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PERFORMANCE EVALUATION OF AIR-CONDITION SYSTEM USING NARM BY EQUATION OF STATE

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ABSTRACT

The paper conducts a method of analyzing air condition system which using NARM of R22 and R142. MH revised equation is adopted in calculation process of VLE. At the same time, the effect is considered of pressure drop and heat transfer of the evaporation. The paper considers that COP of system using R22 and R-142 mixture is about 20% higher than that using pure R-22 when the heat transfer area is equal, but capacity of regrigerating reduces about 15%. If increasing the heat transfer area, the same capacity of refrigerating and the lower work are got.

NOMENCLATURE

A	Heat transfer area (m^2)
d	Diameter of tube (m)
f	Friction factor
G_r	Mass velocity (Kg/m^2s)
h	Specific enthalpy (KJ/Kmol)
P	Pressure (KPa)
Q	Heat transfer rate (W)
R	The constant of gas
S	Specific entropy (KJ/K · Kmol)
T	Temperature (K)
U	Overall heat transfer coefficient (W/m^2K)
V	Specific volume ($m^3/Kmol$)
V^*	Displacement of compressor (m^2/s)
V_C	Volume flow rate of condenser (m^3/h)
V_E	Volume flow rate of evaporator (m^3/h)
x	Vapor quality
Y	Composition of NARM
y	Molar fraction of vapor

ΔP	Pressure drop (KPa)
ΔT_m	Logarithmic mean temperature difference (K)
ε	Heat exchanger factor
η	Isentropic efficiency
μ	Dynamic viscosity
ξ	Void fraction
φ	Molar fraction of liquid
X_{tt}	Martinelli parameter

Subscript

1-4	State point of refrigerant
C	Condenser
E	Evaporator
L	Liquid
in	Inlet
out	Outlet
V	Vapor

INTRODUCTION

Recently because of the problem of CFCs, there is a new high tide of researching nonazetropic refrigeration mixtures (NARMs). In addition for NARMs, the saturation temperature changes during evaporation and condensation at constant pressures, which is termed a gliding temperature effect. When heat transfer fluid exchange heat with NARMs, the thermodynamic irreversibility can be reduced by matching the temperature glide against the drop resulting in an increase in the COP.

For air condition system, especially household air conditioner, energy consumption is problem which wants to solve. This paper takes the calculation of thermodynamic properties of NARMs as the point of departure, and then analyzes the charactics of R22 and R142 mixture and possibility of increase of COP.

CALCULATION OF THERMODYNAMIC PROPERTIES OF NARMS

It is known that there are ready-made figures and tables or claculation method for thermodynamic properties of pure refrigerants but there is nothing for that of NARMs because of its characteristics. A method of equation of state (EOS) is adopted to calculate the thermodynamic properties of NARMs. The key to this method is that an appropriate EOS and an appropriate mixing regulation are requied. In the ready-made EOS, most of EOS describes character of single-phase flow only and there are a few equations that can describes character of VLE. MH revised equation is adopted by authors.

The form of MH revised equation$^{(1)}$:

$$P = \frac{RT}{V-b} + \frac{A_2+B_2T+C_2e^{-KT/T_c}}{(V-b)^2} + \frac{A_3+B_3T+C_3e^{-KT/T_c}}{(V-b)^3} + \frac{A_4+B_4T}{(V-b)^4} + \frac{B_5T}{(V-b)^5} \qquad (1)$$

Where A_n、B_n、C_n (n=2, 3, 4, 5) and b is constants of equation. $K = 5.475$

The problem of calcualtion of VLE which must be solved at first is how to certain constants of MH equation$^{(2)}$. The constants of NARMs are solved with that of pure refrigerants and mixing regulation.

$$L_m = \sum\sum y_i y_j L_{ij} \qquad i\ j\ (i, j=1, 2)$$

L_m represents constant of NARMs, $L_{ii}=L_i$, $L_{jj}= L_j$, they are constants of pure refrigerants. For L_{ij} $(i\neq j)$, there are

$$(A_2)_{ij} = (1-Q_{ij})\left[\frac{(A_2)_i+(A_2)_j}{2}\right] \qquad (A_n)_{ij} = \frac{(A_n)_i+(A_n)_j}{2} \qquad (n=3,4,5)$$

$$(B_n)_{ij} = \frac{(B_n)_i+(B_n)_j}{2} \quad (n=2,3,4,5) \qquad b_{ij} = \frac{b_i+b_j}{2}$$

$$(C_n)_{ij} = \left[\frac{(C_n)_i^{1/3}+(C_n)_j^{1/3}}{2}\right]^3 \quad (n=2,3,4,5) \qquad (T_c)_{ij} = \left[(T_c)_i \cdot (T_c)_j\right]^{1/2}$$

Where Q_{ij} is parameter of action each other.

In two-phase region, pressure P or temperature T, specific enthalpy h and composition of NARM Y are general known, so there is

$$\begin{cases} h = h_L(1-x) + xh_V \\ Y = \varphi(1-x) + xy \end{cases} \qquad (2)$$

CYCLE ANALYSIS

The Temperature-Entropy diagram of an air condition cycle is shown in Fig. 1. The following assumption are employed for the cycle analysis:

1. Exansion process 3-4 is isentropic.
2. Pressure drop in the condenser is negligible and pressure drop in the evaporator is calculated with an equation (described below).
3. The condenser and evaporator are the forced convection exchangers.
4. Compression process 1-2' is non-ideality. The isentropic compressor efficiency in paper is fixed to be 0.55$^{(3)}$.

For the compression process 1-2'

$$s_1 = s_2 \qquad (3) \qquad\qquad h_{2'} = h_1 + \frac{h_2 - h_1}{\eta} \qquad (4)$$

For the condensation process 2'-3

$$P_{2'} = P_3 \qquad (5) \qquad\qquad Q_c = U_c A_c \Delta T_{mc}\, \varepsilon_c \qquad (6)$$

$$\Delta T_{mc} = \frac{(T_{2'} - T_{cout}) - (T_3 - T_{cin})}{\mathrm{Ln}\left(\dfrac{T_{2'} - T_{cout}}{T_3 - T_{cin}}\right)} \qquad (7)$$

For the expansion process 3-4

$$h_3 = h_4 \tag{8}$$

For the evaporation process 4-1

$$P_1 = P_3 + \Delta P \qquad (9) \qquad\qquad Q_E = U_E A_E \Delta T_{mE}\, \varepsilon_E \tag{10}$$

$$\Delta T_{mE} = \frac{(T_4 - T_{Eout}) - (T_1 - T_{Ein})}{\mathrm{Ln}\left(\dfrac{T_4 - T_{Eout}}{T_1 - T_{Ein}}\right)} \tag{11}$$

Where $\Delta P = \Delta P_f + \Delta P_m$

ΔP_f —— pressure drop caused by friction.

ΔP_m —— pressure drop caused by momentum change.

$$\Delta P_m = -\int_0^1 \left[\frac{Gr^2 x^2}{\xi \rho_V} + \frac{Gr^2 (1 - x)^2}{(1 - \xi) \rho_L}\right] dZ \tag{12}$$

Where void fraction ξ is calculated by Smith's equation(4).

$$\xi = x \left\{x + \frac{\rho_V}{\rho_L} (1 - x) \left[0.4 + 0.6 \left(\frac{x(\rho_V/\rho_L) + 0.4(1 - x)}{x + 0.4(1 - x)}\right)^{0.5}\right]\right\} \tag{13}$$

$$\Delta P_f = -\int_0^1 \left[1 + 2.85 X_{tt}^{0.523}\right]^2 \frac{2 f_V Gr^2 x^2}{\rho_V d}\, dZ \tag{14}$$

Where f_V is the friction factor. Colburn's equation is adopted in this paper:

$$f_V = \frac{0.046}{(Gr x d/\mu_V)^{0.2}} \tag{15}$$

RESULTS AND DISCUSSIONS

Through the process of calculation, the results of using NARM are shown in Fig. 2, Fig. 3 and Fig. 4 . Fig. 2 shows that refrigerating capacity Q_E is changed with molar fraction Y of R22. The lower the molar fraction of R22, the lower the refrigerating capacity Q_E. It is because that the refrigerating capacity per unit of swept volume of R142 is lower than that of R22. In addition, the suction specific volume is larger, so the mass flow rate of system is smaller. Fig. 3 shows the COP is changed with the molar fraction Y of R22. When Y 〉 0.7, the COP is higher than that of R22, when y=o. 85, the maxium COP=3. 10.

In the region of low molar fraction, though there is advantage of the temperature glide, efrigerating capacity Q_E is lower, so the COP is lower. When Y 〉 0.70, the effect of temperature glide is evident though Q_E is lower than that of R22, the work of compressor is much lower. So the COP is higher than that of R22.

Generally, refrigerating capacity of system requires satisfied at first. For increasing Q_E of NARM, the evaporation temperature is increased, it causes that ΔT_m becomes small, so A_E must be increased. Fig.4 is shown the change of A_E is required in the same Q_E with the change of Y. In the maxium point of COP, A_E of NARM is about 15% more than that of R22. If this A_E is adopted in the system using R22, the COP of R22 is about 2.95.

CONCLUSIONS

Simulation analysis for air condition cycle, using NARM of R22 and R142 mixture, have been conducted with correlation equations of the heat transfer coefficient and pressure drop for evaporation.

When the system is the same, the molar fraction of R22 is 0.85, the COP of the NARM is about 20% higher than that of R22, but refrigerating capacity Q_E is about 10% lower than that of pure R22. When keeping Q_E not changed, the area of evaporator A_E must be increased. A_E of the NARM is about 15% larger than that of R22.

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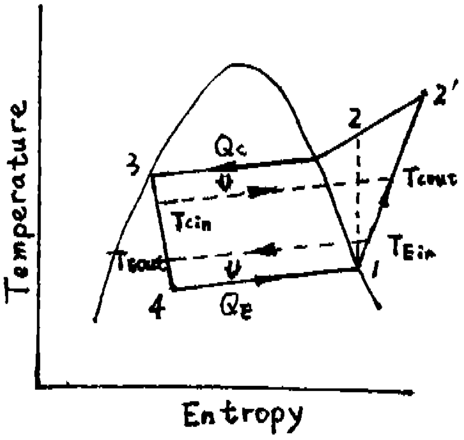

Fig. 1 Temperature - entropy diagram

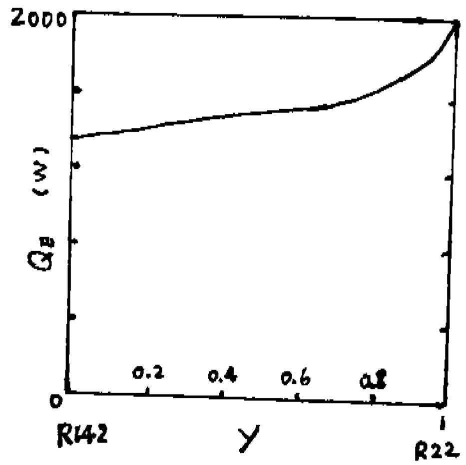

Fig. 2 Change of Q_E with Y in the same system

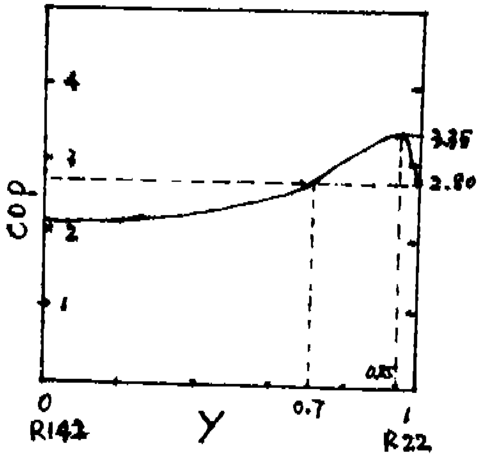

Fig. 3 Change of COP with Y in the same system

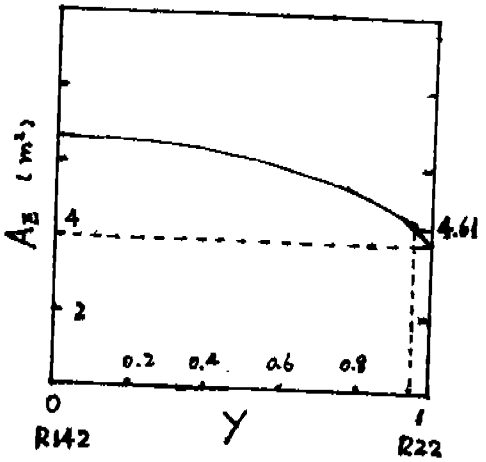

Fig. 4 Change of A_E with Y in the same Q_E