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Effect of changing the thermal Expansion valve orifice diameter on Performance of Vapor Compression Refrigeration Cycle

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Abstract
For A computational model based on the analysis of the effect of increasing and decreasing the orifice capacity of the thermal expansion valve was presented to study the performance coefficient of the refrigerant compression cycle (R134a). Experiments were carried out on a cooling device with a thermal expansion valve with a design diameter of 2 mm, and this diameter was changed to 3 mm and 1 mm, and the results be compared. It found that the quantity of heat absorbed in the evaporator, the amount of heat released in the condenser, and the work of compressors decreased when the diameter of the valve orifice increased and decreased from the ordinary orifice. while the Coefficient of Performance (COP) of the cycle increased when the diameter of the valve increased and decreased when the valve decreased. The pressure ratio of the cycle was decreased when the diameter increased and increased when the diameter decreased.

Keywords: Metring Device, Thermostatic Expansion Valve, TEV, Expansion Tool

1. Introduction

When In past years, air conditioning systems (HVAC) [1-4], optimization of heat transfer and heat exchanger [5-8], energy consumption in buildings [9, 10], thermal power plants, and other applications always become the main concern of many researchers. Refrigeration systems are used in diverse applications such as food preservation, and offering comfort (residential and commercial buildings, vehicles, etc.). Optimizing the energy utilization of all the facilities' equipment is difficult. Particularly to reduce the energy consumption of the building by optimizing the HVAC, for this reason, any improvement made in the refrigeration system tends to involve a wide application area. Reducing the throttling losses in the expansion valve, which increases system irreversibility, is one of the methods of improving system performance. There are four Parts in the vapour compression cycle, which are the compressor, condenser, metering device, and evaporator as shown in Fig 1.

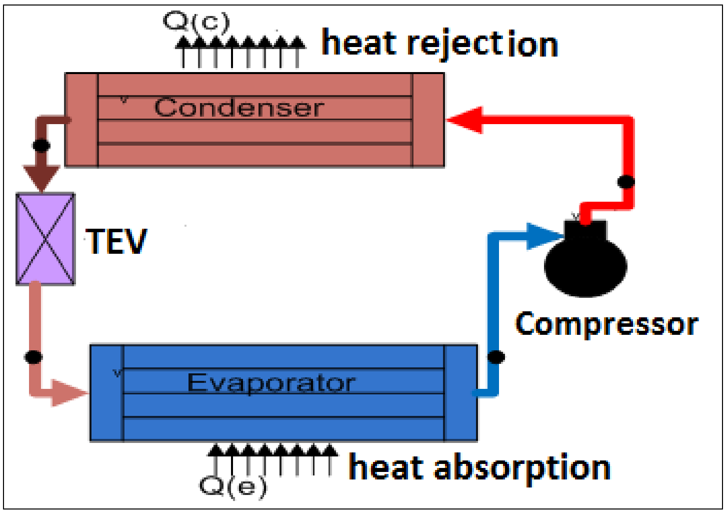

Fig 1: Schematic diagram of vapour compression Refrigeration Cycle

A pressure drop point is provided by expansion tools. These tools have the function to feed refrigerant into an evaporator and hold refrigerant back in a condensed state. When compared to a capillary tube, the TEV provides more cooling effect, and as load increases, its performance rises [1]. The thermostatic expansion valve (TEV) maintains a nearly constant superheat in the evaporator to circulate the refrigerant. By increasing or reducing the flow until the superheat returns to the valve's setting, the TEV regulates refrigerant flows based on the load.

When choosing a size for each part of the system in the design of a compression Refrigeration cycle system, this size is appropriate to the size of the other part and is designed to work under the influence of a specific external condition and by using a specific refrigerant. While choosing the pressure ratio between high and low pressure depends on the size of the compressor and the expansion tool. However, the size of the compressor and the expansion tool must be considered when deciding on the pressure ratio between high and low pressure. In order to select the expansion tool that best suits the system capacity and the size of the compressor, extremely precise calculations are done. Therefore, switching out the expansion tool for a different one during maintenance operations results in a number of issues, such as Changing the length of the capillary tube produces an increase in the compression ratio, a change in the evaporator temperature, and a decrease in flow rate. If its length is cut down, the result is the opposite.

The influence of capillary tube diameter on refrigerator performance was examined in an experiment by Ali K. Al-Sayyab [11] using a combination of the refrigerants R134a, R290, and R600a. The three capillary tube diameters used were 1.4 mm, 1.8 mm, and 2.2 mm. The experimental work demonstrates that the performance of a refrigerator using R134a and a capillary tube diameter of 2.2 mm gives the highest coefficient of performance (COP) compared to other refrigerants with the same diameter, whereas the performance of a refrigerator using a capillary tube diameter of 1.4 mm and an alternative ozone-friendly refrigerant gives a 1.3% reduction in COP from the base case of R134a. Three different-length capillary tubes were used in A. Baskaran et. al. [12] experimental work and the data on R152a were examined under a variety of circumstances to determine how changing the length would affect the results. a maximum COP of 3.65 m was attained for the capillary length, the conclusion was when the capillary length is increased to 3.65 m from 3.35 m and 3.96 m, the system performance improves, the system's performance, therefore, gets better when the capillary length rises up to a certain point. A study of K. P. Bhangale et. al. [13] focused on enhance performance, and a simulated analysis of the impact of various capillary tube sizes and diameters on vapor compression refrigeration systems revealed that helical coil capillary tubes perform better than straight tubes, but the ideal length and diameter size will vary depending on the system's capacity and the enhancement of the cooling effect. K. Neelakanta *et al.* [14] looked at the effects of capillary tube length on the performance of a vapor compression refrigeration system for a unit with a capacity of 30 lts, and R-134a as the refrigerant, they discovered that 4.5 feet were the optimum capillary tube length for the system in all areas, Coefficient of performance, cooling effect, compressor power, refrigerant mass flow rate, and compressor pressure ratio. A Nirupam Kumar el al. [15] they have used calculates the capillary, constant expansion valve, and thermostatic expansion valve performance coefficients for vapour compression refrigeration systems, it found thermostatic expansion valves have a higher COP than constant expansion and capillary tubes, according to Carnot. Thermostatic expansion valves offer the highest level of efficiency over a broad temperature and load range. They increase refrigerant return to the compressor, ensuring greater cooling at high temperatures and lowering the likelihood of liquid slugging, which can damage the compressor. According to the Thamir K. Salim el. [16] Al. study, compressor power increases when capillary tube length and condenser temperature increase by (9.54%) and (68.36%) respectively, the sub-cooling temperature declines by (34.35%) at higher flow rates while remaining constant at lower flow rates, and it drops by (38.14%) as the mass flow rate rises from (2–6g/s) and by (6.65%) as the CT length rises from (80–120 cm), the (COP) will decrease when the condenser temperature rise for all lengths. In order to determine how much COP and power consumption may be improved by modifying the system, an experimental inquiry was utilized in this study to assess the impact of adjusting the refrigerant flow rate by utilizing a different orifice diameter for the thermal expansion valve TEV.

2. Experimental method

The The experimental apparatus for analysis purposes was used to study a compression refrigeration circuit operating using a fluid (R134a), this cycle was calculated as the main comparison line for the rest of the cycle. The circuit was used to operate with an expansion valve orifice diameter less than the primary cycle first and was used to operate with an orifice diameter expansion valve larger than the main circuit once again. The inlet pressures of the condenser and evaporator were measured by special-type Bourdon gauges suitable for a refrigeration system with an accuracy of ±0.05 bar. Pressure drops in the condenser and evaporator were estimated to be 7% and 5%, respectively, based on experimental findings [10]. Calculations showed that considering these pressure drops had no significant effect on the results. Temperatures of a refrigerant at different points were recorded with K-Type thermocouples. Fig 2 shows the locations of temperature and pressure measurements in the cycle. The surface of the tube was cleaned to remove any dust or rust prior to temperature measurement, and the thermocouple probe was then placed on the surface. Thermal grease was applied at the point of contact to lower the thermal contact resistance between the thermocouple probe and the tube surface. In order to ensure proper contact and to counteract any convection effects of surrounding air on temperature readings, the insulating tape was wrapped around the probe.

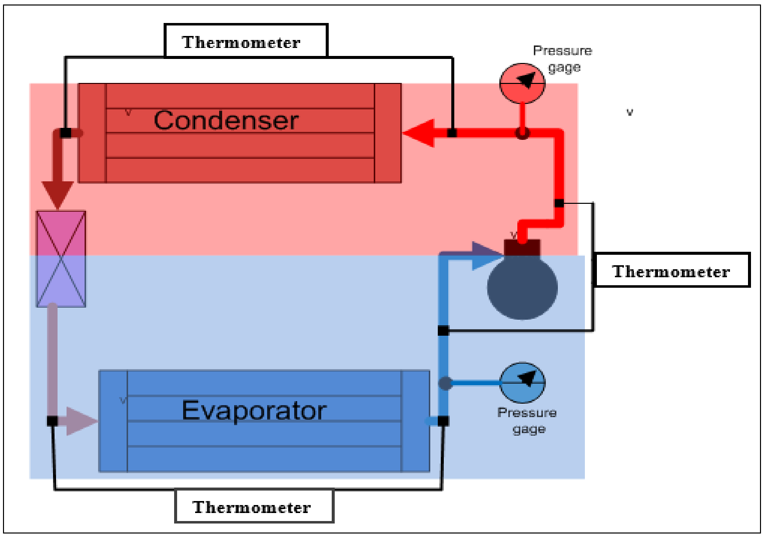

Fig 2: Temperature and pressure measurement Points

Performance parameters calculation

The performance of the system, the evaporator capacity, the condenser temperature, and the compressor's operation were calculated by equations (1)–(6) were used to calculate the desired parameters. The voltage and current of the compressor work can be evaluated by the

Table 1: Data Collection

S. No	Symbol	Units	Calculation	Description
1	WIC	Watt	Eq. 1	Electrical work energy of compressor
2	Wc	Kj/Kg	Eq. 2	Mechanical work of compressor
3	Qe	Kj/Kg	Eq. 4	heat absorption from evaporator
4	Qc	Kj/Kg	Eq. 3	heat rejection from the condenser
5	M	Kg/s	Eq. 6	Mass flow rate of the refrigeration
6	C.O.P	Unitless	Eq. 5	Coefficient of performance

3. Instrumentation

Thermocouples were utilized to measure the refrigerant temperatures before and after the evaporator and the condenser by connecting them to the copper pipe wall. Other measuring tools were also employed to collect data from the experiments that were carried out on the device. At two sites of the refrigeration cycle system, a gauge pressure was utilized to measure the system's pressure. A digital ampere meter was used to gauge the compressor's current & voltage.

4. Result and discussion

Electrical work of the compressor by using eq. (1). Compressor mechanical work can be obtained by eq. (2). The Heat released into the condenser was calculated by eq. (3). Cooling capacity and COP can be obtained by using eq. (4) and eq. (5), respectively. Mass flow rate can be obtained by eq. (6). As can be seen, in order to get a comparison between the overall performances of all cases of the system.

In all equations, subscripts (1), (2), (3), (4), (5) and (6) stand for exit conditions from the evaporator, compressor, condenser, and expansion valve.

$$WIC = I.\ V.\ Pf \tag{1}$$

$$Wc = h2 - h1 \tag{2}$$

$$Qc = h2 - h3 \tag{3}$$

$$Qe = h1 - h4 \tag{4}$$

$$C.O.P = (h1-h4)/\ (h2-h1) \tag{5}$$

$$\dot{m} = Qe/\ (h1 - h4) \tag{6}$$

practical experiments were carried out in the laboratory On a refrigeration device with a thermal expansion valve (TEV) having an orifice diameter of 2 mm. This orifice diameter was changed to 1 mm diameter and 3 mm diameter, and the results were compared with each other in the three cases as shown in fig 3 which shows the diameter shape of TEV that were used in the expermint. This investigation focuses on the effect of changing the expansion device between the refrigeration system's high-pressure and low-pressure sides of the refrigeration system which was the TEV. First, the experiment was carried out for the thermostatic expansion valve (TEV) under the standard design operation, and all of the physical parameters were monitored from the system. The coordinate points from (P–h) chart was calculated to specify the enthalpy and the coefficient of performance for three cases of the cycle. After selecting the refrigerant, the data were entered which were high pressure, low pressure, and entry and exit temperatures of the compressor, condenser, and evaporator. The cycle was drawn P-h diagram by using Cool-Pack software (V1. 50) as shown in fig 4, which shows the drawing of the refrigeration cycle for the three different diameters at time 30 min of device operation.

The performance parameters for the three cases and the comparison of performance parameters for the different orifice diameters of the (TEV), Qe is the heat absorbed in the evaporator; Qc is heat of the condenser; Wc is compressor capacity. Using the cool-pack program, all of the physical parameters from the three examples of the system were plotted to the P-h diagram.

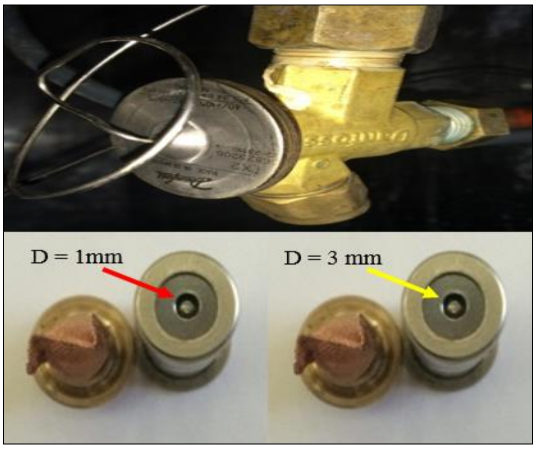

Fig 3: Thermal expansion valve TEV

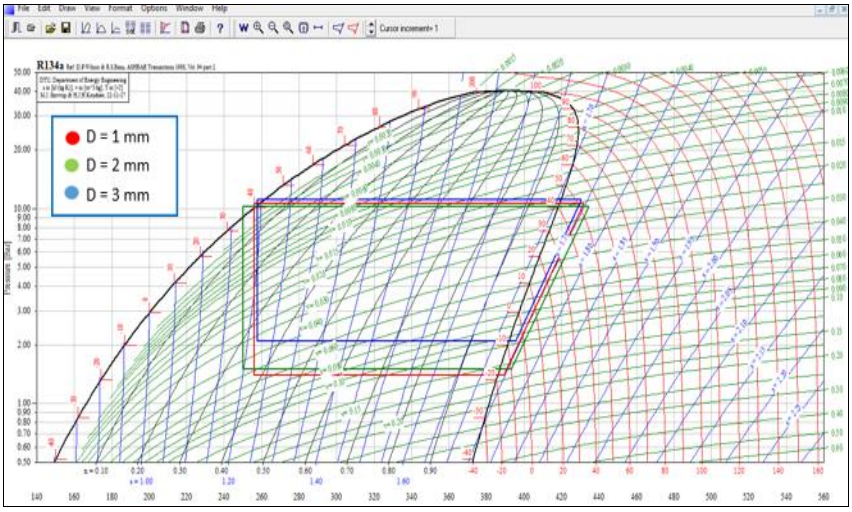

Fig 4: Refrigeration cycle on P-h diagram for Diameters (1, 2 & 3 mm) at Time (30 min)

Table 2: The experimental data input

Diameter (mm)	Experiment No.	Time (Min)	Insid Temp. (°C)	Loud Temp (°C)	Low Pressure (bar)	High Pressure (bar)	Pressure Ratio
1	1	20	-5.5425	11.8962	1.6	10.6	6.62
1	2	30	-6.058	10.8899	1.5	10.6	7.06
1	3	40	-5.3363	10.3868	1.4	10.5	7.5
2	1	20	-8.12	8.07245	1.6	10	6.25
2	2	30	-11.213	7.87120	1.5	10.3	6.86
2	3	40	-10.3882	6.96557	1.4	10.8	7.71
3	1	20	-4.4084	12.3993	2.3	11	4.78
3	2	30	-3.6897	11.8962	2.1	11.1	5.28
3	3	40	-3.3	11.2924	2	11.2	5.6

Table 3: The performance parameters data

Diameter (mm)	Experiment No.	Time (Min)	$\dot{m}$ (Kg/s)	Qe (KJ/Kg)	Qc (KJ/Kg)	Wc (KJ/Kg)	C.O.P
1	1	20	1.120	135.7	180.32	135.7	3.104
1	2	30	1.110	133.6	175.85	133.6	3.121
1	3	40	3.121	132.5	175.63	132.5	3.073
2	1	20	1.117	144.42	186.51	144.42	3.694
2	2	30	1.091	142.42	184.26	142.42	3.436
2	3	40	1.091	140.15	182.83	140.15	3.284
3	1	20	1.107	140.58	175.95	140.58	4.213
3	2	30	1.102	137.72	172.93	137.72	3.913
3	3	40	1.081	136.041	172.11	136.04	3.703

Was Table 2 shows all the data that were recorded using three diameters of the expansion valve several times from (0 - 70) minutes by holding all conditions of room temperature, constant cooling load, constant charging amount, and changing the valve diameter (1, 2, and 3 mm) and since at the beginning of the operation the state of the system is unstable, as well as at the end of the experiment, so the first 20 minutes and the last 30 minutes of the experiment were neglected and the most stable intermediate periods were taken (20, 30 and 40 minutes). The data was entered into the cool pack software to perform the calculations to extract and record the results as shown in Table 3. This phenomenon demonstrates that the TEV had superior control over the expansion process, which was related to the compressor's pumping capacity.

Fig 5 shows the relationship between the compression ratio of the cycle with time using three diameters of the thermal expansion valve (1, 2, and 3 mm). A great convergence between the case of 1 mm with 2 mm, or there is a slight difference in the first ten minutes, then it becomes a great convergence for it, which is what means that the change in the temperature of the load overwhelms the action of the valve while for the case of 3 mm, the large diameter reduces the flowrate and the possibility of forming a pressure difference, so we note that it is the lowest compression ratio for the largest diameter, and this is logical. In general, all diameters have a compression ratio that increases with time, because with the passage of time the low pressure decreases clearly, therfor the compression ratio increases. These operational ratios give space temperatures (depending on the temperature of the evaporator, which mainly depends on the low pressure) different with different of diameters. In the Fig 6 the case of a diameter 3 mm, the highest temperature of a space is followed by a case of 1 mm, then the lowest is a case of 2 mm, the indicates of preference of diameter is (2 mm) in this case. Since the temperature of the space is the main factor for obsorption the heat of the load in the space, we notice the same discrepancy clearly in the temperature of the load directly in Fig 7.

Fig 8 shows the relationship between the amount of heat gained in the evaporator with time for the three cases of diameter 1, 2, and 3 mm. The stability in the amount of heat acquired in the evaporator is for diameters 2 and 3 mm. As for the diameter of 1 mm, there is a clear change in the amount of heat between the time period of 20 and 30 minutes. This instability in the withdrawn heat clearly affects the amount of heat lost in the condenser, which is the sum of the heat of the evaporator and the work of the compressor.

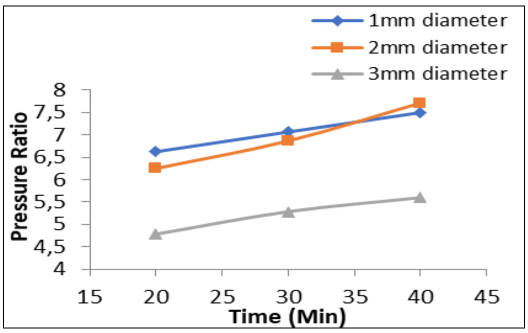

Fig 5: The relationship between compression and time for three valve diameters

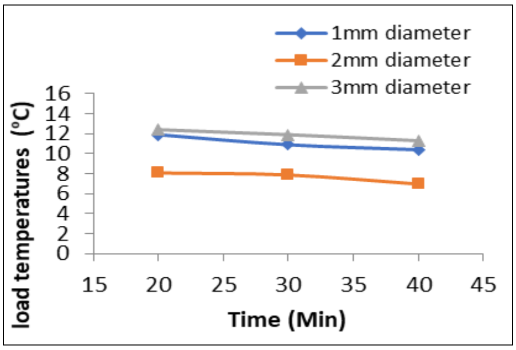

Fig 6: The relationship between load temperatures with time

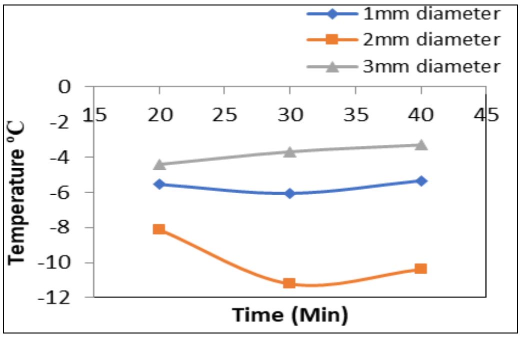

Fig 7: The relationship between the temperatures of the refrigerated with time

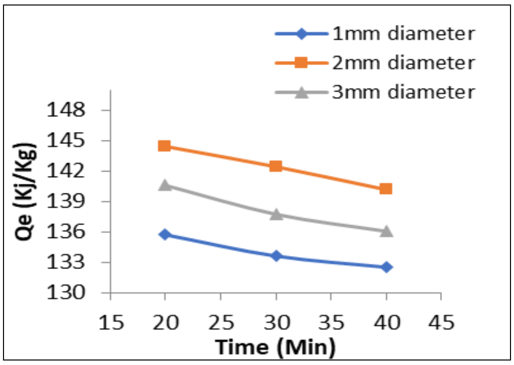

Fig 8: The relationship between the thermal evaporator capacity with time

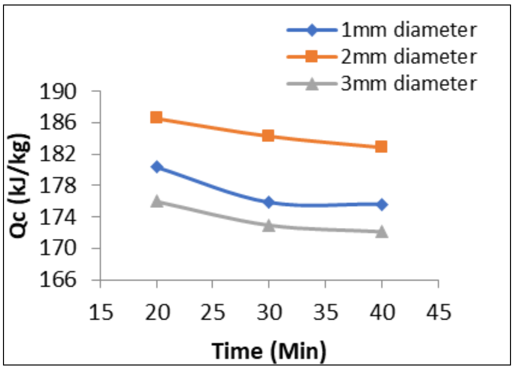

Fig 9: The relationship between the thermal capacities of the condenser with time

Fig 9 shows the relationship between the amount of heat released in the condenser with time for the three cases of diameter 1, 2 and 3 mm, where the decrease in the amount of condenser heat for a diameter of 3 mm compared to 2 and 1 mm, but it results from the little work spent on the compressor for this diameter (3 mm), which is illustrated in

Fig 10, and this difference in the work of the compressor, it leads that the pressure difference between low and high pressures reduces the effort exerted on the compressor, so the work spent is less, noting the instability in cases 1 and 3 mm, and the most stable case is 2 mm.

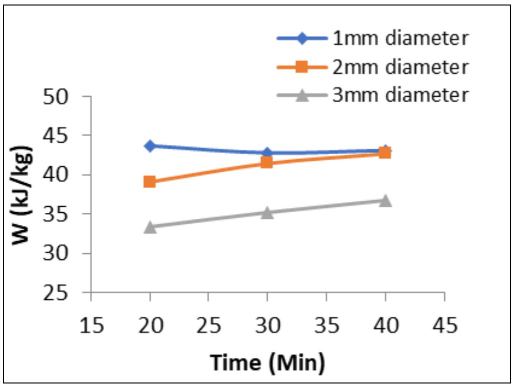

Fig 10: The relationship between compressor work with time

The amount of heat of the condenser and the evaporator and the work expended in the compressor were studied with the calculation of the flow rate of the refrigerant in the cycle for the three diameters of the thermal expansion valve in general for the cycle. Where the coefficient of performance were studied for all the effect of the changing of the refrigerant flowrate in the three cases of the expansion valve diameters effect. Fig 11 shows the relationship between the system performance coefficient with time for the three diameters 1, 2, and 3 mm, where the obvious stability of the 2 mm diameter of TEV and the instability of performance in the 1 mm diameter of the TEV was observed, and the obvious increase in the 3 mm diameter does not add a basic value to the circuit because it results from little compressor work As we mentioned above in the discussion of the figure and the lack of this increase in Fig 11 in the amount of heat acquired for the evaporator, so the increase in cycle performance for diameter 3 mm is invaluable and can be neglected.

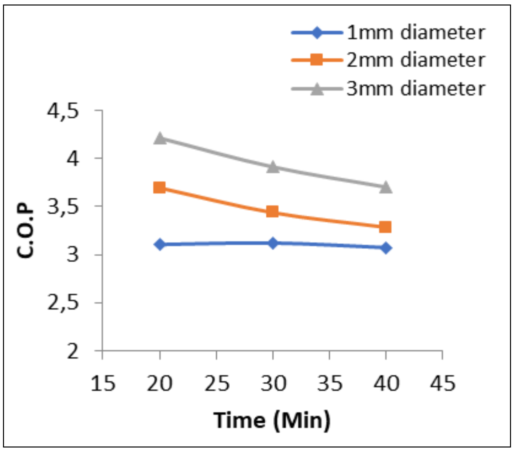

Fig 11: The relationship between the cycle performance coefficients with time

The amount of heat of the condenser and the evaporator and the work of the compressor were studied with the calculation of the refrigerant flow rate in the cycle for the three diameters of the thermal expansion valve in general for the cycle. Where the coefficient of performance studied for the effect of changing in the three cases of the expansion valve diameters effect. Fig 11 shows the relationship between the system coefficient of performance & time for the three diameters 1, 2, and 3 mm, where the obvious stability of the 2 mm diameter of TEV and the instability of performance in the 1 mm diameter of the TEV, and the obvious increase in the 3 mm diameter does not add a basic value to the cycle because it results from little compressor work and the lack of this increase in Fig 8 in the amount of heat acquired for the evaporator, therefor the increase in cycle performance for diameter 3 mm is slight and can be neglected.

5. Conclusion

An increase in the diameter of the thermal expansion valve orifice or a decrease in it from the design diameter orifice leads to a decrease in the quantity of heat absorbed in the evaporator, the amount of heat released in the condenser, and the work of compressors. as well as, The pressure ratio of the cycle decreased when the diameter increased and increased when the diameter decreased. The coefficient of performance (COP) of the cycle increased when the diameter of the valve increased and it decreased when it decreased.

Nomenclature

TEV	Thermal expansion Valve
COP	Coefficient of performance
WIC	The electrical work of the compressor (W)
Wc	work of compressor (KJ/kg)
h	Enthalpy(KJ/kg)
I	electric-current (A)
V	electric-voltage (V)
$m^{\cdot}$	mass flow-rate (Kg/s)
Rf	Refrigeration Effect (KJ/kg)
Qe	Evaporater capacity (KJ/kg)
Qc	Condenser capacity (KJ/kg)

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