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DEVELOPMENT OF A REFRIGERANT TWO-PHASE FLOW DISTRIBUTOR FOR A ROOM AIR CONDITIONER

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ABSTRACT

A new type of refrigerant two-phase flow distributor has been developed to improve an evaporator and therefore to improve a cooling capacity of a split room air conditioner. The distributor consists of the capillary mixing space and the dividing space of two-phase flow to the each evaporator path. This report examines the influence of the mass flow rates, vapor qualities at the distributor inlet and the installation angles of it on distribution characteristics. In addition, the cooling capacity of the room air conditioner with the new distributor was measured, and compared to that with the conventional one. The experimental results show that the new distributor divided refrigerant two-phase flow equally into the each evaporator path regardless of the mass flow rates, vapor qualities at the distributor inlet and the inclination angle of it. The cooling capacity of the room air conditioner with the new distributor was therefore improved compared to that with the conventional one.

NOMENCLATURE

C : Maximum cooling capacity difference [%]
D : Inner diameter of the capillary mixing space in the new distributor [mm]
d : Diameter of the orifice in the conventional distributor [mm]
G : Mass flow rate [kg/h]
L : Length of the capillary mixing space in the new distributor [mm]
M : Mass velocity [kg/(m^2·h)]
Q : Cooling capacity [W]
t : Thickness of the orifice in the conventional distributor [mm]
X : Vapor quality at the distributor inlet

1 INTRODUCTION

A refrigerant two-phase flow distributor at the inlet of an evaporator is required to mix the refrigerant homogeneously and to divide it equally to all evaporator paths. If the distributor could not divide two-phase flow equally to the each evaporator path, the excessive liquid refrigerant might flow in one of the evaporator paths. The cooling capacity of the evaporator might be reduced, because the insufficient liquid refrigerant flows in the other paths.

In a room conditioner, the distributor of the indoor heat exchanger is connected to the connecting pipe with a complicated shape such as an elbow. The flow pattern of the gas-liquid two-phase refrigerant at the distributor inlet depends on the mass flow rates, vapor qualities at the distributor inlet and the shape of the connecting pipe.

In addition, the distributor is installed at any inclination angles to keep the compactness of the indoor unit. The flow pattern of the two-phase refrigerant is also affected by the inclination of the distributor. So it is important to develop a distributor to divide refrigerant two-phase flow equally into the each evaporator path regardless of the mass flow rates, vapor qualities at the distributor inlet and the inclination of the distributor.

Therefore, we have developed a new type of the refrigerant two-phase flow distributor. This paper describes the configuration of the new distributor and the experimental results of distribution characteristics. In addition, the cooling capacities of the room air conditioner with the new distributor are examined and are compared to these with the conventional one.

2 TEST DISTRIBUTORS

Figure 1 shows the sectional view of the conventional distributor. It consists of the inlet pipe, the orifice, the dividing space and the distributing pipes. In the dividing space, refrigerant two-phase flow is divided into the each evaporator path. Two-phase flow might be mixed in the orifice by increasing the refrigerant velocity. However, sufficient mixing of two-phase flow has not been induced in the orifice, partly because the thickness of the orifice is thin. In addition, the inner diameter of the inlet pipe is much lager than that of the orifice. Two-phase flow might not tend to flow uniformly through the orifice, because the refrigerant velocity is reduced in the front of orifice.

Figure 2 shows the sectional view of the new distributor. It consists of the dividing space and the distributing pipes, as used in the conventional one. The capillary mixing space is used instead of the orifice to mix two-phase flow homogeneously. The diameter of the inlet pipe is smaller than that of the conventional one to avoid phase separation in the inlet pipe.

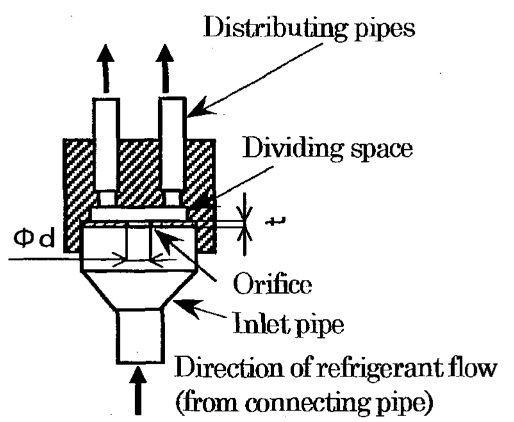

Figure 1 Sectional view of the conventional distributor

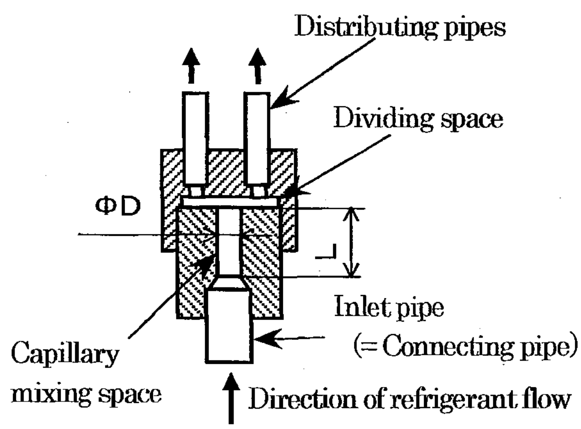

Figure 2 Sectional view of the new distributor

Table 1 Specifications of the new distributor

Inner diameter of mixing space D	3 mm
Length of mixing space L	10 to 50 mm
Number of distributing pipes	3
Diameter of inlet pipe	8 mm
Diameter of distributing pipe	3 mm

Table 2 Testing conditions

Refrigerant	R22
Mass flow rate G	50,100 kg/h
Vapor quality X	0.08 to 0.24

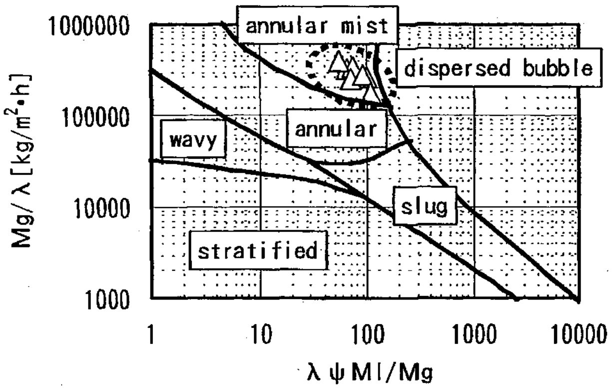

Figure 3 Two-phase Baker flow-pattern map [1]

The new distributor is designed to apply to the indoor heat exchanger of the cooling capacity of 5 kW. Table 1 shows the specifications of the new distributor. The inner diameter D and the length L of the capillary mixing space are optimized to formulate circumferentially uniform two-phase flow inside the capillary mixing space. Table 2 shows the design conditions of the mass flow rates G and vapor qualities X at the distributor inlet in the cooling mode of the air conditioner. The inner diameter D is set to 3 mm to formulate annular-mist two-phase flow with the specified mass flow rates G and vapor qualities X. Flow patterns inside the capillary mixing space are estimated using the two-phase flow pattern map [1] in Figure 3. The length L is set between 10 and 50 mm to generate static annular-mist flow inside the capillary mixing space. The influence of the length L on the distribution performance is examined experimentally.

3 EXPERIMENT

Distribution characteristics are measured using an experimental apparatus shown in Figure 4. The experimental apparatus consists of an inverter driven compressor, a water-cooled condenser, an electric heater, an expansion valve, a test distributor and an evaporator with three paths. The refrigerant mass flow rate is controlled by the rotational frequency of the compressor and measured by the mass flow meter located in the liquid line. The vapor quality at the distributor inlet is calculated by the temperature at the inlet of the expansion valve, and is controlled the electric heater. The cooling capacity is measured by the input of the electric heater installed at the each evaporator path. The superheat at the outlet of the each evaporator is kept at 10 K.

When the distributor is positioned in the horizontal, it is not easy to mix refrigerant two-phase flow homogeneously due to gravity. Distribution characteristics in new and conventional distributors in horizontal position shown Figure 5 are evaluated in order to clarify the differences of the distribution performance under the influence of gravity.

The distributor is connected to the connecting pipe with the diameter of 8 mm, which is the same as the actual room air conditioner. The connecting pipe has a straight part of 500 mm to maintain the stable conditions of two-phase flow at the inlet of the distributor.

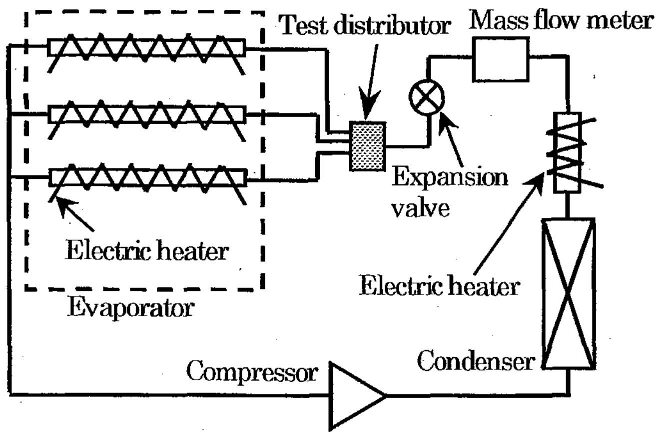

Figure 4 Experimental apparatus

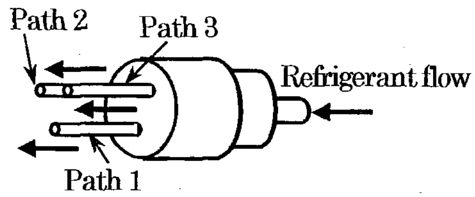

Figure 5 Horizontal installation of distributors

4 EXPERIMENTAL RESULTS

4.1 Influence of the Ratio of L/D

The distribution performance is evaluated by the difference in the cooling capacity of the each evaporator. The maximum cooling capacity difference C is calculated from the following equations.

$$C = (Q_{max} - Q_{min}) / Q_{total} \times 100$$

where;

$Q_{total} = \Sigma Q_i$: Total cooling capacity

$Q_i (i=1 \text{ to } 3)$: Cooling capacity in the each path

Q_{max} : The maximum value of $Q_i (i=1 \text{ to } 3)$

Q_{min} : The minimum value of $Q_i (i=1 \text{ to } 3)$

Figure 6 shows the experimental results of the cooling capacity ratio, Q_i / Q_{total}, of the each path, using the conventional distributor and the new distributor with L/D=5. In the conventional distributor, the maximum cooling capacity difference C is 25 %. Most of the liquid refrigerant tends to flow in the lower distributing pipe, because sufficient mixing of two-phase flow is not induced at the orifice. However, in the new distributor C is only 5 %, which is one fifth of that of the conventional one, because two-phase flow is mixed uniformly inside the capillary mixing space.

Figure 7 shows the experimental results of the maximum cooling capacity difference C as a function of L/D. As the orifice diameter, d, is 3 mm and the orifice thickness, t, is 3 mm, L/D of the conventional distributor indicates one in Figure 7. The values C of the new distributor are less than 6 % and about one forth compared to those of the conventional one. The values C of the new distributor are kept almost constant when L/D is larger than three. These results indicate that the distribution performance of the new distributor with L/D$>$3 is improved significantly compared to that of the conventional one.

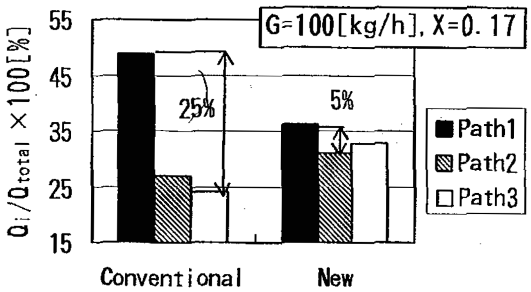

Figure 6 Comparison of distribution performance between conventional and new distributors

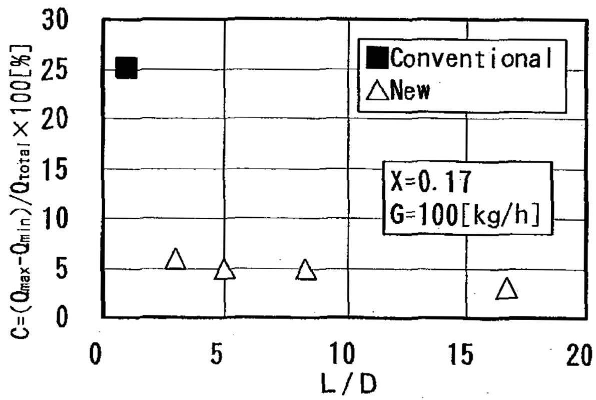

Figure 7 Influence of L/D on the maximum cooling capacity difference C

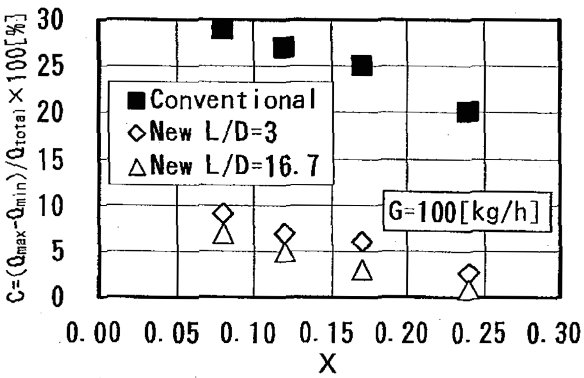

Figure 8 Influence of X on the maximum cooling capacity difference C at the G of 100 kg/h

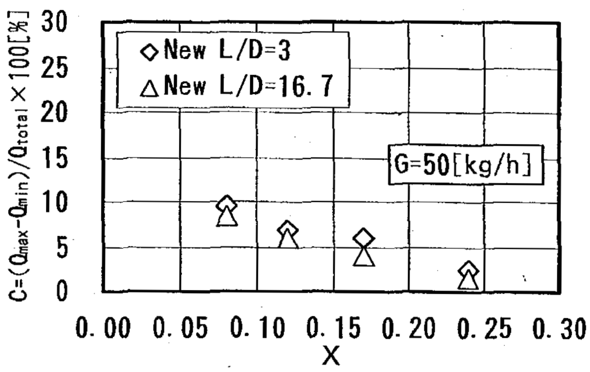

Figure 9 Influence of X on the maximum cooling capacity difference C at the G of 50 kg/h

4.2 Influence of Vapor Quality and Mass Flow Rate

Figure 8 shows the experimental results of the maximum cooling capacity difference C as a function of the vapor quality X at the distributor inlet at the mass flow rate G of 100 kg/h. The values C of all distributors become higher in lower vapor quality, because the liquid refrigerant in two-phase flow tends to flow along the bottom of the capillary mixing space. The values C of the new distributor are less than 9 % and about one third compared to those of the conventional one when vapor quality X is 0.08. This result indicates that the new distributor improves the distribution performance significantly regardless of vapor qualities.

Figure 9 shows the experimental results of the maximum cooling capacity difference C of the new distributor as a function of the vapor quality X at the mass flow rate G of 50 kg/h. Comparison between Figures 8 and 9 indicates that the values C remain almost the same. This result means that two-phase flow is mixed sufficiently inside the capillary mixing space regardless of the refrigerant mass flow rates.

From these results, it is conformed that the distribution performance with the new distributor is improved greatly regardless of vapor qualities at the distributor inlet and the mass flow rates.

4.3 Unit Performances

The new distributor with L/D=3 is installed in the indoor heat exchanger with four paths in order to evaluate the improvement of the cooling capacity. The rated cooling capacity of the air conditioner is 5 kW. The cooling capacities with the new and conventional distributors are measured in the different installation angles. As shown in Figure 10, the distributors are installed in two cases. In the first case, the distributor is installed at vertical upward position, in the second case that is installed at an angle of 15 degree from the vertical upward axis, as shown by the dotted line in Figure 10. Both distributors have the connecting pipe with an only 110 mm long straight part.

Figure 11 shows the experimental results of the cooling capacity. The vertical axis in Figure 11 indicates the cooling capacity ratio with the conventional distributor installed vertically. The cooling capacity with the new distributor is increased by 1.2 % compared to that of the conventional one, when distributors are installed vertically. Sufficient mixing of two-phase flow is not induced at the orifice of the conventional distributor, because of the influence of the elbow and the short connecting pipe.

The reduction of the cooling capacity according to the inclination angle by 15 degree is 1.5 % with the conventional distributor and is only 0.4 % with the new one compared to the vertical installation. These results indicate that two-phase flow is mixed sufficiently in the capillary mixing space of the new distributor regardless of various flow patterns due to gravity.

The cooling capacity of the room air conditioner with the new distributor is improved compared to that with the conventional one, regardless of the inclination angle of the distributor and the connecting pipe with a complicated shape such as an elbow.

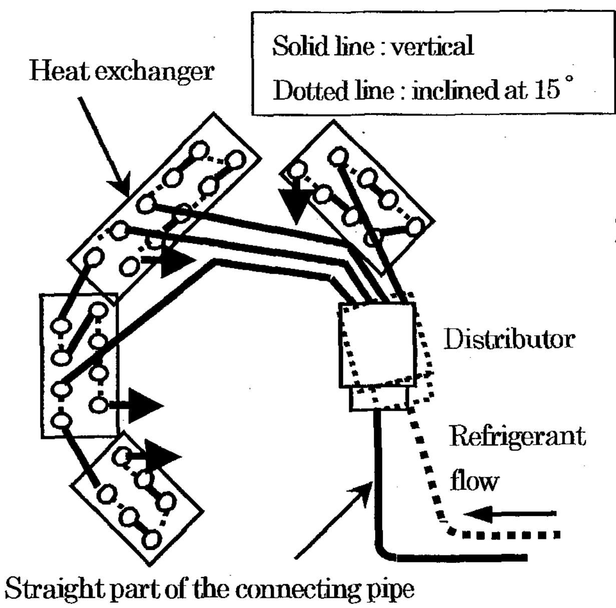

Figure 10 The distributor installed in a indoor heat exchanger

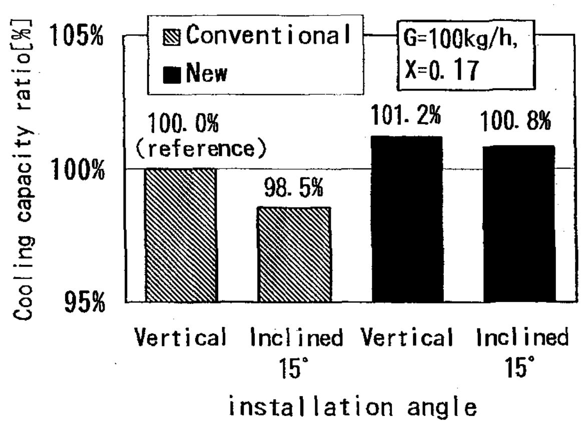

Figure 11 Results of the unit performance

5 CONCLUSIONS

In order to improve the cooling capacity of the room air conditioner, we have developed a new type of refrigerant two-phase flow distributor that has the capillary mixing space instead of the orifice of the conventional one. Test results indicated the improvement of the distribution performance as follows.

(1) The length L of the capillary mixing space in the new distributor did not affect distribution characteristics when L was larger than three times of the inner diameter D of the capillary mixing space.

(2) The maximum cooling capacity difference C with the new distributor was reduced between one third and one fifth compared to that with the conventional one. The distribution performance of the new distributor was improved compared to that of the conventional one, regardless of the mass flow rates and vapor qualities at the distributor inlet.

(3) The cooling capacity of the room air conditioner with the new distributor was increased by 1.2 % compared to that with the conventional one.

(4) The reduction of the cooling capacity according to the inclination angle by 15 degree was only 0.4 % with the new distributor comparing to 1.5 % with the conventional one.

REFERENCE

[1] Hewitt, G.F., Delhaye, J.M., Zuber, N., *Multiphase Science and Technology Volume 2*, Hemisphere Publishing Corporation, 1986.