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The Effect of Capillary Tube Length & Diameter on Compressor Performance of Refrigeration System

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تأثير طول وقطر الانبوبة الشعرية على أداء الضاغط في منظومة التبريد

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Abstract:
As the name suggests, the compressor is a device that compresses and raises the pressure of the refrigerant vapor coming from the evaporator, resulting in a saturation level that is higher than that of the chilled medium. As a result, the compressor needs to be powered by the actuator or main engine. The compressor can be referred to as a heat pump since it transfers heat from a low-temperature medium (the evaporator) to a high-temperature medium (the condenser).
To determine how the capillary tube's width and length affected the compressor's performance in the refrigeration system, a basic refrigeration system was put together and used in this study. Three distinct lengths of capillary tubes were used, which are ((3m, 2m, 1m)) and two different diameters, which are (2.0mm, 2.2mm).
Among the results obtained, the best performance coefficient and equivalent to the size of the compressor used were achieved when using the length ((1m)) and diameter ((2.0mm)) for the capillary tube, where the performance coefficient was ((6.8)).

Keywords: evaporator, condenser, capillary tube, refrigeration system.

الملخص
الضاغط كما يبين اسمه هو ماكنة تستخدم لضغط بخار مائع التبريد من المبخر وزيادة ضغطه بحيث أن درجة التشبع الناتجة أعلى من الوسط المبرد، كما يقوم بتدوير مائع التبريد خلال نظام التبريد، ولان عملية انضغاط مائع التبريد تحتاج شغل يعمل عليه، لذلك يجب أن يحرك الضاغط من المشغل أو المحرك الابتدائي وبما أن الضاغط يأخذ الحرارة من وسط ذو درجة حرارة منخفضة وهو المبخر وضخها إلى وسط ذو درجة حرارة مرتفعة وهو المكثف لذا يمكن أن يطلق عليه مضخة حرارة.
في هـــذا الورقة تم تجميع وتنفيذ منظومة تبريد بسيطة لمعرفة تأثير طول وقطر الانبوبة الشعرية على أداء الضاغط في منظومة التبريد حيث تم استخدام ثلاثة اطوال مختلفة للأنبوبة الشعرية وهي ((3m, 2m, 1m)) وقطرين مختلفين وهمـــا ((2.0mm, 2.2mm)).
ومن النتائج التي تم الحصول عليها أن افضل معامل اداء ومكافئ لحجم الضاغط المستخدم تحقق عند استخدام الطول ((1m)) وقطر ((2.0mm)) للأنبوبة الشعرية حيث كان معامل الاداء هو ((6.8)).

الكلمات المفتاحية: المبخر، المكثف، الانبوبة الشعرية، نظام التبريد.

Introduction
Capillary tubes, which are utilized in all home appliances and numerous business designs, are among the most popular parts of refrigeration systems that run on vapor compression cycles since they are crucial to the system's operation [1]. Its benefits include being error-free, economical, and simple to install.

Relevant references include studies on the effect of the length and diameter of the capillary tube on the performance of the compressor in the refrigeration system. The results of practical experiments revealed that the compressor operation decreases with increasing load and that reducing the diameter of the capillary tube leads to an increase in the rate of mass increase in the system [2, 4, 6].

Other studies focused on the effect of the length of the capillary tube on the performance of the refrigeration system and found that with an attempt to improve the length of the capillary tube, better performance is given [3, 6].

One study showed that the coefficient of performance C.O.P changes in the opposite direction to the diameter of the capillary tube. When the diameter of the capillary tube is smaller, the value of the coefficient of performance C.O.P is greater [5].

These studies collectively confirm that the diameter of the capillary tube has an effect on the performance of the refrigeration system, that the compressor operation decreases with increasing load, and that improving the length of the capillary tube gives better performance to the refrigeration system.

System Components

1. The table

It is the part on which the system is installed. Its dimensions were chosen as follows: length ((m2)), width ((1m)), and height ((m1)), and Figure ((1)) shows a picture of the work table.

Figure 1: The table.

2- The Compressor

The refrigerant gas a134 was used. It has the following specifications:

230v
1.8A
1/2HP
1200RPM
50Hz

Figure 2: The Compressor.

3 – The Condenser

A fan is installed on the Condenser to help expel excess heat. Figure ((3)) shows a picture of a Condenser with a fixed fan installed on it with the following fan specifications:

230/240V
1300/1550 RPM
50/60HZ
0.23A

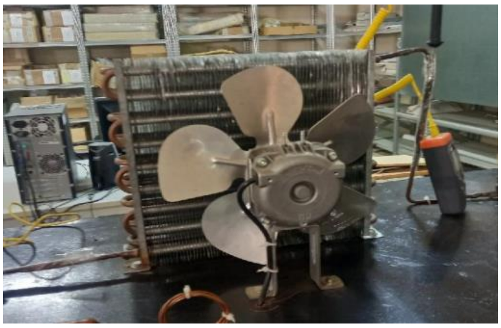

Figure 3: The Condenser.

4- The Expansion valve

(6) valves were used in this system and Figure ((4)) shows a picture of the valves.

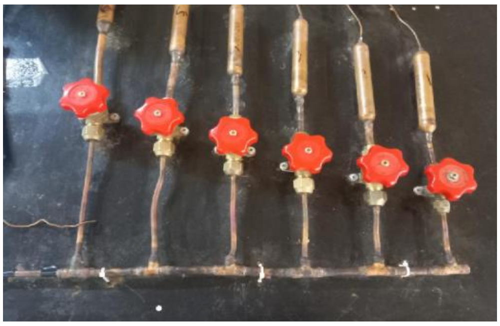

Figure 4: The Expansion valve.

5- The Capillary tube

Two diameters ((2.0mm, 2.2mm)) and three lengths ((1m, 2m, 3m)) were used for the capillary tube. Figure ((5)) shows a picture of the capillary tube.

Figure 5: The Capillary tube.

6- The Sight Glass

Figure ((6)) shows the image of the sight glass on the system.

Figure 6: The Sight Glass.

7- The Evaporator

Figure ((7)) shows a picture of the evaporator on the system.

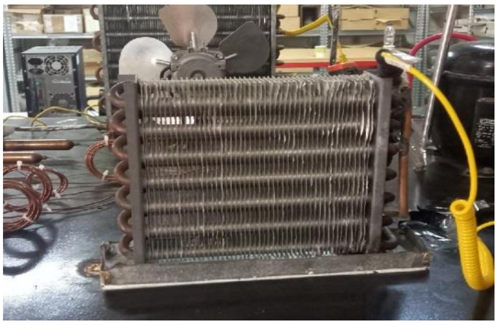

Figure 7: The Evaporator.

8- High and low-pressure gauge

Figure ((8)) shows a picture of the high and low pressure gauge on the system.

Figure 8: The High and low pressure gauge.

9- The Temperature measuring device

Figure ((9)) shows a picture of the temperature measuring device used, type ((Thermometer HT 300)) on the system.

Figure 9: The Temperature measuring device.

The Assembly

In the beginning, we manufactured a metal table with dimensions ((2m * 1m * 1m)) equipped with four wheels for easy movement and transportation. Then, the compressor is installed on the table, and a pipe is installed from the compressor discharge line to the air-cooled condenser with the load. Then a pipe is connected from the evaporator through the indicator lens and then to the capillary tubes, and a main pipe connection is made that comes from the indicator lens and extends horizontally and is closed from the end. From the side of the main tube, six separate pipes are installed, and a dual manual valve is installed in each pipe. A filter is added after each manual valve, and each filter is connected to a capillary tube, and the six branched capillary tubes are connected to one pipe that connects to the evaporator and then to the compressor. Also, a high pressure gauge for the condenser PC and a low pressure gauge for the evaporator PE is installed.

Implementation steps
Activate the system and wait for a while for it to function properly. Install the temperature-measuring devices at four locations after opening the first manual valve and closing the other five:
First, in the tube connecting from the compressor to the condenser.
Secondly, in the tube that connects the capillary tubes to the condenser.
Third, in the tube that connects the evaporator to the capillary tubes.
Fourth, in the tube that connects the compressor and evaporator.

Hold off for a while. After that, close the first valve, go to valve No. ((2)), open it, and close the other valves after taking a reading of valve No. ((1)) with the temperature-measuring equipment and reading the high and low pressure gauge. Continue applying this procedure to the remaining valves after taking a temperature reading and reading the high and low pressure gauges on them.

Next, display the pressure readings on the pressure and enthalpy diagram ((p-h)) and calculate the coefficient of performance ((COP)) for each capillary tube.

The Calculations
1- Values of condenser and evaporator pressures and temperatures from the p-h diagrams of the valves

Table 1 : Shows condenser and evaporator pressure values and temperatures from p-h diagrams of valves.

SN.	Capillary tube length L	Capillary tube diameter D	Evaporator pressure Pe	pressure condenser pc	Inside of compressor T1	Compressor outlet T2	Output from condenser T3	Inside of the evaporator T4
1	3m	2.2mm	0.15MPA	0.6MPA	10C°	35C°	17C°	6.7C°
2	2m	2.2mm	0.09MPA	0.5MPA	11C°	40C°	20.5C°	31C°
3	1m	2.2mm	0.08MPA	0.5MPA	4.5C°	44C°	23C°	25.5C°
4	3m	2.0mm	0.1MPA	0.95MPA	2C°	44C°	22.5C°	27.9C°
5	2m	2.0mm	0.08MPA	0.85MPA	5C°	46C°	23.2C°	26.1C°
6	1m	2.0mm	0.07MPA	0.6MPA	0C°	35C°	31C°	15.8C°

- **Calculating the performance coefficient for valve No. ((1))**

Given the temperature, condenser pressure Pc, and evaporator pressure pe, and representing it on the graph p-h, the enthalpic pressure to find the enthalpy for each stage as in Figure No. ((4-1)), and the readings were as follows:

h_1= 400 kj /kg
h_2 = 430 kj /kg
h_3 = h_4 = 240 kj /kg

By calculating the performance coefficient of valve No. ((1)), we find that:

$$Cop = \frac{h_1 - h_4}{h_2 - h_1} = \frac{400 - 240}{430 - 400} = \frac{160}{30} = 5.33$$

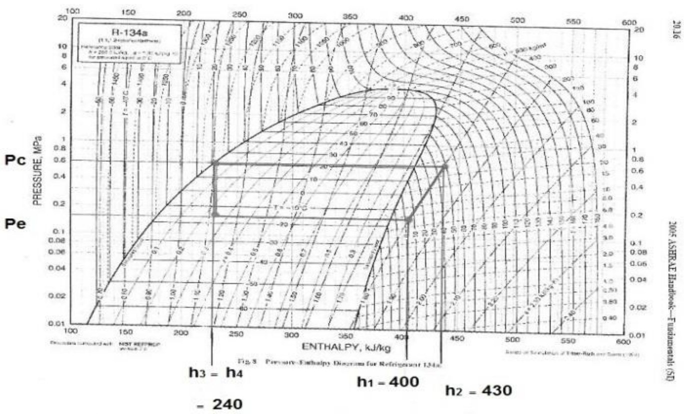

Diagram 1. shows the enthalpy of valve No. ((1))

- **Calculating the performance coefficient of valve No. ((2))**

Given the temperature, condenser pressure Pc, and evaporator pressure pe, and projecting it onto the enthalpy pressure p-h diagram to find the enthalpy for each stage as in Figure No. ((4-2)), and the readings were as follows:

h_1= 410 kj /kg
h_2 = 440 kj /kg
h_3 = h_4 = 225 kj /kg

By calculating the performance coefficient of valve No. ((2)), we find that:

$$Cop = \frac{h_1 - h_4}{h_2 - h_1} = \frac{410 - 225}{440 - 410} = \frac{185}{30} = 6.16$$

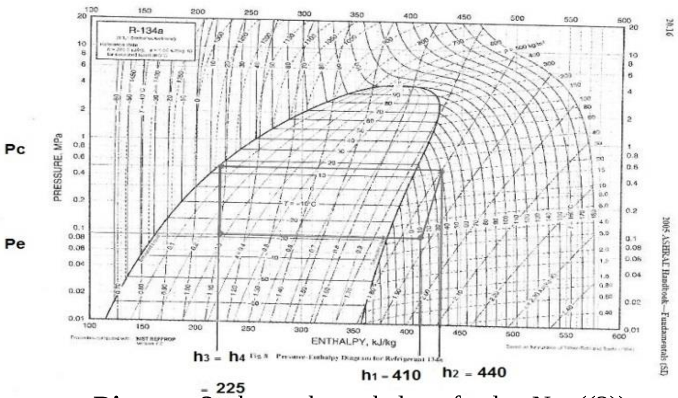

Diagram 2. shows the enthalpy of valve No. ((2))

- **Calculating the performance coefficient of valve No. ((3))**

Given the temperature, condenser pressure Pc, and evaporator pressure pe, and projecting it onto the enthalpy pressure p-h diagram to find the enthalpy for each stage as in Figure No. ((4-3)), and the readings were as follows:

h_1= 415 kj /kg
h_2 = 445 kj /kg
h_3 = h_4 = 220 kj /kg

By calculating the performance coefficient of valve No. ((3)), we find that:

$$Cop = \frac{h_1 - h_4}{h_2 - h_1} = \frac{415 - 220}{445 - 415} = \frac{195}{30} = 6.5$$

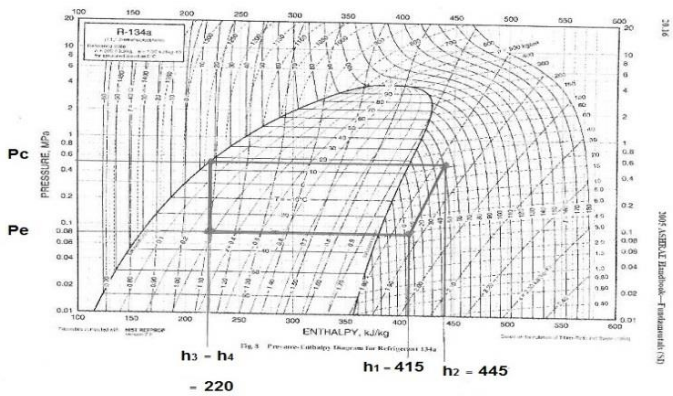

Diagram 3. shows the enthalpy of valve No. ((3))

❖ **Calculating the performance coefficient of valve No. ((4))**

Given the temperature, condenser pressure Pc, and evaporator pressure pe, and projecting it onto the enthalpy pressure p-h diagram to find the enthalpy for each stage as in Figure No. ((4-4)), and the readings were as follows:

h_1= 410 kj /kg
h_2 = 435 kj /kg
h_3 = h_4 = 245 kj /kg

By calculating the performance coefficient of valve No. ((4)), we find that:

$$Cop = \frac{h_1 - h_4}{h_2 - h_1} = \frac{410 - 245}{435 - 410} = \frac{165}{25} = 6.6$$

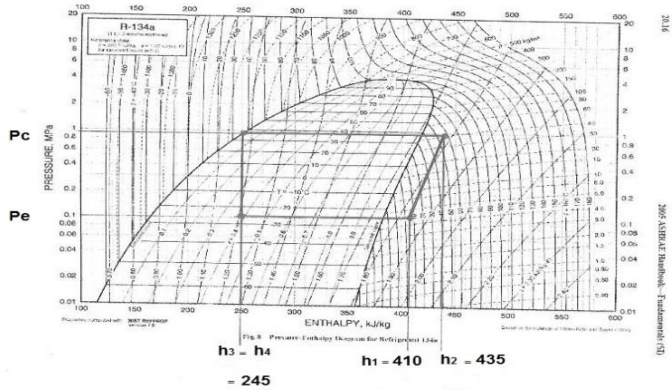

Diagram 4. shows the enthalpy of valve No. ((4))

❖ **Calculating the performance coefficient of valve No. ((5))**

Given the temperature, condenser pressure Pc, and evaporator pressure pe, and projecting it onto the enthalpy pressure p-h diagram to find the enthalpy for each stage as in Figure No. ((4-5)), and the readings were as follows:

h_1= 400 kj /kg
h_2 = 430 kj /kg
h_3 = h_4 = 240 kj /kg

By calculating the performance coefficient of valve No. ((5)), we find that:

$$Cop = \frac{h_1 - h_4}{h_2 - h_1} = \frac{400 - 240}{430 - 400} = \frac{160}{30} = 5.33$$

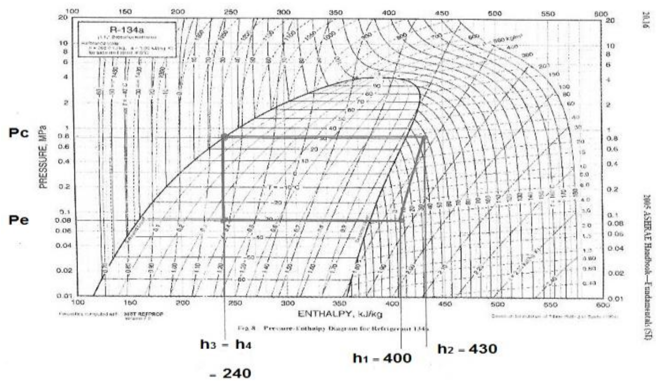

Diagram 5. shows the enthalpy of valve No. ((5))

- **Calculating the performance coefficient of valve No. ((6))**

Given the temperature, condenser pressure Pc, and evaporator pressure pe, and projecting it onto the enthalpy pressure p-h diagram to find the enthalpy for each stage as in diagram No. ((4-6)), and the readings were as follows:

h_1= 400 kj /kg
h_2 = 425 kj /kg
h_3 = h_4 = 230 kj /kg

By calculating the performance coefficient of valve No. ((6)), we find that:

$$Cop = \frac{h_1 - h_4}{h_2 - h_1} = \frac{400 - 230}{425 - 400} = \frac{170}{25} = 6.8$$

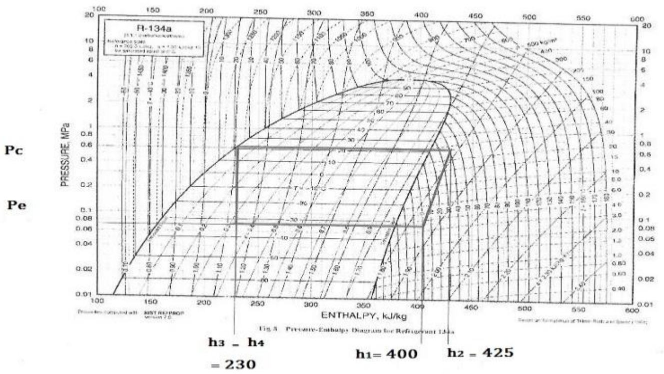

Diagram 6. shows the enthalpy of valve No. ((6))

Analyze the Results and Conclusions

After taking readings and performing calculations related to calculating the performance coefficient of the valves, the following was obtained:

Table 2: shows the effect of changing the length and diameter of the capillary tube on the coefficient of performance (C.O.P).

Valve number	Valve No. ((1))	Valve No. ((2))	Valve No. ((3))	Valve No. ((4))	Valve No. ((5))	Valve No. ((6))
Capillary length	3m	2m	1m	3m	2m	1m
Capillary tube diameter	2.2mm	2.2mm	2.2mm	2.0mm	2.0mm	2.0mm
Coefficient of Performance C.O.P	5.33	6.16	6.5	6.6	5.33	6.8

Result discussion

The following was discovered after readings were taken and the coefficient of performance (C.O.P.) for each diameter and length was extracted:

1.For the first diameter ((2.2 mm)) for the three lengths of the capillary tube, the calculations and results proved the following:

For the length of the capillary tube ((m3)) the coefficient of performance was ((5.33)) and for the length ((2m)) the coefficient of performance was ((6.16)) and for the length ((1m)) the coefficient of performance was ((6.5)). By comparing the coefficient of performance for the three lengths, it was found that the best coefficient of performance and equivalent to the size of the compressor used was achieved at the length ((1m)).

2. For the second diameter ((2.0mm)) for the three lengths of the capillary tube, the calculations and results proved the following:

For the length of the capillary tube ((3m)) the performance coefficients was ((6.6)) and for the length ((2m)) the performance coefficient was ((5.33)) and for the length ((1m)) the performance coefficient was ((6.8)).
By comparing the performance coefficient for the three lengths, it was found that the best performance coefficient and equivalent to the size of the compressor used was achieved at the length ((1m)).

Conclusion

At the end of the paper, when operating the designed and assembled system and observing the effect of changing the diameter and length of the capillary tube on the compressor performance, taking readings and representing them on a (p-h) chart, and performing calculations and obtaining the results and comparing them, the results showed through the values obtained during operation in terms of both temperature and pressure of the evaporator and condenser that the best performance factor and equivalent to the size of the compressor used was achieved when using the length ((1m)) and diameter ((2.0mm)) for the capillary tube.

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