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Performance of window air conditioner using alternative refrigerants with different configurations of capillary tube

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KEYWORDS

Window Air Conditioner, capillary tube, Refrigerant, R-410A, COP and Cooling Capacity

A B S T R A C T

This research paper presents the experimental performance of a window air conditioner using alternative refrigerants (R-22 and R-410A) with different configurations of capillary tube. Three capillary tubes with different length and inner diameter were selected as test sections. The capillary tube lengths were 889mm, 559mm, and 508 mm.The air-conditioner was a 1 TR unit designed for R-22 and R410A. The performance of the air-conditioner with R-410A was compared with the baseline performance with R-22.The performance parameters considered are cooling capacity, coefficient of performance, energy consumption, and compressor work. Test results shows that(1)For R-22, the COP of Capillary tube 889mm was 32% efficient than capillary 559mm and 40% efficient than capillary 508mm for 39°C outdoor temperature (2) For R-410A, the COP of Capillary 889mm was 38% efficient than capillary 559mm and 47% efficient than capillary 508mm for 39°C outdoor temperature.

Introduction

Air conditioning and refrigeration systems plays an important role in industry, infrastructure and in households application. The industrial sector includes the food industry, textiles, chemicals, printing, transport and others. Infrastructure includes banks, restaurants, schools, hotels and recreational facilities. Therefore, installation, repair and maintenance of equipment to function properly are important for the operations associated with these activities. The capillary tube is made from copper pipe, with a diameter around 0.5 mm to 5 mm and length around 0.5 m to 5 m. Its use depends on power and load capacity of the system. The capillary tube is often used with small cooling load or small changing load systems, such as refrigerators, water coolers and small air conditioners (Akkarat Poolkrajang and Nopporn Preamjai, 2009). 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 millimetres, 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 (Pongsakorn Sarntichartsak et al., 2007). 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.

(Pongsakorn *et al.*, 2007). This paper focuses on an investigation of the proper capillary tube length for an inverter air conditioner. Air to air variable capacity systems with R-22 and R-407C were tested and modeled. First, the optimum refrigerant charge was determined for four capillary tubes at full load condition by varying the mass charge from 1.1 kg to 1.9 kg. The capillary tube lengths were 1.016 m, 0.914 m, 0.813 m and 0.711 m. The two zone model, the distributed model and the combined model were compared to estimate the optimal charge inventory. The combined model analysed a simple path evaporator, a complex path condenser with a two zone model and a distributed model,respectively. It obtained good agreement with experimental results for the system performances and the optimum mass charge.

Kim *et al.*, (2002) The objective of this study is to present test results and to develop a dimensionless correlation on the basis of the experimental data of adiabatic capillary tubes for R22 and its alternatives, R407C (R32/125/134a, 23/25/52 wt.%) and R410A (R32/125, 50/50 wt.%). Several capillary tubes with different length and inner diameter were selected as test sections. Mass flow rate through the capillary tube was measured for several condensing temperatures and various degrees of subcooling at the inlet of each capillary tube.

Here are some of the advantages of using capillary tube as the throttling device in the refrigeration and the air conditioning systems:

1) The capillary tube is a very simple device that can be manufactured easily and it is not very costly.
2) The capillary tube limits the maximum amount of the refrigerant that can be charged in the refrigeration system due to which the receiver is not required in these systems.
3) When the refrigeration plant stops the pressure across the capillary tube becomes same and also along the whole refrigeration cycle the pressure is constant. This means that when the plant is stopped the pressure at the suction and discharge side of the compressor are same. Thus when the compressor is restarted there is not much load on it since it does not have to

overcome very high pressures. Due to this the compressor motor of smaller torque can be selected for driving the compressor, thus reducing the cost of the compressor. This along with the above two advantages helps reducing the overall cost of the refrigeration and the air conditioning system (Kim *et al.,* 2002).

Experimental work

Description of the Test Apparatus

A window air conditioner of 1 ton refrigeration capacity was selected for testing. The overall physical dimensions of the window air conditioning system are (60 X 56 X 38) cm and 42 kg weight. Figure 1. Shows the window air conditioner used in the experiment. The unit is having single electricity phase reciprocating compressor. The condenser and evaporator coils are made of copper with smooth inner tube surface. Both evaporator and condenser fins were made of aluminums. The window air conditioner utilizes refrigerant R-22 and mineral lubricating oil. In order to provide superior lubrication with chlorine refrigerants poly ester lubricants were used. The air conditioner accommodates a three speed motor to run the condenser and evaporator fans.

Selection of the Refrigerant

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. These refrigerants are R-410A, comprising of (R32/R125) in a mass fraction composition percentage as (50/50).

Refrigerant Charging

The refrigerant may be charged in a liquid or vapour modes. This is limited by operating factors, such as the amount of refrigerant and time of charging. Charging a refrigeration system, especially the one built-up with capillary tube control, is the most critical task. Amount of refrigerant to be charged is so selected that it maintains desired suction & discharge pressures. It is customary to charge the system with a charging cylinder on volume basis but the short-coming of this method is that since the density of refrigerant varies appreciably with temperature, one can come across erroneous quantity as the charging cylinder does not have different scales for different ambient temperatures. A better alternative method is to charge the refrigerant by weight. Charging without the aid of any equipment requires a high level of skill and human judgment. Sometimes charging is done without the aid of any equipments, this system uses suction pressure and discharge pressure as indicative of the charge quantity. However, this needs a high level of skill and human judgment.

Selection of capillary tube

Three capillary tubes with different inner diameters (1.4mm,1.6mm and 1.3mm) and lengths (889mm,559mm and 509mm) 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 889mm) were used parallel in window air conditioner .The detail characteristics of capillary tube are shown in Table. 1. The photographs of capillary tubes in window air conditioner single, illustrated in Fig. 1 (a) and (b).

Table.1 detail characteristics of capillary tube

S/No.	No of tubes	Type	Inner diameter (mm)	Length (mm)
1	1	straight	1.3	508
2	2	straight	1.4	889
3	1	straight	1.6	559

Figure.1 capillary tubes in window air conditioner single

Fig. 1(a)

Fig. 1(b)

Test Description

At the incipience of the test, the system was kept running at least 10 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 and wet bulb temperature, were recorded. These readings were taken at ambient temperature i.e., 36°C, 37°C,39°C and 41°C DBT to detect the performance of the window air conditioner test ring. This procedure was repeated for the refrigerants R-22 and R410A.

The data reduction procedure includes the refrigerating effect, power consumed by compressor, heat rejected in the condenser, energy efficiency ratio calculated for both R-22 and its alternatives R-410A. In addition, (COP) was calculated from the above mentioned parameters. The properties of R-22 and oR-410A refrigerants were obtained from the published data by ASHRAE Hand Book.

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Table.3 Performance Result of Refrigerant R-22

S. No	Capillary Dia & length (mm)	Ambient temp (°C)	Cooling capacity (kw)	Refrigerant mass flow rate (kg/s)	Heat rejected in the condenser (kw)	Compressor work (Watts)	EER	COP
1	1.4	36°C	2.726	0.02615	3.8545	355	2.95	9.83
	889	39°C	2.523	0.02637	3.8473	348	2.73	10.05
		41°C	2.412	0.02653	3.8335	334	2.61	10.46
2	1.6	36°C	1.414	0.02560	3.9808	481	1.53	7.27
	559	39°C	1.165	0.02569	3.9613	462	1.26	7.56
		41°C	0.841	0.02581	3.8947	446	0.91	7.83
3	1.3	36°C	1.248	0.02556	4.0052	506	1.35	6.91
	508	39°C	1.035	0.02562	3.9890	489	1.12	7.15
		41°C	0.694	0.02569	3.9665	467	0.75	7.48

Table.4 Performance Result of Refrigerant R-410A

S. No	Capillary Dia & length (mm)	Ambient temp (°C)	Cooling capacity (kw)	Refrigerant mass flow rate (kg/sec)	Heat rejected in the condenser (kw)	Compressor work (Watts)	EER	COP
1	1.4	37°C	2.865	0.02230	3.699	223	3.10	15.69
	889	39°C	2.726	0.02344	3.698	199	2.95	17.56
		41°C	2.615	0.02368	3.691	191	2.83	18.24
2	1.6	37°C	1.682	0.02319	3.784	285	1.82	12.26
	559	39°C	1.257	0.02331	3.773	275	1.36	12.72
		41°C	0.749	0.02348	3.754	251	0.81	13.94
3	1.3	37°C	1.423	0.02330	3.804	305	1.54	11.46
	508	39°C	1.165	0.02358	3.794	294	1.26	11.87
		41°C	0.583	0.02385	3.784	286	0.63	12.22

Figure.2 FOR R-22

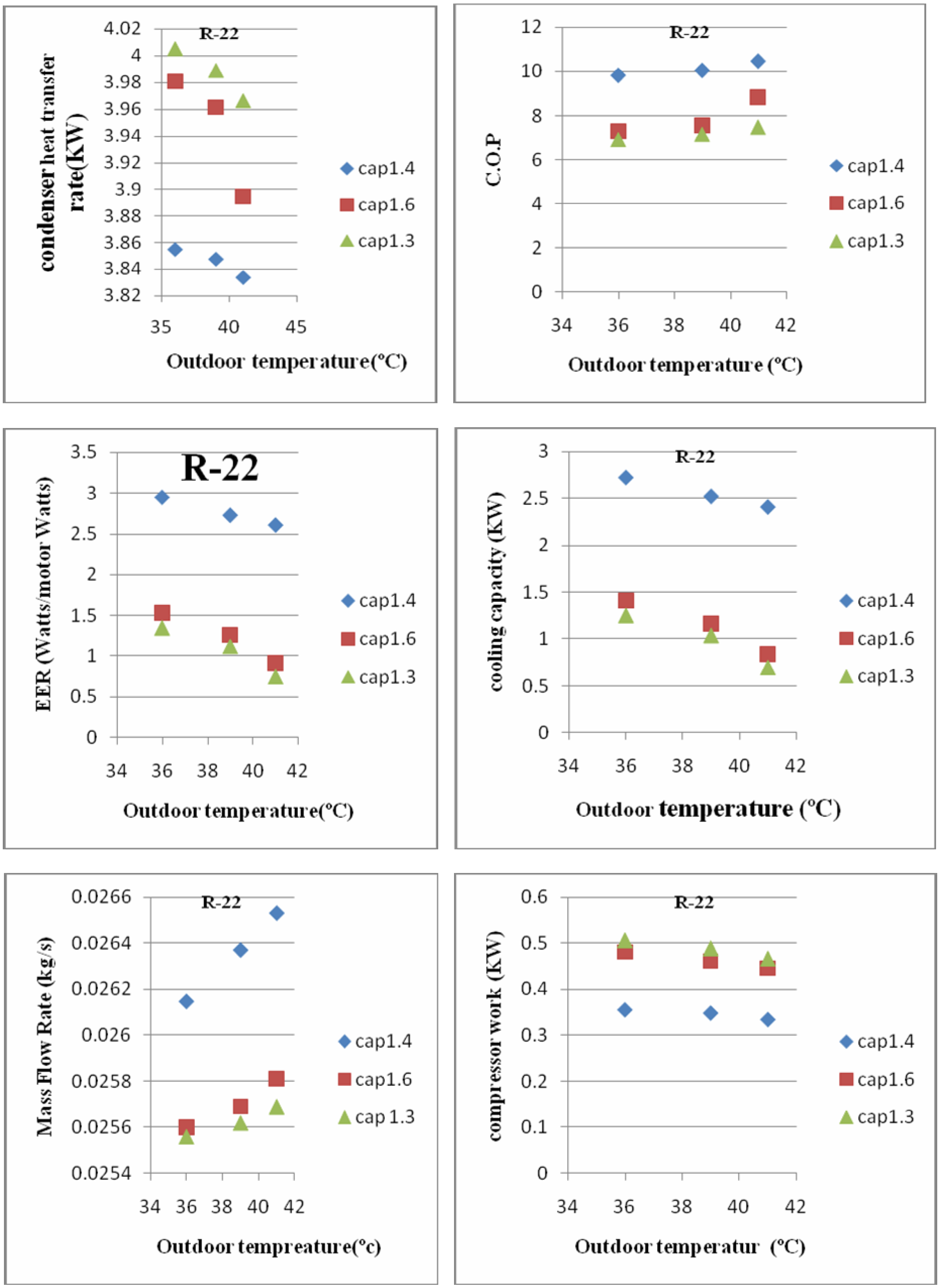
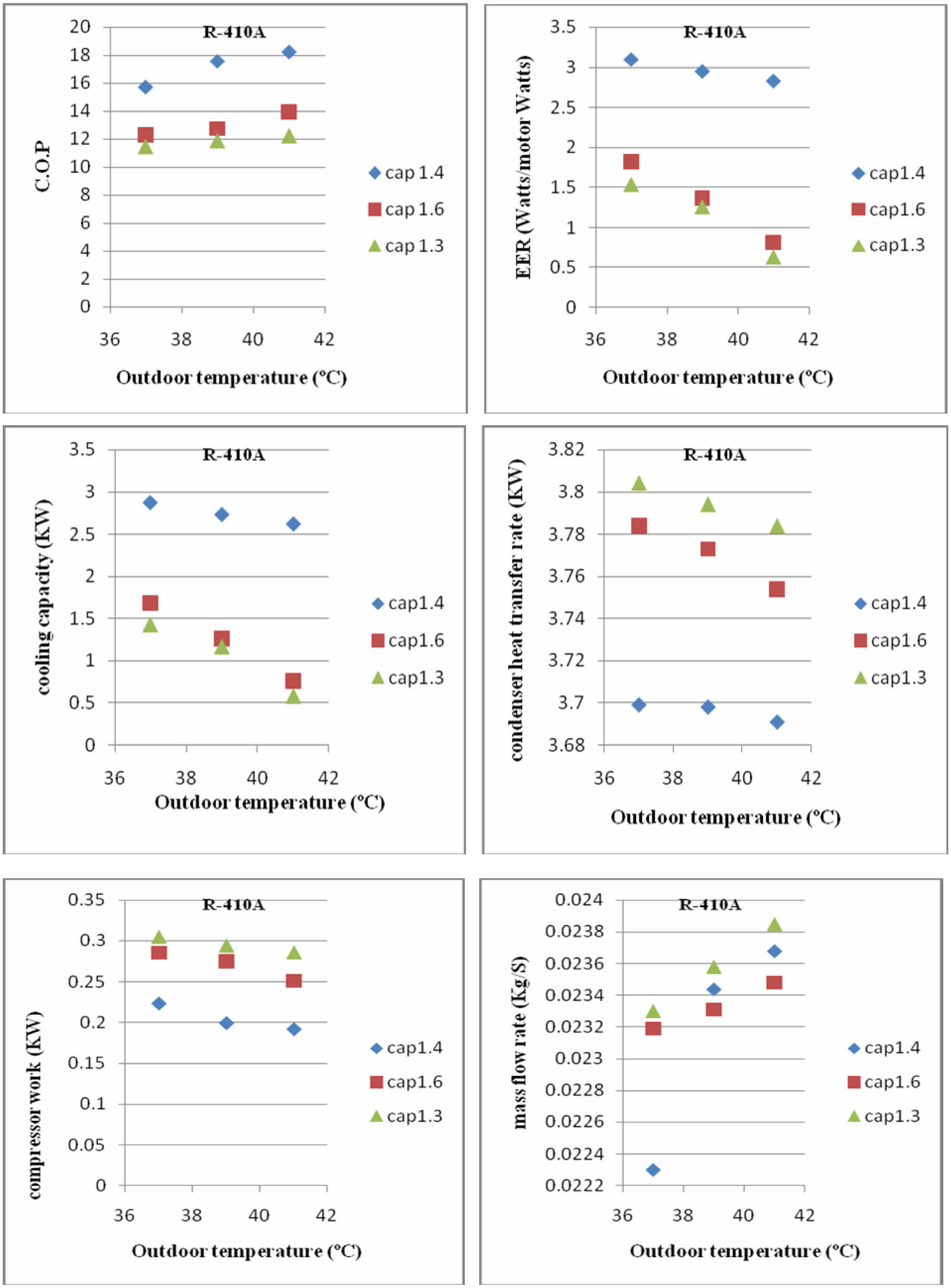


Figure.3 FOR R-410A



Results and Discussion

Table (3) and (4) gives the various measured system parameters for different test conditions.

Cooling Capacity

While testing the alternative refrigerants, the cooling capacity is an important parameter. If the cooling does not match with the base line data, and then the compressor has to be redesigned. Therefore, if an alternative Refrigerant gives closer cooling capacity then only it can be considered for retrofitting. Graph shows the variation of cooling capacity for all three capillary tubes for a range of outdoor conditions. For R-22, Test results Show that capillary tube 1.4mm is having higher cooling capacity than capillary tube 1.6 mm and capillary tube 1.3mm. And for R-410A, Test results Show that capillary tube1.4mm is having higher cooling capacity than capillary tube 1.6 mm and capillary tube 1.3mm.

Coefficient of Performance

Graph shows the variation of COP for both R-22 and R-410A for range of outdoor conditions. For R-22, the COP of Capillary tube 889mm is 32% efficient than capillary 559mm and 40% efficient than capillary 508mm for 39°c outdoor temperature (2) For R-410A, The COP of Capillary 889mm is 38% efficient than capillary 559mm and 47% efficient than capillary 508mm for 39°c outdoor temperature.

Mass flow rate

Figure 4 shows the mass flow rate of R-410A and R-22 for a range of outdoor conditions.. Test results Show that for R-22 capillary tube 1.4mm is having higher mass flow rate than capillary tube 1.6 mm and capillary tube 1.3mm at 39°C outdoor temperature. And for R-410A, Test results Show that capillary tube1.4mm is having higher mass flow rate than capillary tube 1.6 mm and lower mass flow rate than capillary tube 1.3mm at 39°C outdoor temperature.

Operation at Maximum Operating Conditions

It was observed that during the entire test, the window A/C was working without any visible and audible damage and without tripping with both R-22 and R-410A. After a shut down period for 3 minutes, the A/C started again and remained in operation for the next one hour without tripping for both R-22 and R-410A.

Conclusions

The performances of the adiabatic capillary tubes with several length and inner diameter combinations for R22 and its alternative R410A were experimentally investigated. it is observed that for refrigerant R-22 and R-410A the mass flow rate, cooling capacity COP and EER of capillary 1.4mm more than capillary 1.6 mm and 1.3 mm but compressor work done and heat transfer rate of capillary 1.4mm are lower than capillary 1.6mm and 1.3mm.Capillary 1.4mm is 32% efficient than capillary 1.6mm and 40% efficient than 1.3mm for R-22.Capillary 1.4mm is 38% efficient than capillary 1.6mm and 47% efficient than 1.3mm for R-410A.

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