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EXPERIMENTAL RESEARCH WITH THE REPLACING FLUIDS IN THE HOUSEHOLD REFRIGERATOR

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ABSTRACT

The experimental investigation of applying refrigerant R152a and zeotropes R152a / R22, R152a / R22 / R114 to replacing refrigerant R12 is reported in this paper. The operating characteristics have been gotten using R12, R152a, R152a / R22 and R152a / R22 / R114 in the household refrigerator. The experimental results have been analysed. It is known that the energy consumption of the refrigerator with R152a is about 10% lower than that with R12, and that with R12 is basically the same as that with R152a / R22. The results also show that the freezing level of the mixture R152a / R22 / R114 is basically the same as that of R12, the energy consumption of R152a / R22 / R114 is approximately 3% lower than that of R12.

INTRODUCTION

R12 is widely used in small-sized refrigeration system (i.e. domestic refrigerators), for its good performance and low price. But, recently, scientists discovered that R12 seriously depletes the ozone layer of the atmosphere, it cannot be accepted by environment, and it has been listed at one of substances restricted.

Under existing conditions, it is a convient and feasible way to substitute refrigerants used for R12.

CHOICE OF THE REPLACEMENT

The perfect replacement should have better properties of physics, chemistry and thermodynamic, and be safe and economic, its RODP's (i.e. Relative Ozone Depletion Potential) and RGE's (i.e. Relative Greenhouse Effect) values should be as small as possible. Furthermore, in order to apply existing refrigeration installations to the utmost extent and not to make new technical problems in manufacturing engineering, it is expected that properties of the replacing fluid, for example, thermodynamic and physics properties, such as critical parameters, the compressor factor, the freezing temperature, the boiling point, the latent heat, the volumetric refrigeration capacity, the dynamic viscosity, the density, the heat conductor, the electric insulation and so on, ought to be similar to properties of the refrigerant replaced. Both the COP of cycles and the discharge temperature of compressors are also important criterion for the replacing fluid.

Because it needs longer time to develop and research new refrigerants, we best choose the replacement from existing refrigerants. Thus, we pay our attention to refrigerants whose properties

is similar to properties of R12.

R22 is a refrigerant with larger volumetric refrigeration capacity, and it is widely used in air conditioners. If R22 were immediately used in domestic refrigerators, the load of refrigerators would be great and the discharge temperature of compressors would be high, so that the reliability of refrigerators would decrease. Furthermore, the condensing capacity of R22 is larger than that of R12, the corrosion of R22 is greater than that of R12 on material (i.e. motor insulators), it is very unsafe to only substitute R22 for R12 in existing refrigerators. Thus, by mixing R22 with one or several refrigerants which has a smaller volumetric refrigeration capacity and pressure ratio, a lower discharge temperature than R22 does, zeotropes can be composed, and it is possible to make properties of zeotropes like properties of R12 with the concentration of refrigerants changing. R152a is just one of suitable refrigerants. Because R152a is a flammable substance, and the zeotrope is still flammable as including a lot of R152a in it, we add R114 to it, so that its flammability can be decreased further.

CHARACTERS OF USING ZEOTROPES IN REFRIGERATION SYSTEM

Using zeotropes in refrigeration systems, the efficiency of the systems may be improved. The reason is shown as follows:

1. Increase the evaporating pressure and decrease the condensing pressure. Some zeotropes may make such effect.
2. The mixing heat will affect the condensing and evaporating capacity. The condensing process of zeotropes can be regarded as a process in which components with higher boiling point will condense and components with lower boiling point will dissolve. Thus, these components not only give off their potential heat, but also send out their mixing heat, then, the condensing capacity also increases. Evaporating process is just the converse of the condensing process. Hence, the refrigerating capacity of refrigeration systems increases without increasing power consumptions.
3. Decrease the suction temperature. Because the zeotrope contains some components with higher boiling point, entering the compressor, it includes fractional liquid zeotropes at mist state. These liquid zeotropes evaporate rapidly after entering the compressor, so that the temperatur of the compressor and the suction temperature of the zeotrope can be decreased to some extent, the mass flow rate of the system and the volumetric efficiency of the compressor may be improved.
4. Decrease irreversible losses of heat transfer.

COMPARISON OF MAIN THERMODYNAMIC PROPERTIES OF R12, R22, R152a and R114

Properties of the zeotrope are determined by properties of each component and the fraction of each component.

Properties of R12, R22, R152a and R114 are shown in table 1. Theoretical cycle's performances of R12, R22, R152a and R114 are shown in table 2. The calculating condition in table 2 is at

the condensing temperature of +55℃ (328.15k), the evaporating temperature of −25℃ (248,15k), the subcooling temperature of +30℃ (303.15k), the suction temperature of +15℃ (288.15k).

Table 1 Properties of R12, R22, R152a and R114

Refrigerant	Formula	Molecular mass(g)	Boiling (℃)	Critical temperature (℃)	Critical pressure (MPa)	RODP	RGE
R12	CCl_2F_2	120.93	−29.79	112.0	4.113	1.0	1.0
R22	$CHCLF_2$	86.48	−40.8	96.0	4.940	0.05	0.07
R152a	$C_2H_4F_2$	66.05	−25.3	113.5	4.750	0	<0.1
R114	$C_2Cl_2F_4$	170.94	3.5	145.8	3.275	1.0	1.4

Table 2. Cycle's performances of R12, R22, R152a and R114

Cycle's performances	R12	R22	R152a	R114
Condensing pressure (MPa)	1.366	2.250	1.332	0.5083
Evaporating pressure (MPa)	0.123	0.200	0.1075	0.0291
Pressure ratio	11.05	11.25	12.39	17.47
Discharge temperature (℃)	112	140	121	80
Suction specific volume (m^3 / kg)	0.160	0.135	0.351	0.480
Refrigeration capacity per unit mass (KJ / kg)	112.54	158.0	237.8	92.18
Volumetric refrigeration capacity (KJ / m^3)	703.4	1170	677.8	192.0
Power consumption per unit mass (KJ / kg)	52.5	75.3	105	42.5
COP	2.14	2.1	2.26	2.17

It can be seen from table 1 and 2:

1. R152a has a lower saturated pressure, a larger suction specific volume and a smaller volumetric refrigeration capacity than R12 does at the same working condition.
2. R22 has a higher saturated pressure, a smaller suction specific volume and a larger volumetric refrigeration capacity than R12 does at the same working condition.
3. Comparing with R12, R22 and R152a have smaller RODP's and RGE's values. When the fraction of these two components is the same, the RODP's value of the zeotrope (i.e. R22 / R152a) is less than 0.05 and the RGE's value of the zeotrope is less than 0.1, in other words, its effect on environment is very little. When the weight fraction of R22. R152a and R114 is 36%, 24% and 40%, the RODP's value of the zeotrope (i.e. R22 / R152a / R114) is equal to 0.42 and the RGE's value of the zeotrope equals 0.61, which are also less than

those of R12.

Furthermore, R152a is a flammable refrigerant, but both R22 and R114 are non-flammable refrigerants, mixing them can further decrease the flammability of zeotropes.

Therefore, we choose R22 / R152a and R22 / R152a / R114 as replacements of R12 in domestic refrigerators. In this paper, in order to compare R152a with zeotropes, the experiment using R152a as the replacement in the domestic refrigerator has been carried out.

THE EXPERIMENT OF REPLACEMENTS

The experiments using replacements have operated in single-door domestic refrigerator. In these experiments, the structure of the refrigerator unchanges, and the working conditions are the same, we only vary the fraction of the zeotrope and adjusting or tuning the charge of the refrigerant (or zeotrope). As stated above, we can change the concentration of components in the zeotrope, so that the cycle's performances move toward expecting direction. The larger the number of components, the greater degrees of freedom of adjustment, but workloads of theoretical model and experimental choice are also much great. Futhermore, because the throttling device in the refrigerator is capillary tube, the charge can also affect performances of the refrigerator. The difference and relationship between these two influent factors should be carefully treated in experiments.

Fig.1,2 and 3 respectively show the temperature T versus the time t of the refrigerator with R12, R152a and R152a / R22 at a certain fraction from starting of the compressor to stoping of it.

Table 3 Performances of the refrigerator with R12, R152a and R152a / R22 at the certain fraction (ambient temperature 15℃ (288.15k))

Refrigerant	Highest temperature of 1 point (℃)	lowest temperature of 3 point (℃)	Energy consumption (kwh / 24h)
R12	34.0	−28.0	0.781
R152a	33.6	−19.6	0.664
R152a / R22	35.2	−23.5	0.797

Table 4 Performances of the refrigerator with R12 and R152a / R22 / R114 at a certain fraction (ambient temperature 25℃ (298.15k))

Refrigerant	Freezing degree (℃)	Discharge pressure (MPa)	Suction pressure (MPa)	Relative Power consumption (%)
R12	−23.2	1.01	0.14	100
R152a / R22 / R114	−22.9	1.36	0.15	97

Table 3 shows operating performances of the refrigerator with R12, R152a and R152a / R22

at a certain fraction, in which 1 point is the certain point on the surface of condenser and 3 point is the certain point on the surface of evaporator. Table 4 represents operating performances of the refrigerator with R12 and R152a / R22 / R114 at the certain fraction.

CONCLUSIONS

1. The evaporating temperature of the refrigerator with R152a is higher than that with R12, the energy consumption of the refrigerator with R152a is about 10% lower than that with R12. For the refrigerator with R152a to reach freezing degree of the refrigerator with R12, we must make a great change on the structure of the existing refrigerator.
2. The refrigerator with R22 / R152a has a lower evaporating temperature than that with R152a does, and a higher evaporating temperature than that with R12 does. Furthermore, the condensing temperature of the refrigerator with R22 / R152a is higher than that with R12 to some extent, and the energy consumption of the refrigerator with R22 / R152a is basically the same as that with R22.
3. Substituting R152a / R22 / R114 for R12, performances of the refrigerator is very good. The refrigerator with R152a / R22 / R114 can reach the same freezing level as that with R12 without changing the structure of the refrigerator, and the energy consumption of the refrigerator with R22 / R152a / R114 is about 3% lower than that with R12.

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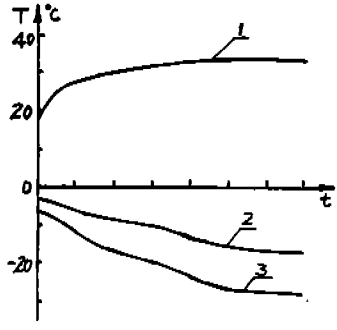
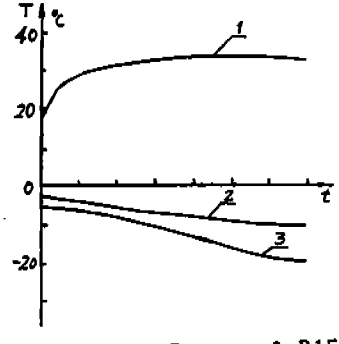


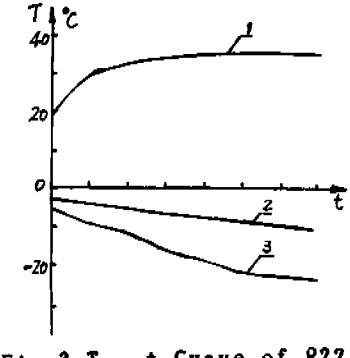
1 -- The Temperature of the Certain Point on the Surface of Condenser
2 -- The Temperature of the Certain Point in Freezing Room
3 -- The Temperature of the Certain Point on the Surface of Evaporator

Fig 1 T - t Curve of R12



1 -- The Temperature of the Certain Point on the Surface of Condenser
2 -- The Temperature of the Certain Point in Freezing Room
3 -- The Temperature of the Certain Point on the Surface of Evaporator

Fig 2 T - t Curve of R152a



1 -- The Temperature of the Certain Point on the Surface of Condenser
2 -- The Temperature of the Certain Point in Freezing Room
3 -- The Temperature of the Certain Point on the Surface of Evaporator

Fig 3 T - t Curve of R22/R152a