Development of "HCCV1001" Commercial Condensing Unit Employing CO_2 as Natural Refrigerant

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Various measures against global warming have been undertaken in the industrial world. Concerning commercial condensing units, it is necessary to promote the adoption of refrigerant with a low global warming potential (GWP). Mitsubishi Heavy Industries Thermal Systems, Ltd. has developed the "HCCV1001" commercial condensing unit using CO_2 as a natural refrigerant with a GWP of 1. In this condensing unit, the refrigerant flows in the medium-pressure range, facilitating the reduction of the piping design pressure, a wide range of evaporating temperatures and operating ambient temperatures and allows the unit to be installed with a long pipe. This paper describes the technological features of the HCCV1001.

1. Introduction

In order to address global warming, in Japan, the Fluorocarbons Emission Control Law stipulates that the GWP of the refrigerant used in a commercial condensing unit with a capacity of 1.5 kW or more shall be 1,500 or less by 2,025. Internationally, in October 2016, the Kigali Amendment to the Montreal Protocol was agreed to by the signatory countries to reduce HFC refrigerant. In the EU, under the F-gas Regulations, the GWP of the refrigerant used in stationary refrigeration equipment shall be 2,500 or less from 2,020 onward, and the GWP of the refrigerant used in a multipack centralized refrigeration system with a refrigerating capacity of 40 kW or more shall be 150 or less from 2,022 onward. Under these circumstances, we are at a major turning point where the refrigerant used in commercial condensing units will be changed from R404A (GWP3, 920) or R410A (GWP2,090), which is HFC (hydrofluorocarbon) refrigerant, to a low-GWP non-fluorocarbon refrigerant or HFO (hydrofluoroolefin)-HFC mixed refrigerant.

Mitsubishi Heavy Industries Thermal Systems, Ltd. has already put a commercial water heater employing, among low-GWP refrigerants, a CO_2 refrigerant with a GWP of 1 on the market, and has more than five years of market results. The newly-developed HCCV1001 commercial condensing unit uses components, such as the compressor, that are also used for hot water supply and are optimized for refrigeration, thereby ensuring reliability and achieving high efficiency.

2. Requirements

The commercial condensing unit employing CO_2 refrigerant is connected and used with a loading apparatus such as a showcase in supermarket or a unit cooler in a cold-storage facility. For use in such an operating environment, the following requirements need to be satisfied:

(1) Countermeasure to high pressure

Since CO_2 refrigerant has a higher operating pressure compared to HFC refrigerant, it is required that the design pressures of not only the condensing unit, but also the loading apparatus such as a showcase or unit cooler, as well as that of the connecting pipe, should be high.

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(2) Wide range of evaporating temperatures can be set

The evaporating temperature can be set at any temperature within the range of -45°C to -5°C.

(3) Use at a wide range of ambient temperatures

The condensing unit can be used in an ambient temperature range of -15°C to 43°C.

(4) Secures installation flexibility

A pipe with a length of 0 to 100m can be used for connecting the loading apparatus and the condensing unit. In addition, the condensing unit can be operated with the loading apparatus installed 22m below the condensing unit.

The issues raised by the above requirements and the measures to deal with them are described in the subsequent sections.

3. Countermeasure to high pressure: Reduction of design pressure by adoption of gas injection cycle

CO_2 refrigerant has a higher operating pressure compared to HFC refrigerant, which has been conventionally used. A comparison of the operating pressures at the same evaporating temperature and ambient temperature between the CO_2 refrigerant and the HFC refrigerants is shown in **Table 1**. The newly-developed condensing unit adopts the gas injection cycle, which enables medium-pressure refrigerant after one-stage expansion to be fed to a loading apparatus such as a showcase or unit cooler. The feeding of the refrigerant at medium pressure enables the reduction of the design pressure of the connecting pipe and the loading apparatus, the facilitation of piping installation, the reduction of costs, and the improvement of reliability against leakage of the refrigerant. (**Figure 1**)

Table 1 Comparison of operating pressure (between the HFC refrigerants and CO_2 refrigerant)

Refrigerant	Low pressure (*1) (MPaG)	High pressure (*2) (MPaG)	High design pressure (MPaG)
R404A	0.032	2.0	3.0
R410A	0.074	2.3	4.15
CO_2	0.90	8.8	14.0

*1 Saturation pressure at the evaporating temperature of -40°C
*2 Pressure in operation at the outdoor temperature of 32°C

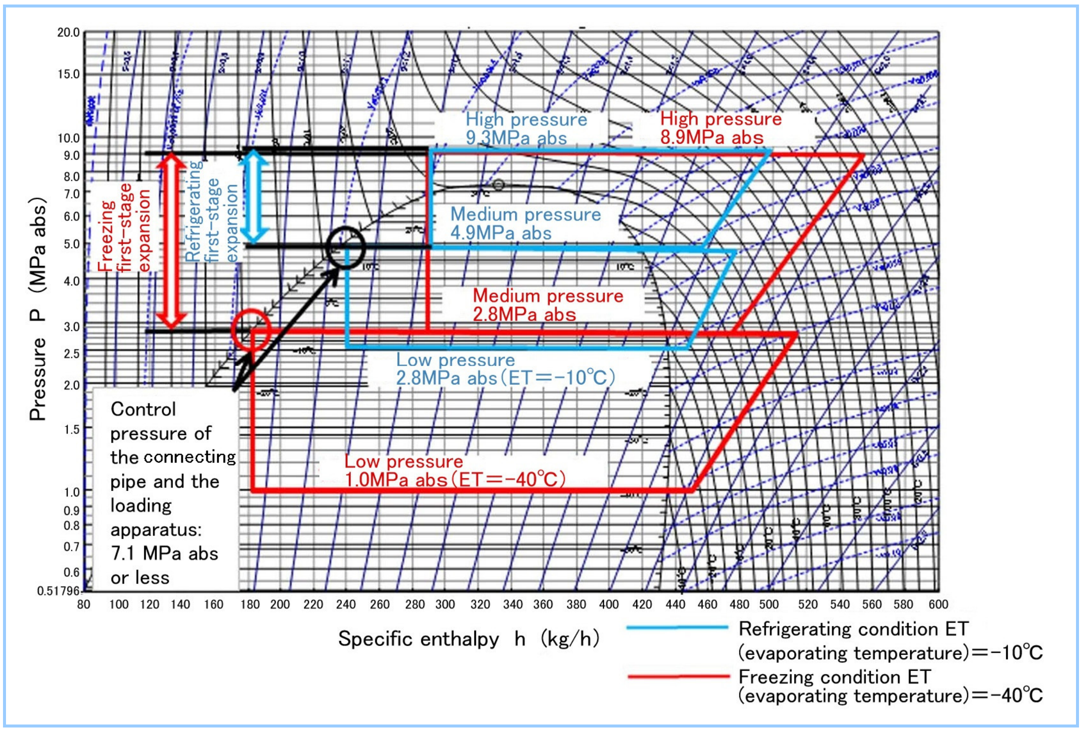

Figure 1 Operating cycle under the freezing condition and the refrigerating condition

4. Wide range evaporating temperatures can be set: Optimization of CO_2 "Scrotary" Compressor for freezing and refrigerating application

When the condensing unit operates at the evaporating temperature of -45°C, the amount of circulating refrigerant is drastically reduced and the temperature of the motor coil of the compressor that is cooled by the refrigerant causes a problem. In particular, when the ambient temperature is 43°C, the problem comes to the forefront because the high pressure rises, resulting in an increase of the load on the compressor. Furthermore, the pressure difference between the high and low pressures becomes large, resulting in an increase of the discharge gas temperature, and the mechanical compression parts also need to be cooled. As a normal measure against such an increase in temperature, there is a method of bypassing the liquid refrigerant from the gas injection pipe. A compressor for hot water supply is installed, with high priority given to the gas injection temperature, at the rear side of the motor (top of the compressor) relative to the flow of the refrigerant. On the other hand, the compressor for refrigeration is installed at the front side of the motor (bottom of the compressor), so that the motor is cooled more positively. (**Figure 2**)

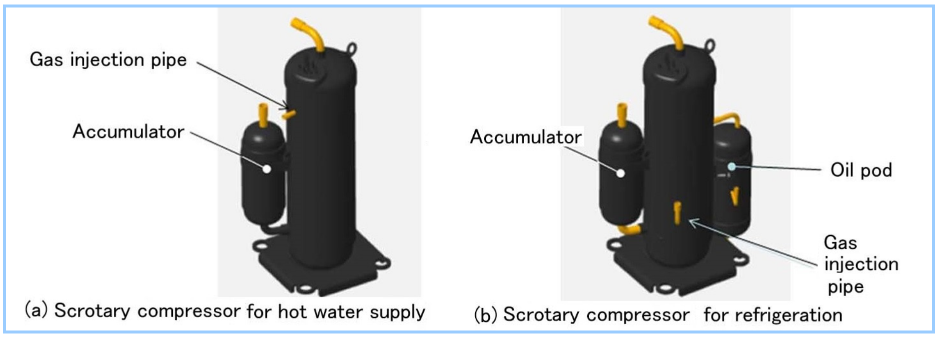

Figure 2 Scrotary compressors for hot water supply and for refrigeration

5. Specifications at a wide range of ambient temperatures: Optimum design of gas cooler specifications

When the ambient temperature becomes -15°C, the high temperature decreases and the refrigerant stays in the gas cooler. As an apparent result, a shortage of refrigerant occurs, resulting in the degradation of performance. In order to prevent this problem, the speed of the gas cooler fan, which determines the high pressure, is controlled, and at the same time, the motor operated valve between the high pressure and the medium pressure is controlled so that the refrigerant is positively discharged to the medium-pressure receiver.

For a 2-row φ7.94 mm fin-and-tube gas cooler, the number of circuits was determined from the target heat radiation amount. The conditions for determining the target radiation amount are shown in **Table 2**. Based on the conditions, the number of circuits that satisfy both the refrigerating and freezing conditions was determined. (**Figure 3**)

Table 2 Target specification of gas cooler

Operating condition	Ambient temperature (°C)	Evaporating temperature (°C)	Gas cooler inlet pressure (MPaG)
Refrigerating condition	32	-10	9.0
Freezing condition		-40	8.8

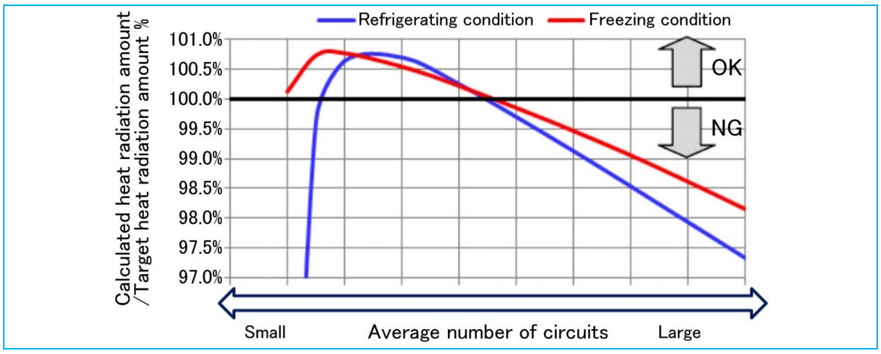

Figure 3 Calculation results for the gas cooler in a 10-horsepower condensing unit (average number of circuits and heat radiation amount)

The allocation of paths (the number of divisions of heat transfer pipes and their arrangement) is set so that the air flow and the refrigerant flow are opposed, thereby curbing the increase in the outlet temperature of the gas cooler. Furthermore, in order to avoid heat transfer between the inlet and outlet of adjacent circuits, the inlets and outlets are located in an assembled manner, respectively. (**Figure 4**)

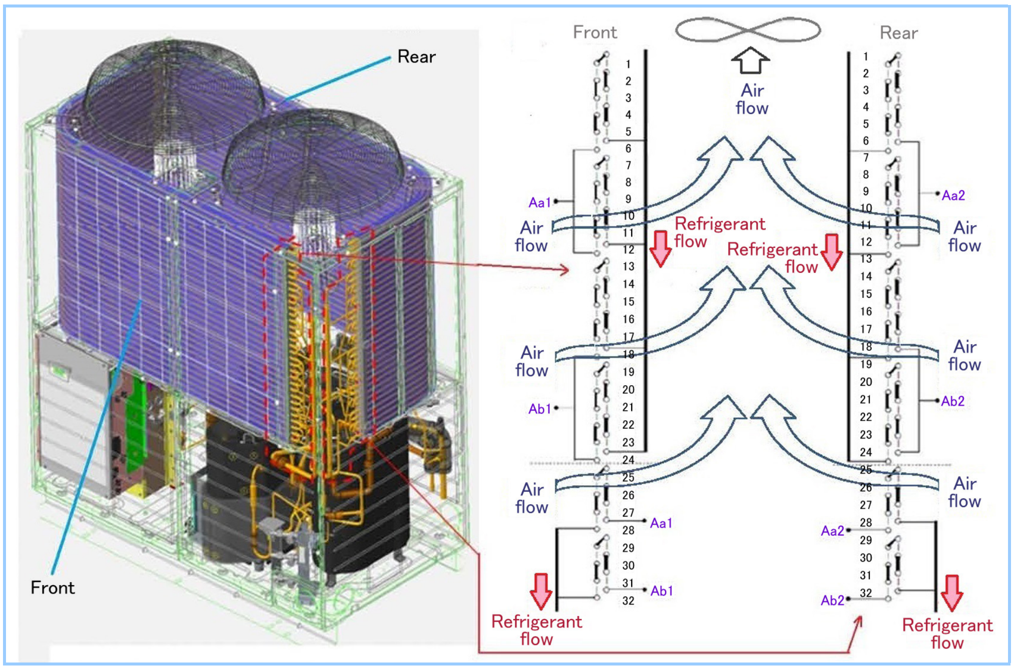

Figure 4 Specification of gas cooler (allocation of paths)

6. Securing installation flexibility: Control of subcooling for securing performance and addition of oil pod for securing oil level

Condensing units are installed in various places. Therefore, even if a long pipe is used for connecting with the loading apparatus such as a unit cooler or a showcase, the condensing unit must be able to operate. In this case, the problems are the degradation of performance due to insufficient subcooling and the compressor running out of oil. To prevent the former, a subcooling coil is installed to optimize the subcooling control, thereby enabling the supply of refrigerant in a stable liquid phase to the loading apparatus. To prevent the latter, the flow rate in the gas pipe needs to be secured in order to return oil to the compressor, and its bore (φ19.05) and the minimum number of revolutions of the compressor have been set. In addition, the number of revolutions of the compressor is controlled so that oil does not stay in the pipe even if lengthy continuous operations are conducted or the condensing unit is installed higher than the loading apparatus, and the oil level is secured. Moreover, an oil pod has been added to the compressor to increase the amount of oil stored in the system, which allows for sudden changes in exceeding the normal amount. (Figure 2)

7. Conclusion

The newly-developed "HCCV1001" commercial condensing unit employing CO_2 as a natural refrigerant is not only environmentally friendly, but can also be handled as easily as the conventional unit using an HFC refrigerant. In April of 2017, the production and sale of a 10-horsepower type condensing unit began, and the development of the series will continue. We will expand the application of this series to not only refrigerated warehouses and supermarkets, but also to plant facilities, thereby reducing CO_2 emissions and contributing to the conservation of the global environment.