Development of compact air heat pump inverter module chiller

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Abstract:

A further improvement of energy-saving performance has been required in the air-cooled heat pump inverter module chiller from the viewpoint of preventing global warming. In addition, in recent years there has been a growing demand to improve the partial load performance, not only the full load performance.
To meet such needs, we have developed a compact air heat pump inverter module chiller with high efficiency.
By connecting multiple 60HP modules, it is possible to cope with a large capacity easily.
Diversification of risks of a refrigerant leak and a unit stop becomes possible by multiple modules, and it becomes possible to apply to a data center that needs temperature stability.
We report the following.
・Energy saving performance of the module which has adopted the new technology of the inverter-driven scroll compressor and 2 evaporation temperature by new refrigeration cycle.
・Each module performs most efficiently with improved operation. The unit is equipped with a module unit control device which determines the optimal operation number using the sum of the frequency of the compressor in the system.
As a result, a multi-module system can achieve a further partial load efficiency compared to a single module system.
・This unit has a built-in header in the module, to reduce the setting time of the piping in case of installation of multiple modules.

Keywords:module chiller, inverter-driven compressor, energy saving, compact

1. INTRODUCTION

Air cooled heat pump chillers [1-3] are used as air conditioning for large buildings, schools, hospitals, and factories and is the central heat source machine for outdoor air processing.

Recently, chillers have been focusing on effective ways to prevent global warming [4] by reducing the refrigerant and they are required to reduce power consumption at part load conditions as well as the rated conditions.

In addition, because many of the numbers of chillers in the market are in demand for replacement, chillers are required to have an increased capacity for cooling and heating with the same foot print in the installation area.

Therefore, the air-cooled heat pump chiller DT-R was developed to reduce power consumption and to improve the installation area. This was done by improving the device and adopting a new shape for the unit. The DT-R can reduce installation space requirements with a new modular connection structure, and improves partial load characteristics with the number of controls in a large load system.

2. FEATURES OF PRODUCT

The chillers are used with multi units for high demand of heat load to avoid the risk of failure. Fig.1 shows the appearance of DT-R with 4-connetions. A heat exchanger is placed diagonally on the machine room which is rectangular. The fan is on top of unit. Therefore, DT-R is designed as a Y-structure to obtain service space and to prevent a decreased flow rate, during installation of multi units.

Table.1 shows the DT-R performance. DT-R achieved the highest COP in the chiller market of 50HP by using a highly efficient device for the refrigeration circuit.

DT-R can reach a capacity of 60HP with the same foot print as a 50HP (1.08m×3.40m) by decreasing the elements volume of the refrigeration circuit. Therefore, DT-R can decrease installation area.

DT-R has a better part load performance than conventional machines due to the mounted inverter compressor. SEER is a 4.5.

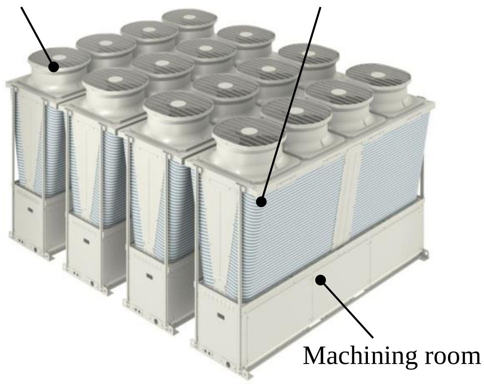


Fig1. Externals of DT-R (4-connection)

Tabel.1 Performance of DT-R

		DT-R	
Horsepower		60HP	50HP
Cooling	Capacity(kW)	180	150
	COP※1	3.12	3.47
	SEER	4.12	4.44
Heating	Capacity(kW)	180	150
	COP	3.24	3.42
Dimension		2,350(H)×1,080(W)×3,400(D)	
Refrigerant		R410A	
Capacity per area(kW/m^2)		49.02	40.85

※1 Difference of inlet and outlet water temperature is 7 degree celsius

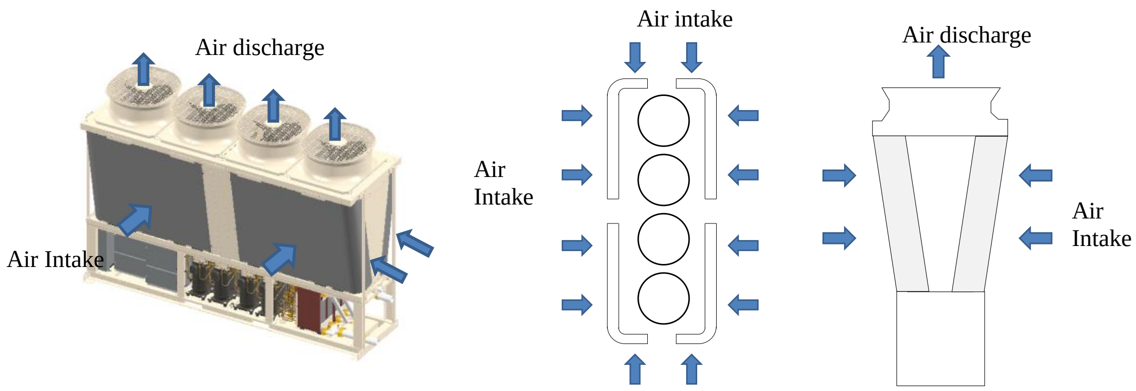
3. ENERGY-SAVING TECHNOLOGY AND DOWNSIZING TECHNOLOGY

We introduce energy-saving technology and downsizing technology, which was introduced into the DT-R.

3.1 Air heat exchanger

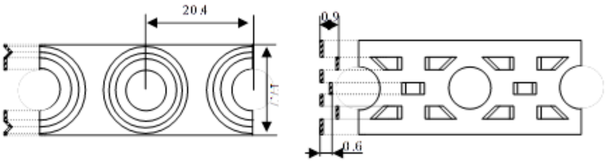
DT-R reduced the air heat transfer area by about 37% compared to our conventional unit in order to maintain a general foot print for chillers in the market (width 1.08m×depth 3.40m). To prevent decreasing overall heat transfer coefficient of a new, small air heat exchanger, DT-R was fitted with the new zigzag slit fin that is shown in Fig.3 [5] and a large diameter fan. Therefore, it was as same as our conventional unit.

Further, to achieve downsizing of the unit and to reduce space with multiple installation, DT-R was shaped for intake from all four sides by mounting the four L-bend air heat exchangers diagonally as shown in fig2.



(a) External (b) Top view (c) Front view

Fig.2 Installation of air heat exchanger and flow of air



(a)Ring fin (b)Zigzag slit fin

Fig.3 The new fin type with high heat transfer rate

3.2 *dual inverter(High-efficiency scroll compressor and fan motor)*

DT-R is equipped with an inverter driving scroll compressor and an inverter-driven fan motor in order to improve the efficiency both at the regular load and partial load.

Fig.4 shows the characteristics of a scroll compressor. Conventional screw compressors are at their highest efficiency when at their 100% capacity. The inverter compressor reaches maximum COP when at about 60% capacity.

Fig.5 shows the relationship of the air volume and COP. If the flow rate is low, the air-side heat exchanger cannot sufficiently exchange heat when the passing wind speed is low. As a result, when high pressure is increased COP decreases. If the air volume is high, fan input is increased and the compressor input decreases due to a decrease in the high-pressure, as a result, COP is reduced. DT-R can run at high efficiency due to rotational speed control for optimum air flow in accordance with the operating conditions of the unit.

As a result, a COP ratio becomes 25% higher at 55% capacity rather than at 100% capacity. Because of the optimal control of the compressor frequency and fan rotation speed as shown in Fig.6, DT-R has a higher efficiency operation at partial load.

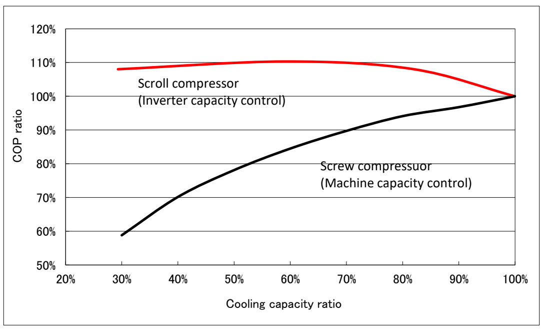


Fig.4 Comparison of compressor performance

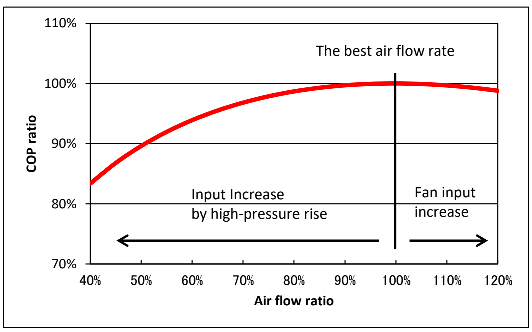


Fig.5 Performance to change in air flow rate

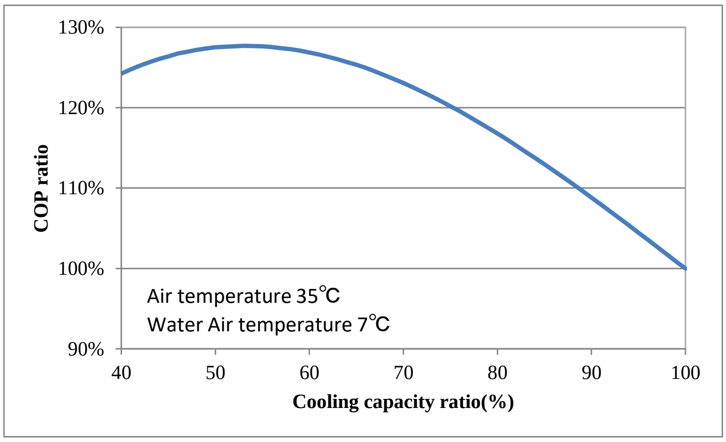


Fig.6 Part load performance of DT-R

3.3 Two evaporation temperature cycle

DT-R consists of 4- independent circuits as shown in Fig.7. Each circuit is equipped with an expansion valve and compressor and the heat exchanger. The water heat exchanger is configured to flow in a series. The plate heat exchangers of circuit 1 and 2 are arranged for the upper stream of the water circuit, and those of circuit 3 and 4 are arranged for the downstream.

For example, if the water temperature into the upper inlet is 12℃. The temperature will decrease to 9.4℃ when it leaves the upper circuit outlet. It will be cooled further from 9.4℃ to 7.0℃ after entering and exiting the lower circuit. In this case, the evaporation temperature of the upstream side circuit rises higher than the conventional model.

Because of the high evaporation temperature, the unit can be driven more efficiently than usual. Fig.8 shows the comparison of the evaporation temperatures between one evaporation cycle and two evaporation cycles. When the water temperature difference of the unit is 5℃, the evaporation temperature of the upstream heat exchanger rises 2.2℃ higher than usual, and it improves unit efficiency by 2%. In the case of use with large temperature differences, when water temperature fluctuation in the unit is 7℃, the evaporation temperature of the upstream heat exchanger rises 3.1℃, and this improves unit efficiency by 3%.

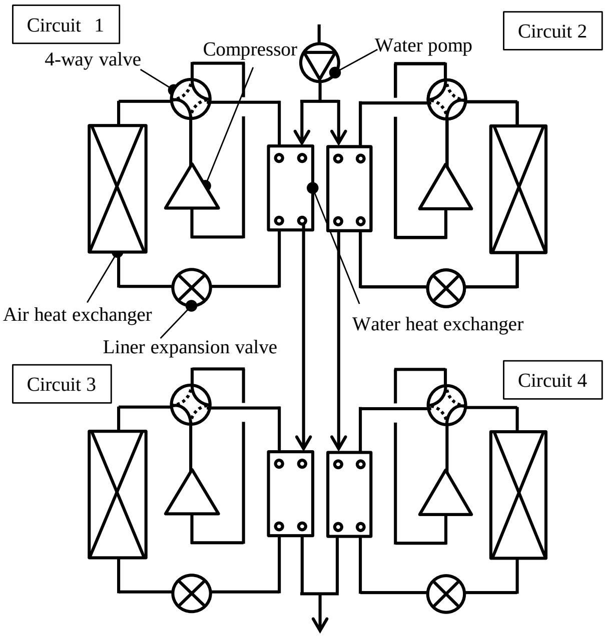


Fig.7 Refrigeration cycle of 'DT-R'(2-evaporation temperature circuit)

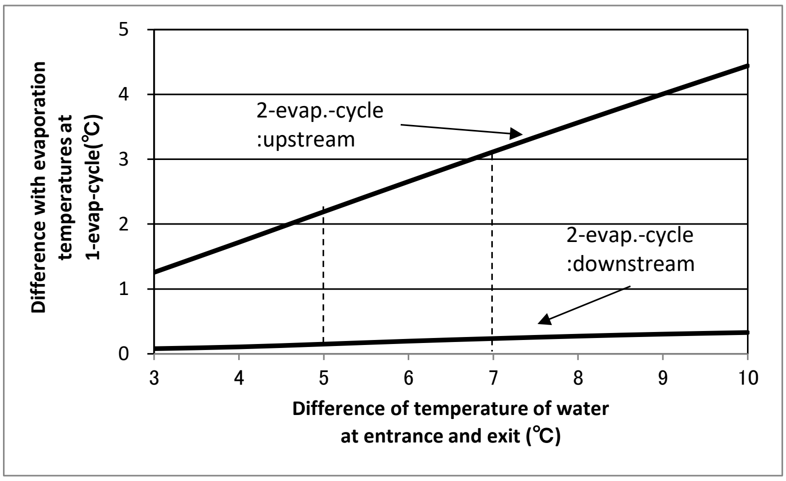


Fig.8 Comparison of evaporation temperatures at 1-evap.-cycle and 2-evap.-cycle

3.4 Module coupling structure

Fig.9 shows air intake space for consolidated installation. Because of the shape of the DT-R, the module can be connected to a Y-shaped structure. It is easy for it to suck in air even with consolidated installation.

Fig.10 shows the comparison of conventional machines (100HP ×3 units) and DT-R (60HP × 5 units) for an area installation with a load of 300HP.

By connecting the module, DT-R achieved a great reduction of installation space.

The installation space of DT-R is 48% of a conventional model.

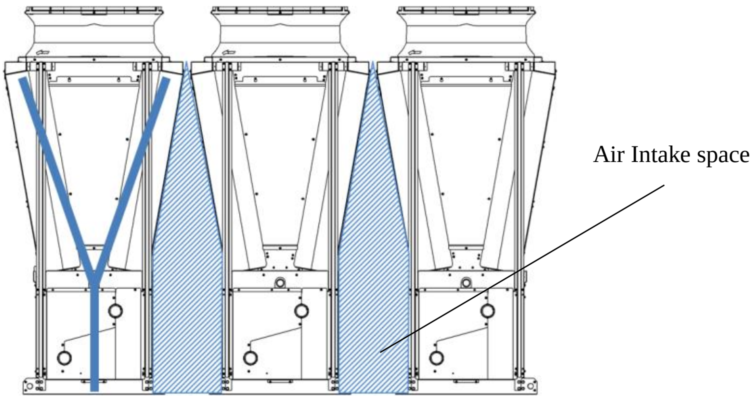
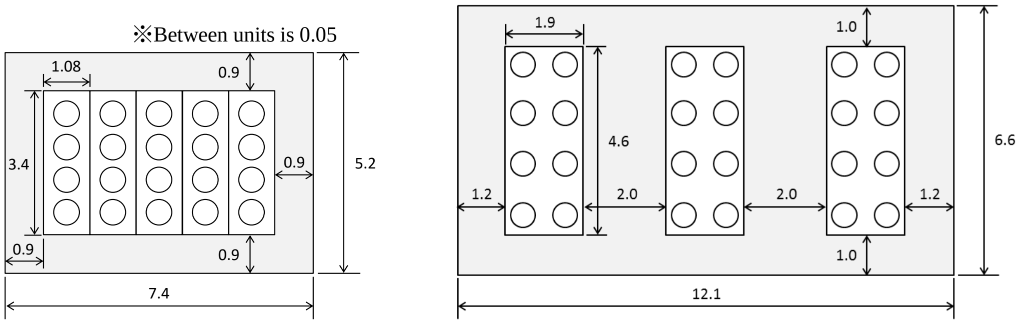


Fig.9 Air intake space in consolidated installation



(a)Development model
Installed areas: 38.5m2(48%)

(b) Conventional model
Installed areas: 79.9m2(100%)

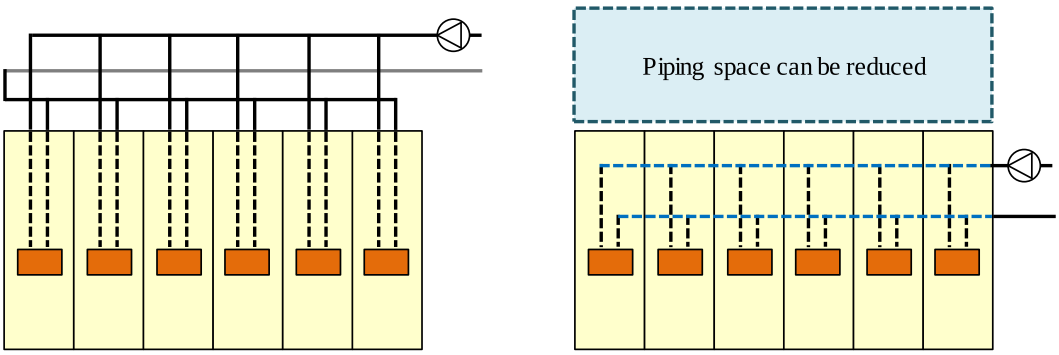
Fig.10 Comparison of installation areas (when there is no wall in the surroundings)

4. SIMPLIFICATION OF MULTIPLE INSTALLATION CONSTRUCTION

Water piping specifications of the DT-R was prepared using standard piping specifications and built-in header specifications as shown in fig.11. Standard piping specifications of various systems are easy to adapt and easy to design.

Built-in header specification is a specification to establish header pipe connection for each module (collection piping) in the machine room.

Fig.12 shows the construction configuration with internal header specifications. It can easily be constructed and shorten the construction period by reducing the connection points and the piping space at the time of multiple installation.



(a) Standard piping specifications (b) Built-in header specification

Fig.11 Water piping construction method

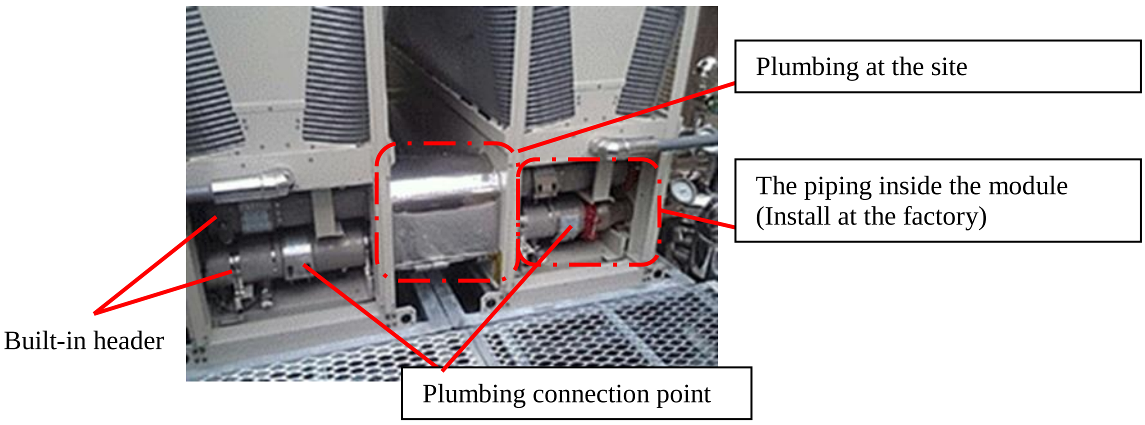


Fig.12 Construction situation of 'Built-in header specification'

5. HIGH EFFICIENCY BY THE MODULE MULTIPLE CONTROL

DT-R is designed for high-efficiency operation that can control a number of units during multiple operations.

The number controller determines the number of units based on the amount of the compressor frequency of all units. Because the DT-R increases the efficiency of partial load by more than 100% capacity, multiple operation controllers determines the number of operating units so that it can be operated by the compressor frequency which creates better unit efficiency.

Fig.13 shows a comparison of the partial load characteristics in controlling the number and the total number Batch control. Although the performance of number controllers and batch controllers are the same at a capacity of about 60% or more, number controllers can also maintain high efficiency operation in the low capacity range.

As a result, number controllers are able to manage the number of units so that the optimum frequency around 60% capacity is kept. Efficiency is better than the collective control.

The efficiency of the capacity ratio of 30% is improved by 20% when compared to the Batch control by control number.

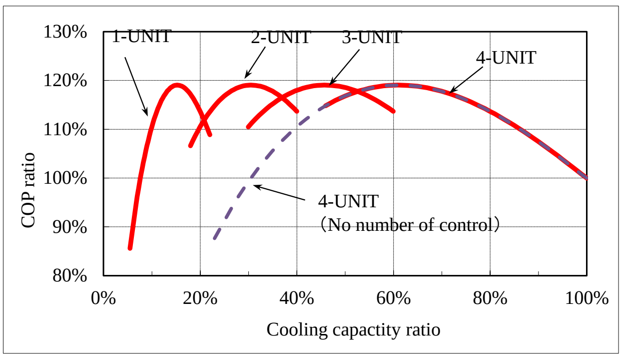


Fig.13 Comparison of part-load performance of the multiple numbers of controls

6. CONCLUSION

The new type chiller DT-R was developed to improve energy saving and the installation area of air-cooled heat pump chillers. This was done in order to meet the requirements of excellent energy saving performance from the point of view of global environmental protection.

DT-R has achieved a 48% smaller footprint than conventional machines by the following technology.

1) By New-Y-Shape structure, the modules can connect unit to unit and the space between the modules can eliminate.
2) By using high-efficient inverter compressor and adopting high-efficient small air heat exchanger equipped with Zigzag-slit fin, we could achieve high-efficient and small installation space both.
3) By using application of high-efficient 2-evaporation temperature cycle, we could achieve the reduction in water heat exchanger.

We will continue to push further for high efficiency, compact designs and global environment friendly products.

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