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INVESTIGATION OF USING NONAZEOTROPIC REFRIGERANT MIXTURE AS THE REPLACEMENT OF R12

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ABSTRACT

This paper investigates the effects of nonazeotropic refrigerant mixtures (NARMs) as replacement of CFCs. The thermodynamic properties of NARM R22/R142b which is harmless to ozone layer are analyzed. The tests about water-to-water heat pump and dual-evaporator refrigerator-freezer using R22/R142b as alternative to R12 are introduced. The test results show R22/R142b is of energy conserving effects as strict counterflow heat exchangers are used. The refrigerator-freezer system is adjusted in the tests so as to make the construction of refrigerator-freezer to match well with thermo-dynamic characteristic of R22/R142b. The energy consumption has been decreased to a certain extent. The analysis shows using NARMs as short or mid-term alternatives to CFCs would be a better choice.

Keywords: NARMs, Water-to-water heat pump, Refrigerator-freezer, R22/R142b

Introduction

The impact of the CFCs phase-out on the refrigeration and air conditioning becomes very serious. Nonazeotropic refrigerant mixtures (NARMs) are known as alternatives with energy conserving potential. (1)-(4).
The NARM R22/R142b would be acceptable for a short or mid-term

solution. It can provide essential properties such as thermodynamic properties and inflammability in the application range. It's specially important that R22/R142b possibly improves energy efficiency, which is a key criterion for CFCs replacement. We should have the long-term consideration about global warming, ozone depletion and energy efficiency.

At first we study the thermodynamic property of R22/R142b. Measuring a part of bubble points and cycle performance simulation have been conducted. The calculated result of the bubble points is compared with the experimental value in table 1.

Table 1. Comparsion of the calculated result with the experimental bubble points

T (K)	X22 mol frac	Pexp (MPa)	Pcal (MPa)	Dexp (kg/m³)	Dcal (kg/m³)	Y22 mol frac	Vv (m³/kg)
298.20	.5028	.7080	.6921	1146.63	1127.85	.7230	.0330
322.80	.5028	1.2860	1.2693	1065.57	1048.89	.6859	.0178
348.40	.5110	2.1760	2.1757	967.21	957.23	.6512	.0098
372.50	.5110	3.4260	3.4226	834.10	826.62	.6078	.0054

This paper applies R22/R142b as the working fluid in heat pump and domestic refrigerator, which is suitable for our country, and compared its results with those of R12.

<u>Experimental Research of a Water-To-Water Heat Pump Cycle Using R22/R142b</u>

The experimental heat pump system is shown in Fig 1. A 2FM4 hermetic compressor with cylinder diameter 40mm is used in this system(5). The heat exchangers are both strict counter-flow ones to realize the matching of the refrigerant temperature profile with the sensible heat source fluid's temperature profile.

The experiment shows R22/R142b has the temperature gliding about 5--10 °C, which matches well with the temperature changes of heat source. Fig 2 shows the temperature distribution on working fluid and heat source along the heat exchangers. under the same outer heat source (water temperature in the condenser is 30 -- 45 °C and the evaporator is 25 -- 15 °C), the solid line indicates R12, which temperature nearly have no change during the phase change process, the dottedline indicates NARM R22/R142b.

Through the tests under the same outer heat source we find R22/R142b of weight composition 0.51/0.49 approaches R12 in term of refrigeration capacity. The comparison of R22/R142b with R12 is shown in table 2. We can see the heat supplied from condenser using R22/R142b is about 6 percent greater than R12. The compressor power decreases about 3 percent and COP increases 8-10 percent.

Table 2. Comparison of R12 With R22/R142b (weight fraction 0.51/0.49)

Refrigerant	Water temperature (°C)				Supplied Heat	Power	COP
	Tc1	Tc2	Te1	Te2	(kw)	(kw)	
R12	35.0	50.7	20.3	10.1	3.41	1.035	3.30
R22/R142b	35.0	50.5	20.0	10.3	3.61	0.991	3.64
R12	34.9	50.2	25.1	15.1	4.00	1.084	3.69
R22/R142b	35.3	49.7	25.1	15.1	4.27	1.067	4.00
R12	40.0	55.0	20.5	10.8	3.32	1.091	3.04
R22/R142b	39.7	54.4	20.2	10.3	3.51	1.058	3.32
R12	40.7	54.4	25.2	15.4	3.99	1.169	3.41
R22/R142b	40.4	55.0	24.9	15.2	4.74	1.135	4.18

Investigation of Using NARM R22/R142b as The Replacement of R12 in Dual-Evaporator Refrigerator-Freezers

The two different temperature levels in a dual-evaporator refrigerator-freezer give an opportunity to apply NARMs matching the large overall drop in temperature of the air streams in the evaporator. NARMs are possible substitutes for R12 with an improved energy efficiency.

When R22/R142b is applied, the evaporator area ratio is a very important parameter. The refrigeration system must be adjusted to achieve at least approximate counterflow and be fit for the mixture's properties. Meanwhile other unique characteristics of the R22/R142b such as the larger latent heat and mixing heat, the lower condensing pressure and discharge temperature, can also be fully utilized to improve the energy efficiency comparing with that of R12.

The tested system was a 220 L domestic refrigerator-freezer equiped with a hermetic reciprocating compressor, a wire-static condenser, a dual-shell evaporator and manual-defrost. The refrigerant first go through the low and then the high temperature eavporator. An intercooler was added to the end of the high-temperature evaporator where the capillary tube exchanges heat with the suction tube. Figure 3 shows the schematic diagram of refrigeration system.

During the experiments, the composition of R22/R142b mixture was determined on the basis of calculated results to satisfy the required temperature and pressure levels and refrigeration capacity. Meanwhile with each composition a series of tests were also performed to determine the refrigerant amount to obtain a good effect for evaporator.

Some experimental results are shown in table 3. The test I indicates the results using the R12 as a basis of comparison. In test II, the mixture was used where no changes were made to the existing refrigerator-freezer with the exception of replacing R12.

After adjusting the evaporator area ratio and making corresponding changes to the capillary tube, better results were obtained in the test III comparing with the test II.

Table 3. Some test results for the R22/R142b mixture and R12 in a dual-evaporator refrigerator-freezer

test	fluid	on time	off time	energy consump.	freezer temp.	storage temp.	pressure exit to condenser	pressure entrance to evaporator
		min	min	kwh/24	°C	°C	MPa	MPa
I	R12	20.7	41.4	1.02	-18.8/ -21.5	7.0/ 2.6	0.785	0.050
II	R22/ R142b	24.1	43.8	1.25	-21.0/ -24.8	9.3/ 4.6	1.182	0.076
III	R22/ R142b	22.4	45.8	1.10	-20.1/ -24.5	6.6/ 1.6	1.009	0.048
IV	R22/ R142b	15.2	37.3	1.03	-21.6/ -23.1	4.7/ 1.5	0.964	0.005

The energy consumption is slightly decreased as shown in the test IV. Here a compressor with a larger swept volume was applied to match the capacity of the mixture. Correspondingly, the temperature and pressure changes of some measured points in one cycle period (for the test IV) are shown in figure 4 and figure 5.

Conclusion:

NARMs are of good thermodynamic properties. The experiment shows NARM R22/R142b can improve energy efficiency about 8-10 percent in water-to-water heat pump with the both strict counter-flow heat exchangers. By adjusting the evaporator area ratio etc., using R22/R142b can achieve a slight improvement in the dual-evaporator refrigerator-freezer. The analysis and experiment show using NARMs as short or mid-term alternatives to CFCs would be a better choice.

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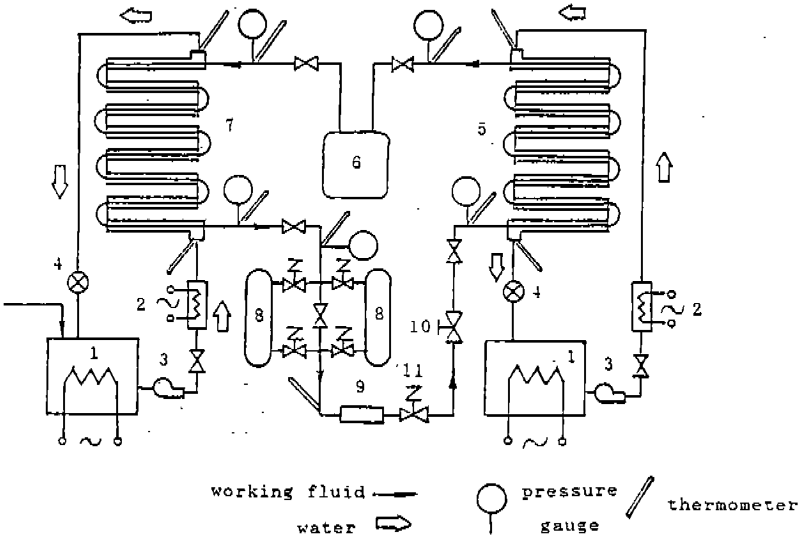

1.Tank 2.Thermostat 3.Pump 4.Flowmeter

5.Evaporator 6.Compressor 7.Condenser 8.Accumulator

9.Filter 10.Solenoid Valve 11.Expansion Valve

Fig 1. Experimental system of water-to-water heat pump

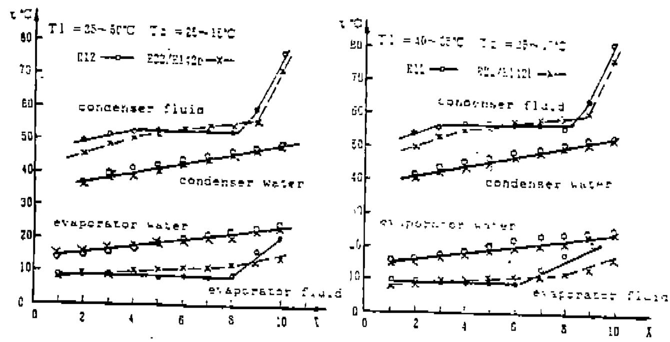

Fig 2. Comparison of temperature distribution on R22/R142b and R12

1 Compressor

2 Condenser

3 High-temperature intercooler

4 Capillary tube

5 Low-temperature evaporator

6 High-temperature evaporator

P1: pressure entrance to the capillary tube
P2: Pressure exit from the capillary tube
t1: Temp. exit from compressor
t2: Temp. exit from condenser
t3: Temp. entrance to low-temp. evaporator
t4: Temp. exit from low-temp. evaporator
t5: Temp. exit from high-temp. evaporator
t': Temperature in the freezer compartment
t": Temperature in the storage compartment

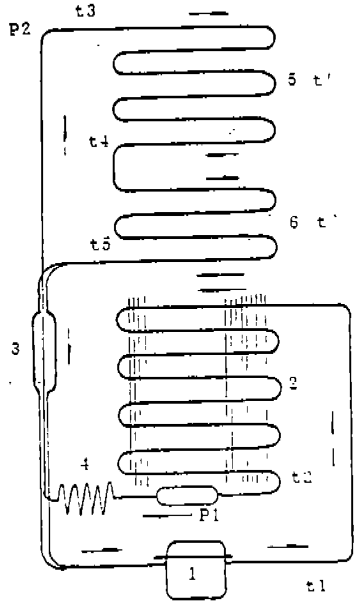

Fig 3. Experimental system of refrigerator-freezer

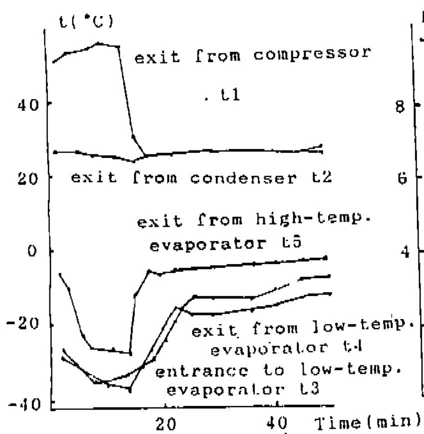

Fig 4. dynamic temperature distribution, measured for the evaporator and condenser (Test IV)

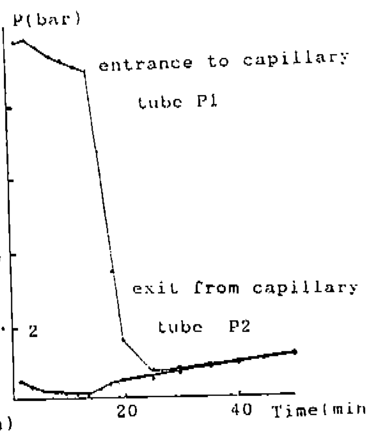

Fig 5. dynamic pressure distribution measured for evaporating and condensing (Test IV)