Al-khwarizmi Engineering Journal

Al-Khwarizmi Engineering Journal, vol.1, no.1,pp 73-82, (2005)

An Experimental Study of Capillary Tubes Behavior With R-12 and R-134a

Issam M.Ali **Hani A.Jasim**

Mechanical Engineering Dept/ College Of Engineering/University Of Baghdad

Abstract:

Experimental work has been performed on three capillary tubes of different lengths and diameters using R-12 and R-134a. The test also studies the effect of discharge and speed of evaporator fan. The results clearly showed that refrigerant type and discharge significantly influence the temperature drop across the capillary tube. While the speed of evaporator fan has small effect. Experimental results showed that the temperature gradient for the two refrigerants are the same, but after approximatly one meter the temperature gradient of R-134a is steeper than R-12.

Keyword: Refrigeration, Capillary Tube, R-12, R134a.

Introduction:

A capillary tube is the heart of a small vapor compression refrigeration equipment such as room air conditioners, household refrigerators and freezers. It is simple, reliable and inexpensive. Capillary tubes commonly used as the expansion and refrigerant controlling device.However with the environmentalists creating a hue and cry over the use of existing CFC and HCFC refrigerants in refrigeration industry, it is now becoming more important to switch over to refrigerants which are more environmental friendly. Thus, a need was felt that if database could be created for more commonly used refrigerants with capillary tubes as expansion devices for smaller refrigeration systems, it shall extremely useful for retrofitting the systems with new or alternative refrigerants. Especially in the past 15 years or so, the flow characteristics of refrigerant passing through capillary tubes have been widely studied experimentally or analytically with alternative and common traditional refrigerants. Hartnett and Minkowcz [1] present theoretical comparison of the flow characteristics of many pairs of refrigerants flowing through adiabatic capillary tubes. The two-phase flow model developed was based on homogeneous flow assumption. Numerical results showed that the traditional refrigerants consistently gave lower pressure drops than the environmentally acceptable alternative refrigerants, which resulted in longer tube lengths. Somchai [2] developed a model to study the flow characteristics in adiabatic capillary tubes of various refrigerants. In addition, an example of capillary tube selection chart developed from the pressure numerical simulation was shown. The chart can be practically used to select the capillary tube size from the flow rate and flow condition or to determine mass flow rate directly from a given capillary tube size and flow condition.

Visinee and Somchai [3] present new correlation for the practical sizing of adiabatic capillary tubes. The developed model is used as an effective tool for studying the effects of relevant parameters on capillary tube length. The correlation can be used to integrate with system models working with alternative refrigerants for practical design and optimization. Pakawat [4] et al developed a numerical study on the local pressure distribution of some common traditional and alternative refrigerants flowing in adiabatic capillary tubes. Numerical results show that the alternative refrigerants consistently give higher pressure gradients than the traditional refrigerants. This model is an important tool for selecting the length of the capillary tube. Sami et al [5] present experimental data on capillary tube using various new alternatives under different geometrical parameters (length, diameter, as well as entrance conditions). The results clearly showed that the pressure drop across the capillary tube is significantly influenced by the diameter of the capillary tube, inlet conditions to the capillary and refrigerant type. Therefore, to be a guide line in the future for selecting the appropriate refrigerants, in the present study, the main concern is to study on the temperature distribution of two refrigerants (R-12 and R134a) along the capillary tubes, of different lengths and diameters, and to compare the flow characteristics between them.

Experimental Apparatus and Measurements:

An experimental set up has been fully instrumented with pressure, temperature, electrical sensors as well as refrigerant flow metering device. **Fig.1** show a schematic diagram of experimental set up. The vapor-compression system was composed mainly of:

- 1/5 HP hermetic compressor.
- Variable flow forced air system with condenser and evaporator, which includes a series of 8-glass tube for visualizing, set by step, the collection and evaporation of liquid.
- 10 valves for interception.
- 3 capillary tubes of various lengths and diameters made from copper.

Table (1) presents the capillary tube geometry.

The two pressures were mesured using calibrated gauge presures. Digital thermometer was used to measure the surface temperature along the capillary tubes. **Table (1)** shows the positions of measurement along the three capillary tubes. Calibrated flow meter was installed in the liquid line to measure the mass flow rate to the capillary tube test section.

First, all tests carried out using R-134a with polyol-esters oil. Following each, the system was drained , evacuated and charge with refrigerant R-12 with appropriate oil. To get required charge , during charging ,disappear of bubbles in flow meter give a signal of suitable charge. The parameters observed during the course of this study were temperature profile along the capillary tubes, discharge and power consumpsion. Usually ,20 to 45 minutes were needed for the system to reach steady state operation at a desired compressor discharge pressure. The three capillary tubes in test had different coiling. Our test neglected the effects of coiling because it is very small. S.J. kuehl and V.W

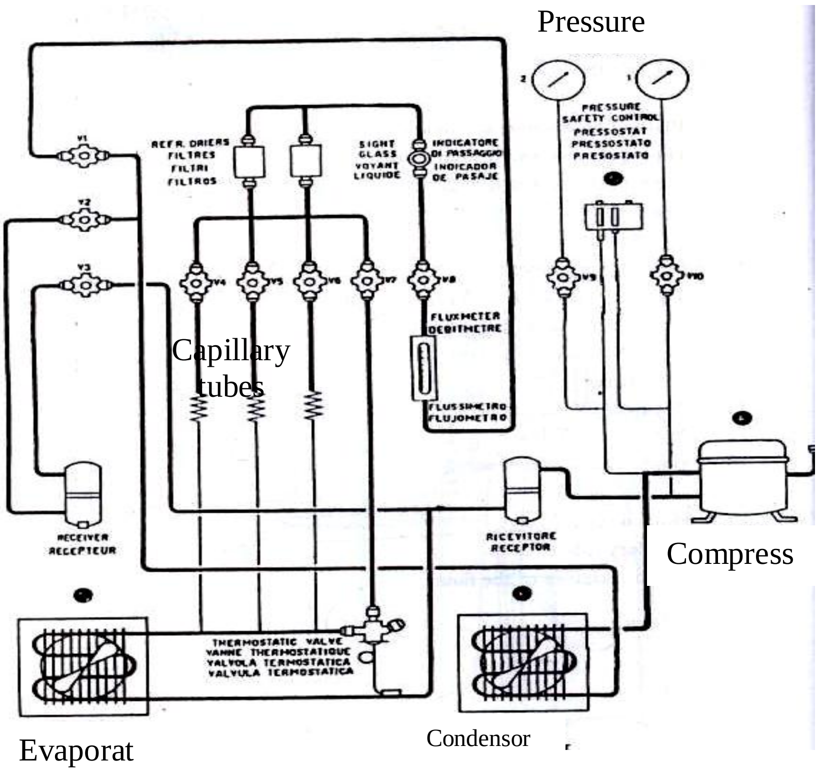


Figure (1) schematic diagram of experimental set up

Table 1 capillary tube geometry

	Capillary Tube (1)	**Capillary Tube (2)**	**Capillary Tube (3)**
Capillary diam.	0.81 mm	1.4 mm	1.5 mm
Capillary length	120 cm	135 cm	160 cm
Temp. port # 1	0 cm	0 cm	0 cm
Temp. port # 2	30 cm	30 cm	30 cm
Temp. port # 3	60 cm	60 cm	60 cm
Temp. port # 4	90 cm	90 cm	90 cm
Temp. port # 5	105 cm	120 cm	120 cm
Temp. port # 6	120 cm	135 cm	150 cm 160 cm

goldschmidt[6] noted that coiling increases the pressure drops by 5% only.

Results and Discussion:

When capillary diameter increases, temperature gradient becomes more extremly for the two refrigerants (R12,R134a) as shown in **Figs 2,3,and 4**. This phenomena is evident because the heat transfer between the air and refrigerant is higher . The same figures explain that temperature gradiant for R12 is faster. Temperature difference (ΔT) in the case of refrigerant R12 is greater than refrigerant R134a. That means more heat transfer.

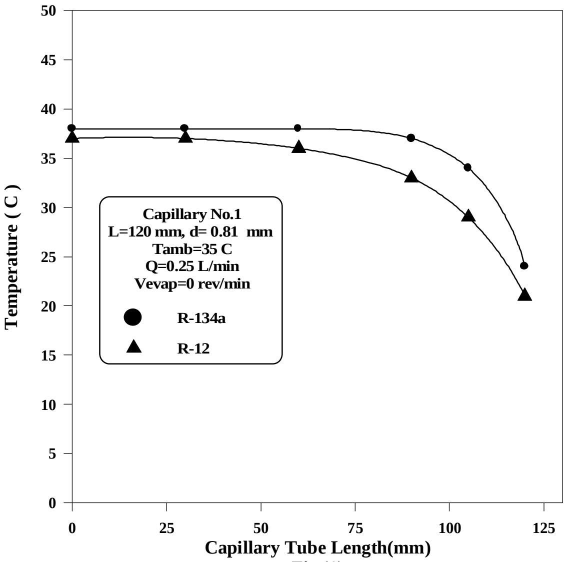
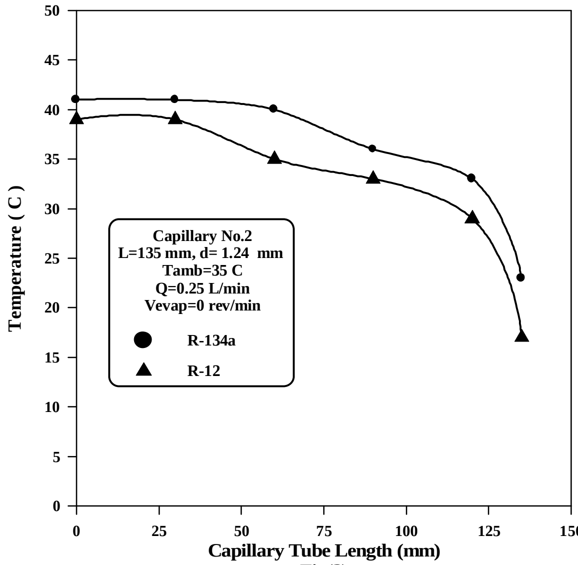


Fig.(1)

Fig.2 Temperature gradient along capillary tube No.1 of two refrigerants



Fig(2)

Fig.3 Temperature gradient along capillary tube No.2 of two refrigerants

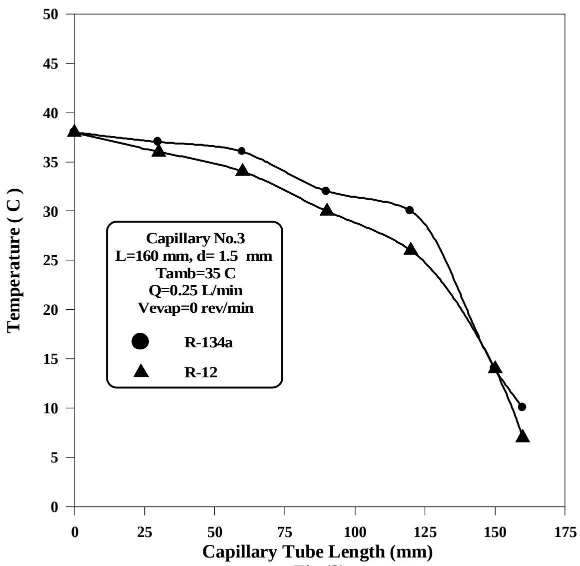


Fig.(3)

Fig.4 Temperature gradient along capillary tube No.3 of two refrigerants

Also increasing the diameter of capillary tubes leads to coincident of the curves of both refrigerants and it seems clearly at starting point.

Decreasing the discharge causes faster temperature gradient as shown in **Figs.5, 6,7,8,9, and 10** for both R12, R134a because of high amounts of heat transfer. As the diameter decreases, the curves become more smoothly and the effect of discharge becomes small.

For the first capillary tube minimum discharge leads to high ΔT) i.e more heat transfer). Notice that the gap between curves resulting from decreasing the discharge at starting point increases as the diameter of capillary tube increase. As a comparison between R12, R134a the approch of curves approximates with decreasing the diameter. This is evident between **Fig.5** and **Fig.6**.

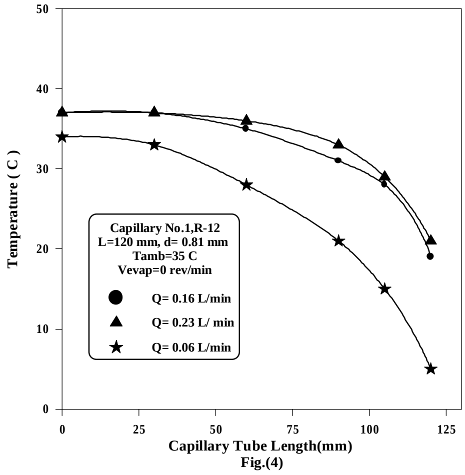


Fig.5 Temperature gradient along capillary tube No.1 under different discharges using R-12

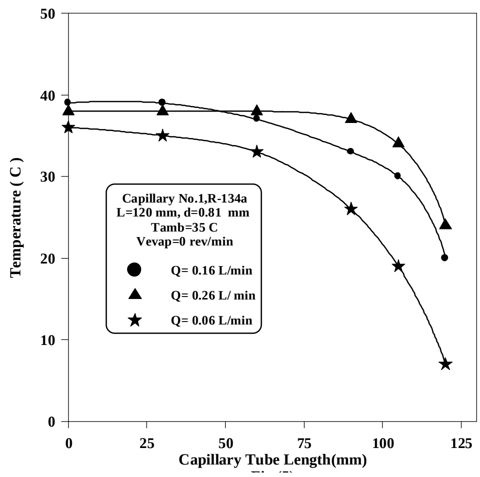


Fig.6 Temperature gradient along capillary tube No.1 under different discharges using R-134a

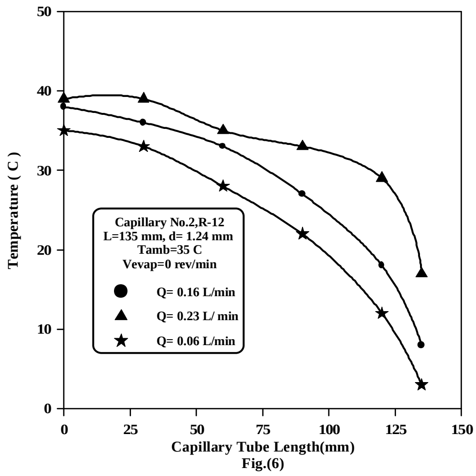


Fig.7 Temperature gradient along capillary tube No.2 under different discharges using refrigerant R-12

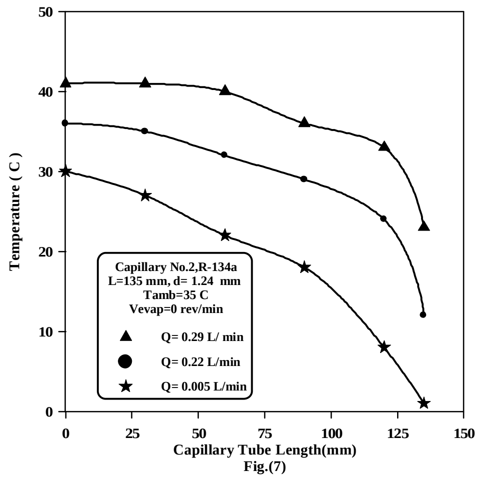


Fig.8 Temperature gradient along capillary tube No.2 under different discharges using refrigerant R-134a

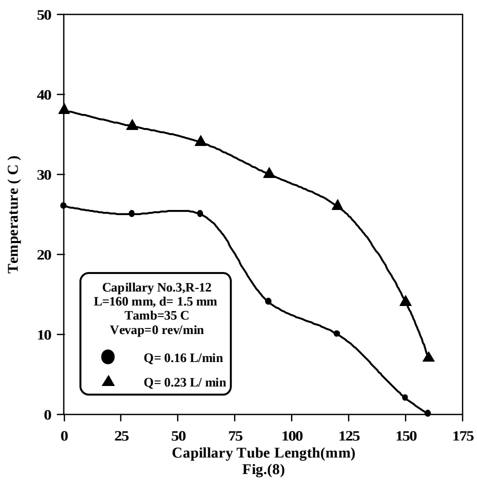


Fig.9 Temperature gradient along capillary tube No.3 ,under different discharges using refrigerant R-12

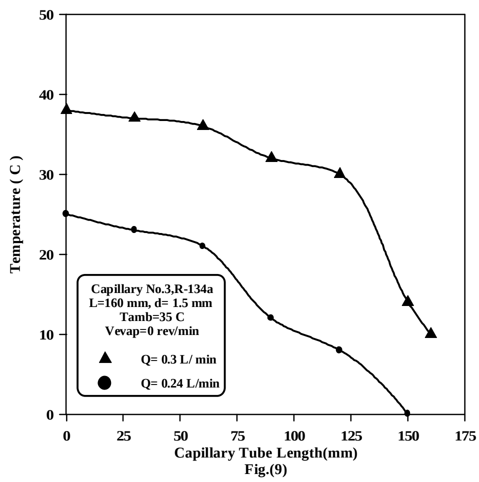


Fig.10 Temperature gradient along capillary tube No.3 under different discharges using refrigerant R-134a

The effect of speed of evaporator fan is more evident in the first capillary tube compare with the two others.(i.e decreasing diameter of capillary tube causes increasing the effect of (V)). See **Figs.11, 12,13,14,15 and 16**.

For the first capillary tube increasing speed of evaporator leads to faster temperature gradient. While increasing of speed have small effect on the second and third capillary tubes. ΔT for refrigerant (R134a) is greater than that of refrigerant (R12) at small and middle speed of evaporator. In general ΔT increases with the diameter for the two refrigerants at all speeds. Temperature along the tube was measured with surface thermocouples. The flash point at which vaporization starts is accompanied by a sudden drop in temperature. The tube wall temperature drops accordingly as the vaporizing starts. **Fig.2** shows that vaporization starts at a distance after (50 cm) for both R12 and R134a because of a sudden drop in temperature. For the third capillary tube (vaporization is starting early (i.e increasing the diameter causes faster vaporization). See **Figs.3and 4**.

Decreasing the discharge leads to faster vaporization. It seems clearly in **Figs.5, 6,7,8,9 and 10**. While decreasing the speed has no effect upon refrigerant vaporization. See **Figs. 11,12,14,15 and 16**.**Table (2)** explain that the discharge pressure (P_h) of refrigerant R12 is higher than R134a.While the suction pressure (P_L) approximately constant. So pressure drop (Δp) of refrigerant R12 is higher than R134a.Decreasing the discharge leads to higher (Δp). While the effect of evaporator fan is negligible. Second and third capillary tubes have similar approach except that the suction pressure is not constant see **Tables (3, 4)**.

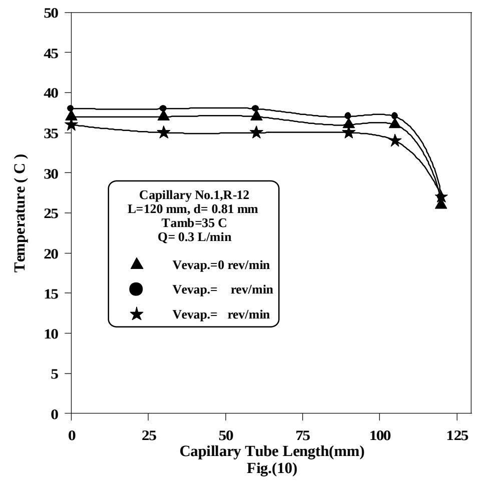


Fig.11 Temperature gradient along capillary tube No.1under different air velocities using refrigerant R-12

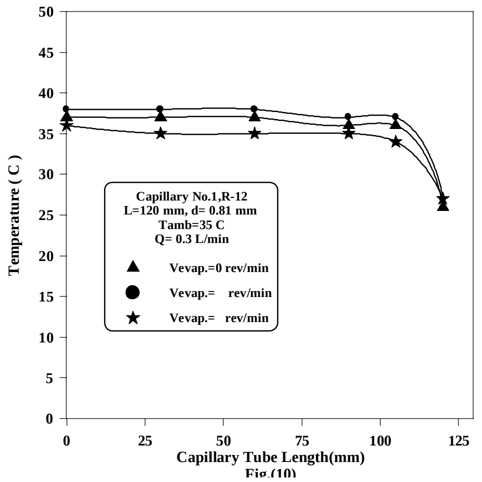


Fig.12 Temperature gradient along capillary tube No.1 under different air velocities using refrigerant R-134a

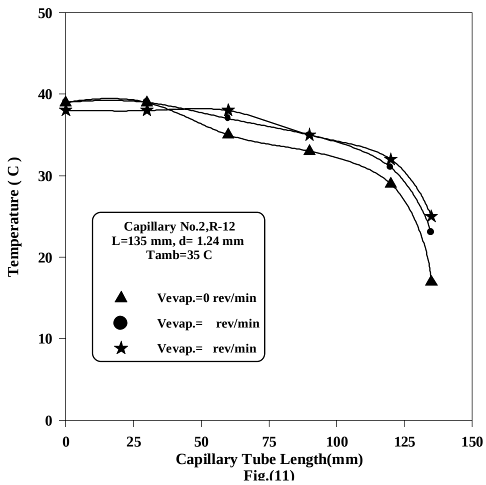


Fig.13 Temperature gradient along capillary tube No.2 under different air velocities using refrigerant R-12

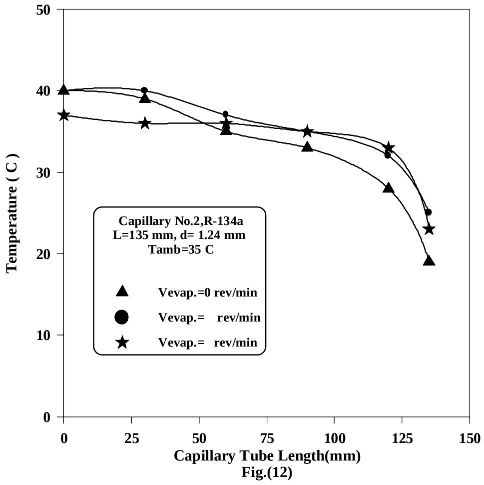


Fig.14 Temperature gradient along capillary tube No.2 under different air velocities using refrigerant R-134a

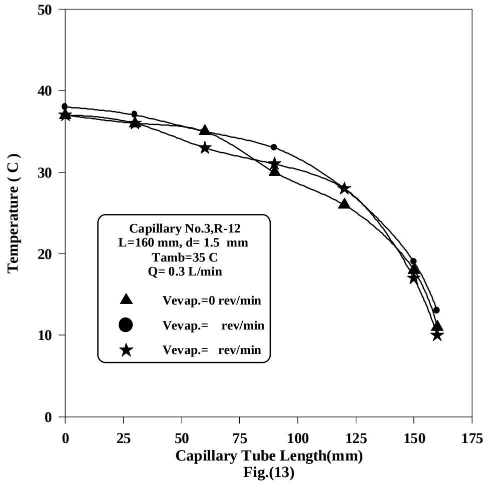


Fig.15 Temperature gradient along capillary tube No.3 under different air velocities using refrigerant R-12

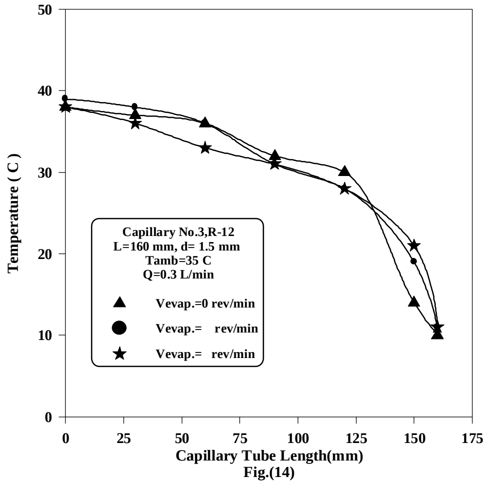


Fig.16 Temperature gradient along capillary tube No.3 under different air velocities using refrigerant R-134a

Table 2.Data of 1st capillary tube

Refrigerant	Discharge L/min	Vevap m/s	P_h bar	P_L bar	Δp bar	Power kW
R12	0.25	0	10.5	1.4	9.1	0.3
R134a	0.25	0	10.2	1.4	8.8	0.32
R12	0.16	0	10.5	1	9.5	0.28
R134a	0.16	0	10	0.8	9.2	0.28
R12	0.3	60	11.5	1.8	9.7	0.36
R134a	0.3	60	11	1.8	9.2	0.34
R12	0.3	120	11.5	1.9	9.6	0.38
R134a	0.3	120	11	1.8	9.2	0.36

Table 3. Data of 2nd capillary tube

Refrigerant	Discharge L/min	Vevap m/s	P_h bar	P_L bar	Δp bar	Power kW
R12	0.25	0	10	1.4	8.6	0.32
R134a	0.25	0	10	1.7	8.3	0.32
R12	0.005	0	9.2	0.3	8.9	0.23
R134a	0.005	0	8.8	0.2	8.6	0.22
R12	0.3	60	11	1.8	9.2	0.35
R134a	0.3	60	11	2.3	8.7	0.37
R12	0.3	120	11.3	2.2	9.1	0.4
R134a	0.3	120	11	2.3	8.7	0.4

Table 4. Data of 3rd capillary tube

Refrigerant	Discharge L/min	Vevap m/s	P_h bar	P_L bar	Δp bar	Power kW
R12	0.3	0	10	1.8	8.2	0.34
R134a	0.3	0	9.5	1.8	7.7	0.32
R12	0.24	0	9	0.6	8.4	0.26
R134a	0.24	0	8.5	0.5	8	0.22
R12	0.3	60	10	2.1	7.9	0.36
R134a	0.3	60	10	2.2	7.8	0.36
R12	0.3	120	10.5	2.4	8.1	0.4
R134a	0.3	120	10.2	2.5	7.7	0.4

In general power consumption for refrigerant R12 is higher for the three capillary tubes.

Conclusion:

Experimental data showed that the temperature gradient for the two refrigerants are the same, but after approximately one meter the temperature gradient of R-134a is faster than R-12.That means more heat transfer .Decreasing the discharge causes faster temperature gradient leads to faster vaporization. The effect of changing the discharge becomes unsensible for small diameters. Changing speed of evaporator fan is evident in the first capillary tube, while at large diameters the effect is negligible .Heat transfer for R134a is greater than R-12 at small and middle speed of evaporator .Discharge pressure of R12 is higher than R134a while suction pressure approximately constant. That means pressure drop of R-12 is higher. Power consumption for R-12 is higher for three capillary tubes.

References:

1. J.P Hartnett and W.J. Minkowycz " A comparison of the flow characteristics of refrigerants flowing through adiabatic capillary tubes" Heat mass transfer,vol. 27, NO.5,pp 611-621,2000.
2. Somchi wongwises, worachet pirompach" Flow characteristics of pure refrigerants and refrigerant mixtures in adiabatic capillary tubes". Applied thermal engineering 21(2001) 845-861.
3. Visinee trisaksri and somchai wongwises"Correlations for sizing adiabatic capillary tubes" International journal of energy research 2003:27:1145-1164(doi:10.1002/er.937).
4. Pakawat et al "Pressure distribution of refrigerant flow in an adiabatic capillary tube" science asia 28 (2002):71-76.

Nomenclature:

d: Inside diameter of capillary tube(mm).

L: Length of capillary tube (cm)

P_h: Discharge pressure (bar).

P_L: Suction pressure (bar).

Q: Refrigerant discharge (L/min).

T_{amb}: Ambient temperature (^oC).

V: Speed of air delivered by evaporator fan (m/s).

Δp: Difference between discharge and suction pressure (bar).

ΔT: Difference between maximum and minimum temperature along capillary tube (^oC).

دراسة مختبرية لمنظومة تبريد تحتوي ثلاثة أنابيب شعريةباستخدام نوعين من موانع التثليج (R12-R134a)

عصام محمد علي هاني عارف جاسم
قسم الهندسة الميكانيكية/كلية الهندسة/جامعة بغداد

الخلاصة:

اختبار عملي تم اجراءه على ثلاثة أنابيب شعرية مختلفة الأقطار والأطوال في منظومة تثليج باستخدام موائع التثليج R-12, R-134a. الاختبار هو دراسة تأثير تغير معدل التدفق و سرعة مروحة المبخر على المنظومة.النتائج بينت بوضوح أن نوع المائع المستخدم ومعدل التدفق يؤثران على تغير درجات الحرارة على طول الأنبوب . بينما سرعة مروحة المبخر لها تأثير قليل . الاختبار العملي بين كذلك تغير درجات الحرارة على طول الأنابيب الشعرية متشابهة بالنسبة للمائعين ولكن بعد متر واحد من طول الأنبوب الشعري فأن التغير لمائع R134a أسرع من R12 .