1986

Investigations into the Use of Refrigerant Mixtures in Air Conditioner Operating on a Steel Industry Crane Cabin

K. Maczek

J. Schnotale

INVESTIGATIONS INTO THE USE OF REFRIGERANT MIXTURES IN AIR CONDITIONER OPERATING ON A STEEL INDUSTRY CRANE CABIN

K. MACZEK, J. SCHNOTALE
Technical University of Kraków (W-3)
Poland

1. INTRODUCTION

High ambient temperature dominated in steel industry makes it necessary to use air conditioners in the crane cabins.
According to safety requirements a number of our working crane cabine air conditioners designed and filled with refrigerant R142 had to be out of operation. On account of necessary continuous operation and soving investment costs we decided to refill air conditioners with either another single refrigerant or with refrigerant mixture applicable to existing ambient temperature but having necessary cooling capacity in such thermal conditions. Refilling was preceded with thermodynamic analyzis and laboratory investigations.

2. THEORETICAL INVESTIGATIONS

Working media designed for operating in air conditioners at the high ambient temperature should be of similar qualities to used for heat pumps. Criteria of desired quality are primarily as follows: general applicability (thermal stability etc) and certain thermodynamic characterisitics suitable for realized cycle (eg. low condensing pressure for given temperature). Economic aspects can be taken into comideration by calculating total cost of operation due to the coefficient of performance (COP) and investment costs resulting of the compressor displacement volume.
First we investigated some pure refrigerants. Thermodynamical calculations and the analysis of the refrigerant cycle was made for the following ranges of the operating variables

- condensing temperature $t_c = 90^oC$
- boiling temperature $t_o = 5^oC$
- cooling capacity $\Phi_o = 8{,}0$ kW

Some comparable data and general results of our calculations are presented in the Table 1.

I.I.F. - I.I.R. - Commissions B1, B2, E1 and E2 - West Lafayette, IN (U.S.A)

TABLE 1

Results of calculations of refrigerating cycles in air conditioner realised with different pure refrigerants

Component			R12	R142	R114	R21	R11
boiling pressure	Po	Pa 10^5	3,7	1,77	1,1	0,89	0,5
condensing pressure	Pc	Pa 10^5	25,6	15,5	11,4	9,5	6,0
compressor displacement volume	V	$\frac{m^3}{h}$	37,5	71,5	144,9	153,1	293,3
elektrical pwer of the compressor	P	kW	7,56	6,73	7,81	9,91	11,50
critical temperature	t_{cr}	^oC	111,5	136,5	145,7	178,5	198,0
critical pressure	Pcr	Pa 10^5	41,2	41,1	33,3	51,7	44,0

From the Table 1 it is evident that neither refrigerent R12 - because of too high condensing pressure, nor refrigerants 114 and 11 - becouse of the low volumetric efficiency can be used instead of refrigerant R142. With the refrigerant R114 eg. the cooling capacity of the air conditioner would have decrease about twice. In our next investigations we decided to replace R142 with zeotropic mixtures of R12/R114. For the purpose of thermodynamical calculations and computer symulations of the cycles realized with zeotropic mixtures thermodynamic properties ot refrigerant R12 and R114 and the mixtures of R12/R14 have been determined using Marltn - Hou equation of state [1] with principles ot mixtures rules given by Kandlikar [2] .

For given reference temperature and pressure the enthalpy H and entropy S were determined as follows:

$$H_{(T,P)} = \int_{T_{ref}}^{T} C_V^o \, dT + \int_{P_{ref},V_{ref}}^{P,V} d(PV) - \int_{V_{ref}}^{V} [P - T(\partial P/\partial T)_V] dV + H_{ref} \quad (1)$$

$$S_{(T,P)} = \int_{T_{ref}}^{T} \frac{C_V^o}{T} dT + \int_{V_{ref}}^{V} \left(\frac{\partial P}{\partial T}\right)_V dV + S_{ref} \quad (2)$$

For the refrigerant mixture R12/R114 entalpy H_m and entropy S_m have been determined using ideal mixtures behavior:

$$H_m = \sum_{i=1}^{n} x_i H_i \quad (3)$$

$$S_m = \sum_{i=1}^{n} x_i S_i - R \sum_{i=1}^{n} x_i \ln x_i \qquad (4)$$

Transport properties of the refrigerant mixtures have been estimated on the bese of kandlikar equations [2] .

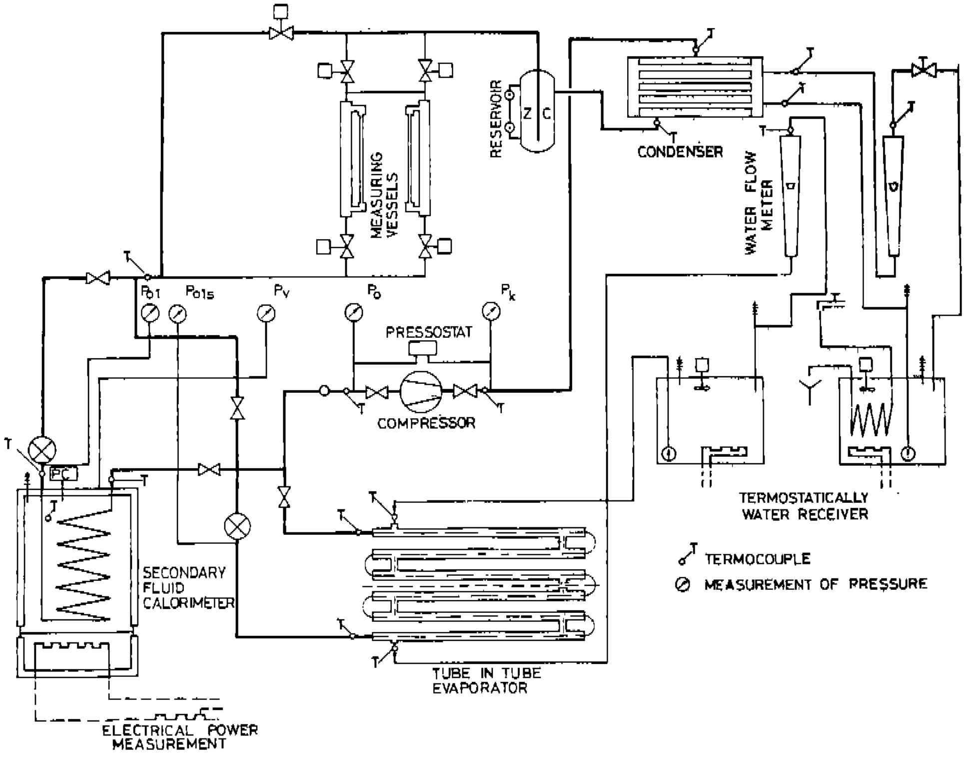

Fig. 1 - Test arrangement

3. MEASUREMENT EQUIPMENT FOR EXPERIMENTAL INVESTIGATIONS

Measurements of the thermodynamic cycle were made on our laboratory experimental stand. The general problem was to make the refrigerant mixture of R12/R114 which would give the best working parameters at the conditions of the overhead air conditioner.

Refrigeration capacity and the condenser pressure at given ambient temperature can vary according to the concentration of refrigerants in the mixture.

Experimental stand for laboratory measurements is presented on Fig. 1. The compressor is a hermetic one with 0,8 kW nominal power of the electric driving motor. On the stand a conventional single stage compession circuit was realised and measured. The refrigerating capacity of the evaporator was measured with a secondary fluid calorimeter. Alternative measurement procedure was made with the tube - in - tube counterflow evaporator. This evaporator made of glass makes it possible to study the flow regime in the process of evaporation of the mixtures and evaporation temperature profile. The flow rate of the mixture is determined by means of measuring vessels. Heat is sup plied to the evaporator with water curcuit throughout ultrathermostat. The heat from the condenser being removed to the cooling water - circuit is measeured with flow meter and termocouple and then calculated.

4. RESULTS OF MEASUREMENTS

The measurements on the described laboratory stand were made for the following ranges of the operating wariables.

- condensing temperature $t_c = 50^oC$ to 90^oC
- boiling temperature down to $t_o = + 3^oC$
- filling concentrations of the mixture $\xi = 0,25$ to 0,75 kg R12/kg (R12+R114).

Fig. 2 shows the cooling capacity, versus condensing temperature for the refrigerant R142 and the mixture R12/R114 with varied concentrations. Tests were made in steady - state conditions and measurement walues were approximated using straightline approximation.

As it was expected the measured values are between the values of the mixtu res component.

Diagram (Fig. 3) represents the temperature gliding line of evaporating mixture $\xi = 0,54$ kg R12/kg (R12 + R114) in the evaporator. It is evident that at the and of evaporator there is only a small amount of liquit which can be transportet throughout the loop into the suction line together with oil returning to the compressor (Fig. 4).

On the basis of our measurements. The selected mixture of concentration $\xi = 0,4$ was proposed with thermodynamic characteristic similar to the obtained with R142.

Selected mixture of refrigerants has been applicated into the operating air conditioners with good results. The only problem now we have is, what kind of mixture should be used to fill up the air conditioner after it leaks. Till now in such cases we refill air conditioner with new whole portion of selected mixture of refrigerants.

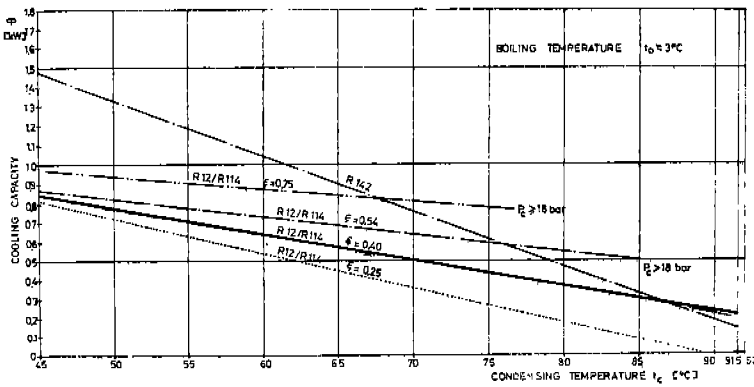

Fig. 2 - Cooling capacity

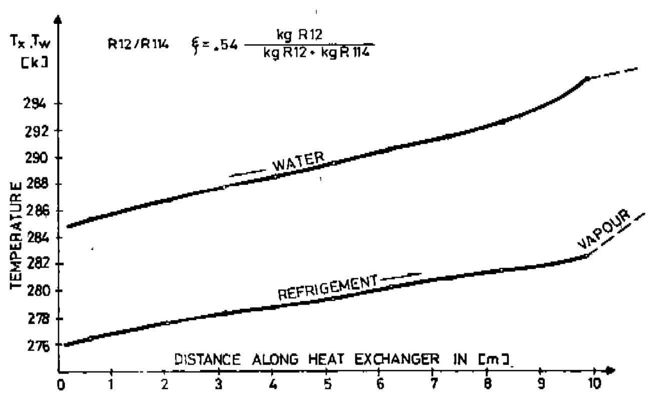

Fig. 3 - Temperature profiles at the tube in tube evaporator

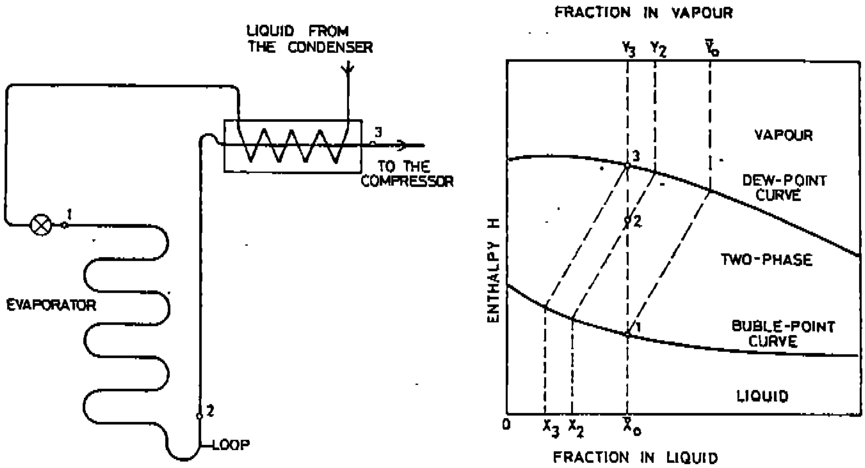

Fig. 4 - Phase equilibria beforethe inlet into the compressor

5. CONCLUSIONS

1. Refrigerating system with pure refrigerant can be refilled and operate satisfactory with selected zeotropic mixture of refrigerants adequate to thermal conditions and refrigerating capacity.
2. For high ambient temperature prevailing in steel industry air conditioners with zeotropic mixture of refrigerants R12 and R114 can be used as substitute of refrigerant R142.

6. NOMENCLATURE

C_v^o - specific heat capacity of vapour at zero pressure, $\frac{kJ}{kg\,K}$

H - specific enthalpy, $\frac{kJ}{kg}$, $\frac{J}{mol}$

P - pressure, Pa

t - temperature, ^oC

T - temperature, K

S - entropy, $\frac{kJ}{kgK}$, $\frac{J}{mol\,K}$

R - gas constant $\frac{J}{mol\,K}$

Φ_o - cooling capacity kW

V - specific volume of vapour $\frac{m^3}{kg}$

X_i - mole fraction of component i

ξ - mass fraction, $\frac{kg\ R12}{kg(R12+R114)}$

Subscripts

o - boiling

c - condensing

cr - critical

ref - reference

m - mixture

7. REFERENCE

1. C.Y. Chan, G.G. Haselden, Computer-based Refrigerent Thermodynamic Properties Part 1 and 2 Int. Journal of Refrigeration 1981/1
2. S.G. Kandlikar and co., Predicting the Properties of Mixtures of R22 and K12 Port 1 and 2 ASHRAE Transactions 1975
3. M. Kuver and co., Measurement and Calculation of p-v-T-x Data of Binary Mixture R12/R114. I.I.R Paris 1983

RESUME

"L'etude sur l'emploi des melanges des freons comme frigorigenes dans les climatiseurs des cabines de pont d'enfournement".

La temperature ambiante elevee dans l'industrie siderurgique exige d'employer des climatiseurs dans cabines de pont d'enfournement.
On a fait les etudes sur la possibilite d'appliquer d'une melange zeotropique des freons R12/R114 dans les climatiseurs construits premierement pour les freons purs. L'application de cette melange dans les climatiseurs a ete precede par l'analyse thermodynamique du cycle et par les etudes experimentaux qui avait permis de determiner une composition convenable de la melange R12/R114 en tenant compte de la temperature ambiante existante et de la puissance frigorifique requise.

SUMMARY

STUDY ON THE USE OF MIXTURES OF FREONS AS REFRIGERANT IN THE AIR-CONDITIONING SYSTEM OF THE CONTROL ROOMS ON THE DESK OF THE BLAST FURNACE CHARGING ENTRANCE

The high temperature in steel industry requires the use of air conditioning systems in the control rooms on the deck of the blast furnace charging entrance.

The possibility of using azeotropic mixture of R12/R114 freons in air-conditioning systems formerly designed for pure freons was studied. This mixture in such air-conditioning systems was used only after the thermodynamic analysis of the cycle and experimental studies had been carried out. Both the analysis and the studies had enabled the determination of a suitable composition of the R12/R114 mixture, according to the temperature in that place and the required cooling power.