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Performance Of Window Air Conditioner Using Alternative Refrigerants With Different Configurations Of Capillary Tube

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Abstract

The objective of this study is to present test results on the basis of experimental data of capillary tubes for R-22 and its alternative R-410A (R-32/125, 50/50 wt.%).Three capillary tubes with different length (500mm, 900mm, and 1500 mm) and inner diameter (1.3mm, 1.4mm, and 1.6mm respectively) were selected as test sections. Compressor work, heat rejected in the condenser, coefficient of performance (COP) and mass flow rate through capillary tubes were calculated for several ambient temperature. Compressor work, heat rejected in the condenser, coefficient of performance (COP) and mass flow rate of R-410A were compared with R-22 for the same test conditions. The results of single capillary tubes were also compared with the results of combination of two capillary tubes. The air-conditioner was 1 TR unit designed for R-22 and R410A. The performance of the air-conditioner with R-410A was compared with the baseline performance of the air-conditioner with R-22.The experiment result shows that (1) the coefficient of performance (COP) for R-410A is lowers than R-22. And the mass flow rate, heat rejected in the condenser and compressor work done for R-410A are higher than R-22 for all capillary tubes. (2)For this experiment the combination of two capillary tubes with inner diameter of 1.4mm and length 900 mm has higher coefficient of performance (COP) than single capillary tubes with inner diameter of 1.3 mm, 1.6 mm and length 500 mm, 1500 mm respectively.(3) The coefficient of performance (COP) of capillary tube with inner diameter of 1.6 mm and length 1500 mm is higher than the capillary tube with inner diameter of 1.3 mm and length 500 mm.(4) For R-22, the coefficient of performance (COP) of combination of two capillary tubes with inner diameter of 1.4mm and length 900 mm is 17.10 % higher than the straight capillary tube with inner diameter of 1.3 mm and length 500 mm. And 13.07 % higher than the straight capillary tube with inner diameter of 1.6 mm and length 1500 mm at 40ºC ambient temperature. (5)And for R-410A, the coefficient of performance (COP) of combination of two capillary tubes with inner diameter of 1.4mm and length 900 mm is 13.00 % higher than the straight capillary tube with inner diameter of 1.3 mm and length 500 mm. And 11.15% higher than the straight capillary tube with inner diameter of 1.6 mm and length1500 mm at 40ºC ambient temperature.

Keywords: Window Air Conditioner, Capillary tube, Refrigerant, R-410A and COP.

Introduction

A capillary tube is a constant area expansion device, which is commonly used in small refrigeration and air conditioning systems. It is a simple tube with inner diameters of a few millimeters, but the flow inside a capillary tube is very complex and pressure drop through the capillary tube has a strong influence on the performance of the whole system. It has advantages of simplicity, inexpensiveness, and the requirement of low starting torque of a compressor **1.** The capillary tube is a copper tube of very small internal diameter. It is of very long length and it is coiled to several turns so that it would occupy less space. Capillary tube used as the throttling device in the domestic refrigerators, deep freezers, water coolers and air conditioners. When the refrigerant leaves the condenser and enters the capillary tube its pressure drops down suddenly due to very small diameter of the capillary. In capillary the fall in pressure of the refrigerant takes place not due to the orifice but due to the small opening of the capillary. The decrease in pressure of the refrigerant through the capillary depends on the diameter of the capillary and the length of the capillary. In the past, capillary tube performances were extensively studied by many researchers. G. Kim, M. S. Kim1 [2],Pongsakorn Sarntichartsak a, Veerapol Monyakul b, Sirichai Thepa c [3],Dongsoo Jung,1, Chunkun Park, Byungjin Park [4],M.K. Mittal, Ravi Kumar [5], Guobing Zhou a, Yufeng Zhang b [6],Guobing Zhou a, Yufeng Zhang b, Yongping Yang a, Xi Wang a [7], Chasik Park, Sunil Lee, Hoon Kang, Yongchan Kim[8],Sukkarin Chingulpitak a,b, Somchai

Wongwises b[9], Jongmin Choi, Yongchan Kim[10] and Zhou Guobing a,Zhang Yufeng b[11].The study on R-410A as alternative refrigerant to R-22 is not sufficiently covered in previous studies, even though this refrigerant is used or considered in new refrigeration systems. Therefore, the objective of this study is to provide a set of capillary tube performance data in a refrigeration system for R-410A and R-22.

Experimental Setup

A. Description of the Test Apparatus

A window air conditioner of 1 ton refrigeration capacity was selected for testing the performance of three capillary tubes. The overall physical dimensions of the window air conditioning system are (60×56 × 38) cm and 42 kg weight .The vapour compression cycle of the conditioner was provided with controlling and measuring devices at the key locations of the refrigeration cycle. The window air conditioner is composed of the basic components of a vapour compression system: a reciprocating compressor, a condenser, a capillary tube and an evaporator, and such attachments as accumulator and fans. The unit was retrofitted with R-410A. In order to have a uniform temperature throughout the room, a ceiling fan of 70 watts power installed in the centre of the room was used to circulate the air inside the room. The schematic diagram representing the experimental air-conditioner is shown in Fig 1. The unit was retrofitted with R-22 and R-410A, one after the other.
The evaporator and condenser of the refrigeration unit were finned tube air heat exchangers. Both evaporator and condenser fins were made of aluminum. The air conditioner accommodates a three speed motor to run the condenser fan. The testing capillary tubes were placed in a horizontal and straight configuration with three on-off valves. The combination of two capillary tubes with same diameter (1.4 mm) and length (900 mm) were connected with one on-off valve. And single capillary tubes with different diameter and length (diameter 1.3 mm, 1.6 mm and length 500 mm, 1500 mm respectively) were connected with another two on-off valves.

B. Measurements

All measuring devices were calibrated in the appropriate operating range. To measure the compressor power, a wattmeter with ± 0.5% accuracy was used. Room temperature was measured with the help of precision thermometer with an accuracy of ±0.5ºC.Refrigerant pressure were measured using precision pressure gauges with an accuracy of ±0.5 kPa .The wet- bulb temperature is determined by the measured dry-bulb temperature and relative humidity. Note that specific enthalpies of air are determined by the measured temperature and relative humidity. The experimental data were recorded continuously for 40 min with 10 s intervals.

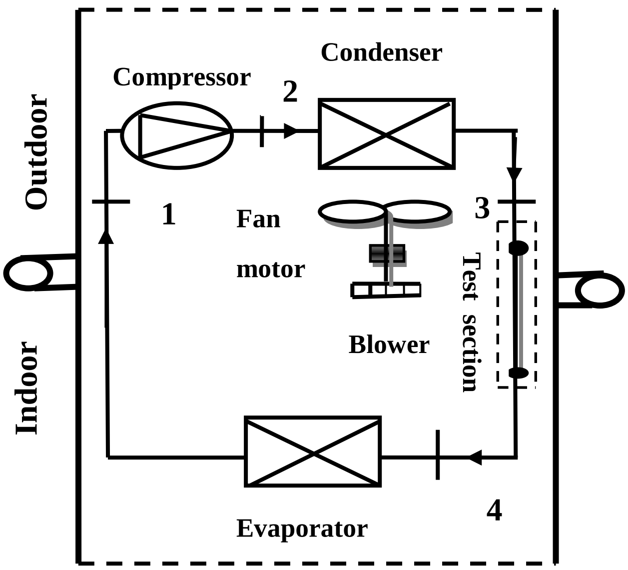

Fig 1 the schematic diagram of the window air-conditioner

C. Selection of the Refrigerant

R22 has been widely used for many decades in vapour compression refrigeration system. It is generally accepted and most suitable refrigerant for air-conditioners. Unfortunately, it belongs to the family of hydro-chlorofluorocarbon (HCFC) refrigerants, which were considered as harmful working fluids to the environment. Due to their stratospheric ozone layer depletion, they are now controlled substances by the Montreal protocol. The new trend is to use zeotrope blend refrigerants in the air conditioning system. In the present experiment, one zeotrope blend refrigerants are selected as alternative refrigerants for R-22 in the window air conditioner. The refrigerants is R-410A, comprising of (R32/R125) in a mass fraction composition percentage as (50/50).

D. Selection of capillary tube

Three capillary tubes with different inner diameters (1.3mm, 1.4mm and 1.6mm) and lengths (500mm, 900mm and 1500mm respectively) were selected as test section in window air conditioner. All capillary tubes were straight and made with copper material. Two capillary tubes with same diameter and length (1.4mm and 900) were used parallel in window air

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conditioner .The detail characteristics of capillary tube are shown in table 1.

Table 1: Description of the capillary tube

S/No.	Inner Diameter (mm)	Length (mm)	No of Capillary
1	1.3	500	1
2	1.4	900	2
3	1.6	1500	1

Test Description

For testing the effect of several capillary tubes with several ambient temperatures, the refrigerant were charged into system with optimum quantity. At the incipience of the test, the system was kept running at least 40 minutes to reach the steady state conditions. This was done by monitoring the temperature and pressure gauge for the circulated refrigerant. After that achievement, the refrigerant side measurements, temperature and pressure, and air side measurements, dry bulb temperature, were recorded. These readings were taken at various ambient temperatures to detect the performance of the window air conditioner. This procedure was repeated for the refrigerants R-410A.The open and closed test unit of window air conditioner system is shown in fig 2.1(a) and 2.1(b).

All test runs for each of the three capillary tubes were performed in an identical manner and at the steady state condition. After testing for refrigerant R-22, the refrigeration unit was evacuated and recharged again with the refrigerant R410A with maximum refrigerant charge.

Fig 2.1 (a) Open unit

Fig 2.1 (b) Closed unit

Results and Discussion

The test results on the performance of various capillary tubes for R-22 and R-410A are presented for various geometric and operating conditions. The mass flow rate, COP, heat rejected in the condenser and compressor work of various capillary tubes for R-22 and R-410 presented in this section.

A. Mass flow rate through capillary tubes

Fig 3.1 and 3.2 represent the influence of various ambient temperature on the mass flow rates of R-22 and R-410A for straight capillary tubes with various diameter (1.3 mm, 1.4 mm and 1.6 mm) and length (500 mm, 900 mm and 1500 mm respectively). This fig shows that mass flow rate increases as ambient temperature increases and the mass flow rate also increases when we increase the inner diameter of the capillary tubes and decreases when we increase the length of capillary tubes. And it also shows that the mass flow rate of R-410A is higher than R-22.For R-22, the mass flow rate of combination of two capillary tubes with inner diameter of 1.4mm and length 900 mm is 1.94% lower than the straight capillary tube with inner diameter of 1.3 mm and length 500 mm. And 1.09 % lower than the straight capillary tube with inner diameter of 1.6 mm and length 1500 mm at 40ºC ambient temperature. And for R-410A, the mass flow rate of combination of two capillary tubes with inner diameter of 1.4mm and length 900 mm is 2.03% lower than the straight capillary tube with inner diameter of 1.3 mm and length 500 mm. And 1.23% lower than the straight capillary tube with inner diameter of 1.6 mm and length1500 mm at 40ºC ambient temperature.

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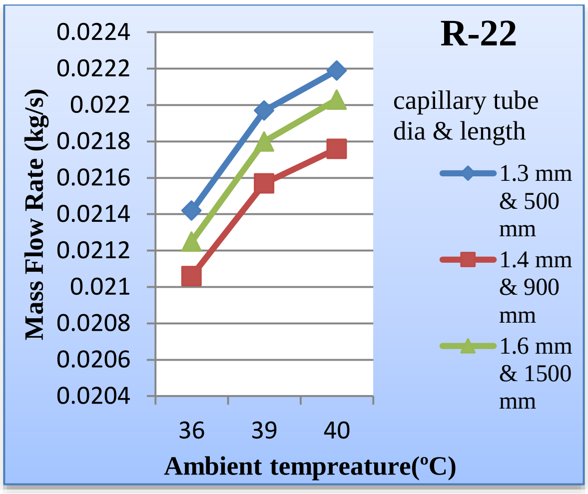

Fig. 3.1 Variation of mass flow rate versus ambient temperature for refrigerant R-22

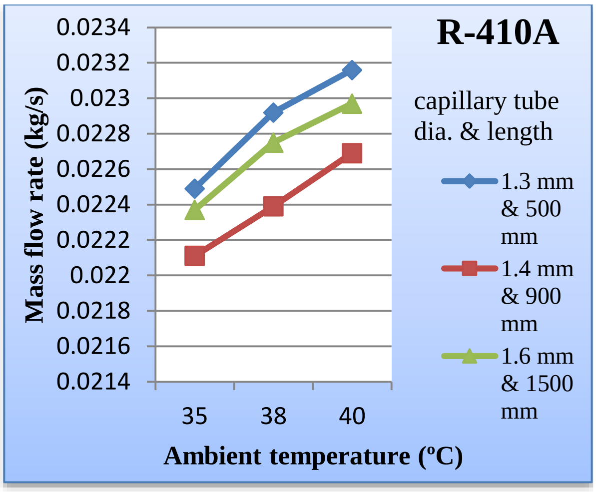

Fig. 3.2 Variation of mass flow rate versus ambient temperature for refrigerant R-410A

B. Heat rejected in the condenser

Fig 3.3 and 3.4 shows that the heat rejected in the condenser of R-410A is higher than R-22.For R-22, the heat rejected in the condenser of combination of two capillary tubes with inner diameter of 1.4mm and length 900 mm is 2.50% lower than the straight capillary tube with inner diameter of 1.3 mm and length 500 mm. And 1.85 % lower than the straight capillary tube with inner diameter of 1.6 mm and length 1500 mm at 40ºC ambient temperature. And for R-410A, the heat rejected in the condenser of combination of two capillary tubes with inner diameter of 1.4mm and length 900 mm is 3.39% lower than the straight capillary tube with inner diameter of 1.3 mm and length 500 mm. And 2.90% lower than the straight capillary tube with inner diameter of 1.6 mm and length1500 mm at 40ºC ambient temperature.

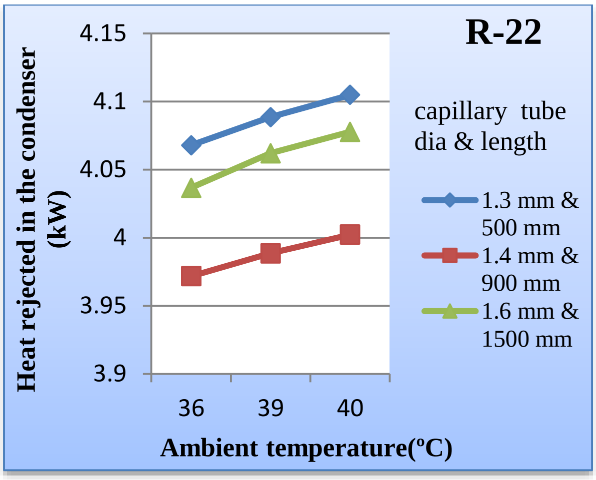

Fig. 3.3 Variation of heat rejected in the condenser versus ambient temperature for refrigerant R-22

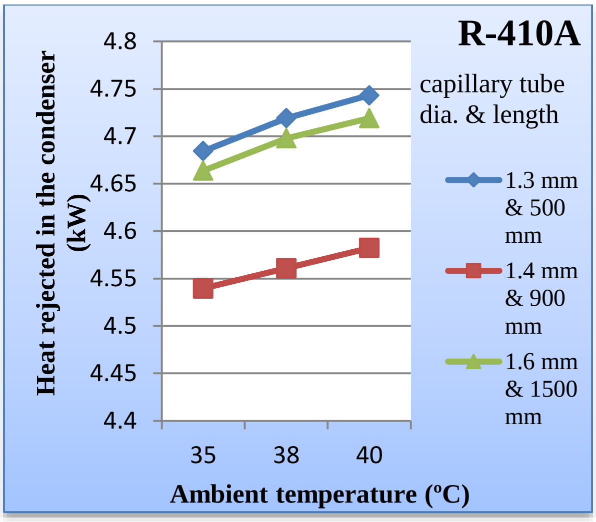

Fig. 3.4 Variation of heat rejected in the condenser versus ambient temperature for refrigerant R-410A

C. Compressor work done

Fig 3.5 and 3.6 shows that the compressor work done of R-410A is higher than R-22. For R-22, the compressor work done of combination of two capillary tubes with inner diameter of 1.4mm and length 900 mm is17.07% lower than the straight capillary tube with inner diameter of 1.3 mm and length 500 mm. And 13.04 % lower than the straight capillary tube with inner diameter of 1.6 mm and length 1500 mm at 40ºC ambient temperature. And for R-410A, the compressor work done of combination of two capillary tubes with inner diameter of 1.4mm and length 900 mm is 12.94% lower than the straight capillary tube with inner diameter of 1.3 mm and length 500 mm. And 11.21% lower than the straight capillary tube with inner diameter of 1.6 mm and length 1500 mm at 40ºC ambient temperature.

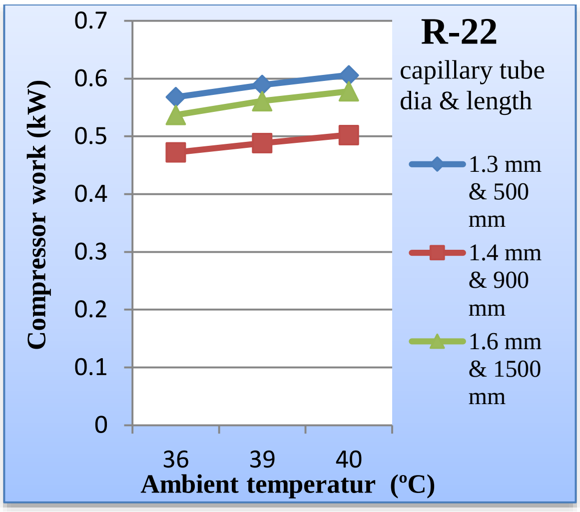

Fig. 3.5 Variation of compressor work versus ambient temperature for refrigerant R-22

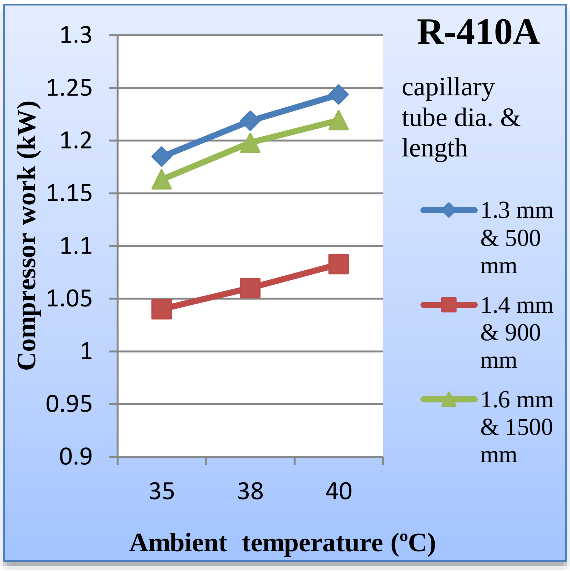

Fig. 3.6 Variation of compressor work versus ambient temperature for refrigerant R-410

D. Coefficient of performance (COP)

Fig 3.7 and 3.8 shows that the coefficient of performance (COP) of R-410A is lower than R-22.The coefficient of performance (COP) of capillary tube with inner diameter of 1.6 mm and length 1500 mm is higher than the capillary tube with inner diameter of 1.3 mm and length 500 mm. For R-22, the coefficient of performance (COP) of combination of two capillary tubes with inner diameter of 1.4mm and length 900 mm is 17.10 % higher than the straight capillary tube with inner diameter of 1.3 mm and length 500 mm. And 13.07 % higher than the straight capillary tube with inner diameter of 1.6 mm and length 1500 mm at 40ºC ambient temperature. And for R-410A, the coefficient of performance (COP) of combination of two capillary tubes with inner diameter of 1.4mm and length 900 mm is 13.00 % higher than the straight capillary tube with inner diameter of 1.3 mm and length 500 mm. And 11.15% higher than the straight capillary tube with inner diameter of 1.6 mm and length1500 mm at 40ºC ambient temperature.

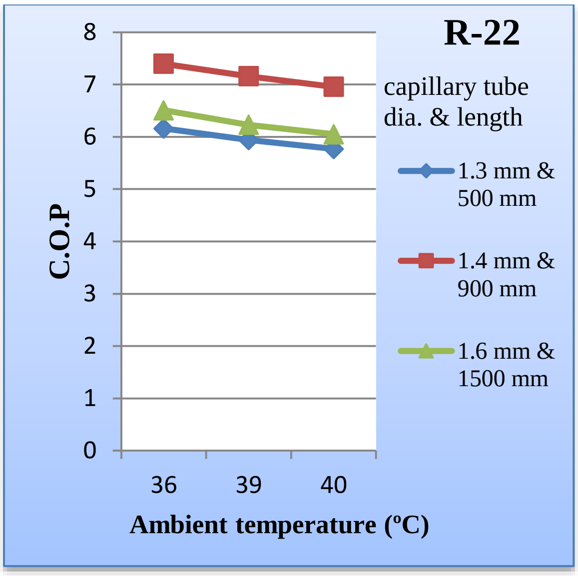

Fig. 3.7 Variation of C.O.P. versus ambient temperature for refrigerant R-22

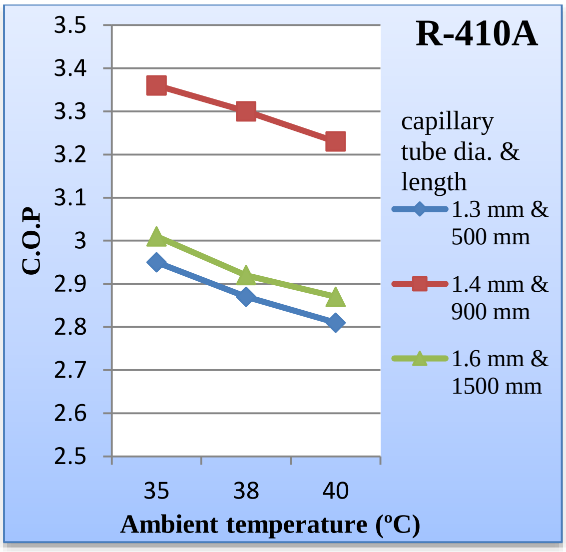

Fig. 3.8 Variation of C.O.P. versus ambient temperature for refrigerant R-410A

Conclusions

The performances of the capillary tubes with several length and inner diameter combinations for R-22 and its alternative R-410A were experimentally investigated. In this experiment we observed that the length, diameter and no. of capillary tubes are playing very important role in the performance of air conditioner. In the air conditioner performance parameter depends upon the mass flow rate between compressor and capillary tube. The conclusion of this experiment can be summarized as follows

- The ambient temperature influences the coefficient of performance (COP), heat rejected in the condenser, compressor work done and mass flow rate of refrigerant R-22 and R-410A for straight capillary tubes with various diameter and length.
- The mass flow rate ,heat rejected in the condenser, and compressor work done of combination of two capillary tubes arranged parallel together are lower as compared with single capillary tubes. The coefficient of performance (COP) of combination of two capillary tube are higher as compared with single capillary tubes .So for this experiment the combination of two capillary tube is better than single capillary tube.
- The mass flow rate ,heat rejected in the condenser, and compressor work done of capillary tube with inner diameter of 1.6 mm and length 1500 mm is lower than the capillary tube with inner diameter of 1.3 mm and length 500 mm.
- The coefficient of performance (COP) of capillary tube with inner diameter of 1.6 mm and length 1500 mm is higher than the capillary tube with inner diameter of 1.3 mm and length 500 mm.
- For this experiment the mass flow rates ,the heat rejected in the condenser and compressor work done for R-410A are higher than R-22.And the coefficient of performance(COP) for R-410A is lower than R-22 for all capillary tubes. .

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