaluation index for centrifugal chillers that takes into consideration the partial load performance. Most of the actual operating time of a centrifugal chiller is accounted for by partial load operation, and therefore performance improvement for partial load operation is truly advantageous for customers. In the GART series, the maximum cooling capacity is enhanced through improvement in the control system of the inlet variable guide vane that controls the capacity of the compressor, and the operating point where the compressor attains the highest

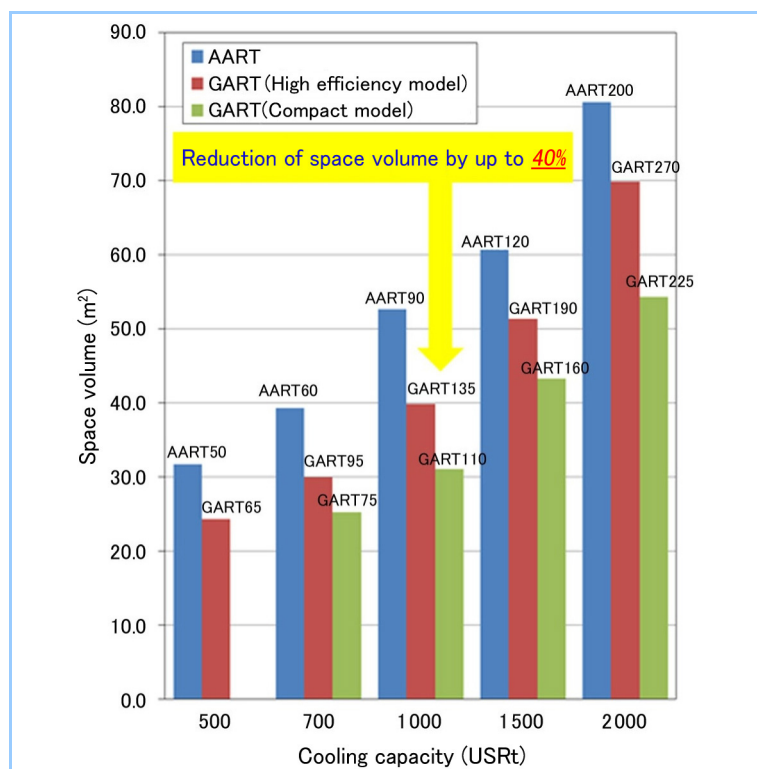
efficiency can be shifted into the partial load operating range. As a result, the COP in partial load operation is improved, and therefore the enhancement of the IPLV to the rated COP or higher can be attained.

## 4.2 Compactness

**Figure 4** shows the external view of the chiller. As described above, the compactness of components is improved and the unit layout is designed so that the evaporator and the condenser are placed at the outermost location in the width direction and the sub cooler, the economizer, and the circuit box of the controlling part do not protrude outward. The GART series chillers are available in high performance GART-65, 95, 135, 190, 270 models and compact GART-75, 110, 160, and 225 models. Customers can select either the high performance model or the compact model according to the priority of their needs. The high performance models are also more compact when compared with existing models. **Figure 5** compares the space volume between the GART series and existing machines for representative cooling capacity. As shown in this figure, the space volume is reduced by up to approximately 40% and attains the smallest level in the market. Also the footprint, which is the projected area based on the length and the width without reference to the height, attains a reduction of up to approximately 30%.



**Figure 4** External view of GART



**Figure 5** Comparison of space volume to existing models



## **5. Conclusion**

A centrifugal chiller is used as heat source equipment in a customer's heat source facility. The reduction of electricity charges and space volume for installation has a direct effect on the customer's business activity. In addition, a centrifugal chiller has an important role not only in economics, but also in the reduction of environmental load such as the suppression of global warming and the reduction of CO<sub>2</sub> emissions. Furthermore, the improvement of compactness can contribute to a reduction in material, as well as the saving of installation space, resulting in the suppression of the consumption of various energy sources during the manufacture of the machine. MHI considers that the needs of customers are the same regardless of whether overseas or domestic, and expects that the GART series launched in February 2014 will become prevalent domestically and abroad, meeting a wide range of demands from customers and society in the future.

The GART series attains high efficiency and compactness, but MHI does not believe that its functions can satisfy the needs of customers eternally. MHI will continue to pursue further improvement of functions without being content with the current functions in order to help customers.