Experimental Research for Lowering Refrigerant Charge with 4mm Tube Heat Exchanger*

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【Abstract】 For this report, the latest developed heat exchanger using Φ4mm copper tube was used respectively to conduct R410A and R290 performance experiments on split air conditioners. The experimental results show that: when using the Φ4mm copper tube, without sacrificing any performance, not only can the volume and cost of the heat exchanger be effectively reduced, the refrigerant charge can also be significantly lowered.

【Keywords】 4mm diameter copper tube, refrigerant charge

0 Preface

From the theory behind heat exchange, we know that a heat exchanger with small diameter tubes can enhance the heat transfer effect within the tube. Therefore, the tube diameter of the air-conditioning heat exchanger has been gradually developed from the initial 9.52mm to 7.94mm, 7mm and 6.35mm. The final version is the heat exchanger with 5mm diameter copper tubes that is starting to be used on a large scale in recent years. From the perspective of energy saving and environmental protection, using environmentally friendly refrigerants and adopting miniaturization are the development trends for future air conditioners in households. The heat exchanger is the part with the largest volume in the air conditioner. It is also the main component participating in heat exchange. Therefore, its extent of miniaturization has a major impact on the miniaturization of the air conditioner. One relatively good method to realize the miniaturization of the heat exchanger is to replace the existing heat exchanging tubes in the heat exchanger with small diameter heat exchanging tubes. The application of the small diameter tube fin type heat exchanger in residential air-conditioning will substantially decrease the manufacturing cost of air conditioners. This will also achieve the objectives of air conditioners being energy saving, environmentally friendly and economical. For this report, the latest developed 4mm diameter inner-grooved copper tube was used respectively to conduct R410A and R290 performance matching and experiments on split air conditioners. The experimental results show that using a small tube diameter not only lowers the volume and cost of the heat exchanger, it also effectively lowers the refrigerant charge and brings about energy saving and environmental protection effects.

1 R410A Refrigerant Performance Design and Experiment for 2600W unit

1.1 R410A Refrigerant Performance Design for 2600W Split Air-con

Based on the 5mm condenser dimensions of the 2600W split air conditioner, the relevant parameters for the 4mm heat exchanger were designed. The detailed comparison with the 5mm tube heat exchanger is as shown in Table 1. Because the difference in tube diameter is not large, the manifold is the same as that of the 5mm heat exchanger prototype. Adjustments were only done for the charge and capillary tube length of the refrigeration system.

Table 1 Condenser Parameters for 2600W Split Air Conditioner

Heat Exchanging Tube Diameter (mm)	Fin space (mm)	Fin Thickness (mm)	Heat Exchanger Row Number

5	1.2	0.095	2
4	1.1	0.095	2

1.2 Performance Experiment for 2600W Air-con

The split air conditioner was tested during standard conditions[1]. The experimental results are as shown in Table 2.

Table 2 Performance Experiment Results Comparison

Heat Exchanger Type	Power (W)	Cooling Capacity (W)	COP	Charge (g)
5mm Heat Exchanger Prototype	784	2635	3.36	680
4mm Heat Exchanger	804	2684	3.34	555

Compared to the prototype, the refrigerant charge was reduced by 18.3%.

2 R410A Refrigerant Performance Design and Experiment for 3500W Split Air-con

2.1 R410A Refrigerant Performance Design for 3500W Split Air-con

Based on the 5mm condenser dimensions of the 3500W split air conditioner, the relevant parameters for the 4mm heat exchanger were designed. The detailed comparison with the 5mm tube heat exchanger is as shown in Table 2.

Table 3 Condenser Parameters for 3500W Split Air Conditioner

Heat Exchanging Tube Diameter (mm)	Fin space (mm)	Fin Thickness (mm)	Heat Exchanger Row Number
5	1.2	0.095	1
4	1.1	0.095	1

2.2 Performance Experiment for 3500W Air-con

The No. 35 split air conditioner was tested during standard refrigeration operating conditions[1]. The experimental results are as shown in Table 4.

Table 4 Performance Experiment Results for No. 35 Split Air Conditioner

Heat Exchanger Type	Power (W)	Cooling Capacity (W)	COP	Charge (g)
5mm Prototype	1234	3378	2.74	560
4mm	1257	3390	2.7	450

Compared to the prototype, the refrigerant charge was reduced by 19.6%.

3 R290 Refrigerant Performance Design and Experiment for 3500W Split Air Conditioner

3.1 R290 Refrigerant Performance Design for Split Air Conditioner

Because the R290 is easily flammable and explosive, a limit is set in both IEC 60335-2-40 and EN 378-1:2008 for the maximum safe perfusion amount of hydrocarbon refrigerant that can be used in an air conditioner. Of this limit, when the air conditioner using R290 is installed within a 10m^2 room at a height of 2.2m, the charge for the 2600W unit should not exceed 290g. As for the 3500W unit, it should not exceed 340g. Based on the physical characteristics of the R290, the compressor was changed to one with a larger discharge. Matching and experiments were then conducted on the prototype with 5mm copper tubes. They were also done on the heat exchanger with 4mm copper tubes. The condenser parameters are as shown in Table 5.

Table 5 Condenser Parameters

Heat Exchanging Tube Diameter	Fin space (mm)	Fin Thickness (mm)	Heat Exchanger Row Number

(mm)			
5	1.2	0.095	2
4	1.1	0.095	2

3.2 R290 Performance Experiment

The 3500W split air conditioner was tested during standard refrigeration operating conditions[1]. The experimental results are as shown in Table 6.

Table 6 R290 Performance Experiment Results for No. 35 Split Air Conditioner

Heat Exchanger Type	Power (W)	Cooling Capacity (W)	COP	Charge (g)
5mm Prototype	1205	3288	2.73	400
4mm	1229	3336	2.71	335

Compared to the prototype, the refrigerant charge was reduced by 16.3%.

4 Results Analysis

From the experiments for the three models, it can be seen that:

(1) For the No. 26 that uses the R410A refrigerant, when using the newly developed 4mm tube heat exchanger, the refrigeration capacity is larger than that of the 5mm tube heat exchanger prototype by 1.86%. Because the tube diameter is reduced, taking into consideration the cost factor, the manifold for the prototype will be borrowed for use. Hence, the power is increased by 2.55%, the COP is reduced by 0.6% and the charge is reduced by 18.3%;

(2) For the No. 35 that uses the R410A refrigerant, when using the newly developed 4mm tube heat exchanger, the refrigeration capacity is larger than that of the 5mm tube heat exchanger prototype by 0.4%. Because the tube diameter is reduced, taking into consideration the cost factor, the manifold for the prototype will be borrowed for use. Hence, the power is increased by 1.86%, the COP is reduced by 1.5% and the charge is reduced by 19.6%;

(3) For the No. 35 that uses the R290 refrigerant, when using the newly developed 4mm tube heat exchanger, the refrigeration capacity is larger than that of the 5mm tube heat exchanger prototype by 1.46%. Because the tube diameter is reduced, taking into consideration the cost factor, the manifold for the prototype will be borrowed for use. Hence, the power is increased by 1.99%, the COP is reduced by 0.73% and the charge is reduced by 16.3%.

5 Conclusion

From the experimental results of the two kinds of R410A and R290 refrigerants, it can be seen that when using the newly developed heat exchanger with Φ4mm copper tubes, the cooling capacity is superior to that of the 5mm tube heat exchanger prototype. Because the tube diameter is reduced, taking into consideration the cost factor, the refrigerant flow path for the prototype will be borrowed for use. Hence, the power is increased and the COP is correspondingly smaller. Judging from the experiments for the three models, using heat exchanger with Φ4mm copper tubes can reduce the refrigerant charge by around 20%. This possesses obvious economic benefit and safety effect. This holds important significance for the natural R290 refrigerant that is currently being promoted.

Reference Documents

[1] GB/T 7725-2004 Room Air Regulator.

[2] IEC 60335-2-40 Household and Similar Electrical Appliances – Safety – Part 2-40: Particular Requirements for Electrical Heat Pumps, Air Conditioners and Dehumidifiers, 2002:57-63.

[3] EN 378-1 Refrigerating Systems and Heat Pumps – Safety and Environmental Requirements - Part 1: Basic Requirements, Definitions, Classification and Selection Criteria. 2008:44-46.

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