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"EFFECT OF COMPRESSOR COOLING ON VCRS PERFORMANCE"

***Kartik Soni* [1], *Krishna Tanwar* [2]**

[1,2] *Department of Mechanical Engineering, Acropolis Technical Campus, Indore*

ABSTRACT

Aim is to improve the coefficient of performance of system which is based on vapor compression cycle. To improve the coefficient of performance, it requires that the compressor work should decrease and refrigeration effect should increase. It means that decrease in condenser pressure and temperature so the refrigerant effect will increase and compressor input work due to this COP will increase. And also increase in pressure and temperature of evaporator the work input will decrease and refrigerant effect will increase due to this COP will increase for a vapor compression refrigeration system in 1834. Perkin built a prototype system and it actually worked. According the drawing in Perkins patent liquid either ($C_4H_{10}O$) was contained in an "evaporator vessel" where it was vaporized under a partial vacuum maintained by the suction of a crude hand \-operated compressor. The evaporator vessel was submerged in a liquid from which the heat required to vaporize the ether was extracted, thereby cooling the liquid.

KEYWORD: *COP, Refrigeration, Vapor compression refrigeration system, $C_4H_{10}O$* .

I. INTRODUCTION

The term '*refrigeration'* may be defined as the process of removing heat from a substance under controlledconditions. It also includes the process of reducing and maintaining the temperature of a body below the general temperature of its surroundings. In other words, the refrigeration means a continued extraction of heat from a body whose temperature is already below temperature of its surroundings. In a refrigerator, heat is virtually pumped from a lower temperature to a higher temperature. According to Second Law of Thermodynamics, this process can only be performed with the aid of some external work. It is thus obvious that supply of power is regularly required to drive a refrigerator. Theoretically, a refrigerator is a reversed heat engine or a heat pump which pumps heat from a cold body and delivers it to a hot body. The substance which works in a pump to extract heat from a cold body and to deliver it to a hot body is known as refrigerant.

Vapor compression cycle is an improved type of air refrigeration cycle in which a suitable working substance, termed as refrigerant, is used. The refrigerants generally used for this purpose are ammonia (NH3), carbon dioxide (CO2) and sulphur-dioxide (SO2). The refrigerant used, does not leave the system, but is circulated throughout the system alternately condensing and evaporating. In evaporating, the refrigerant absorbs its latent heat from the solution which is used for circulating it around the cold chamber and in condensing; it gives out its latent heat to the circulating water of the cooler. Vapor Compression Refrigeration or vapor-compression refrigeration system (VCRS). in which the refrigerant undergoes phase changes. As the name implies, these systems belong to the general class of vapor cycles, wherein the working fluid (refrigerant) undergoes phase change at least during one process. In a vapor compression refrigeration system, refrigeration is obtained as the refrigerant evaporates at low temperatures. The input

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to the system is in the form of mechanical energy required to run the compressor. Hence these systems are also called as mechanical refrigeration systems. Vapor compression refrigeration systems are available to suit almost all applications with the refrigeration capacities ranging from few Watts to few megawatts. A wide variety of refrigerants can be used in these systems to suit different applications, capacities etc. The actual vapor compression cycle is based on Evans-Perkins cycle, which is also called as reverse Rankine cycle. Before the actual cycle is discussed and analysed, it is essential to find the upper limit of performance of vapor compression cycles. This limit is set by a completely reversible cycle.

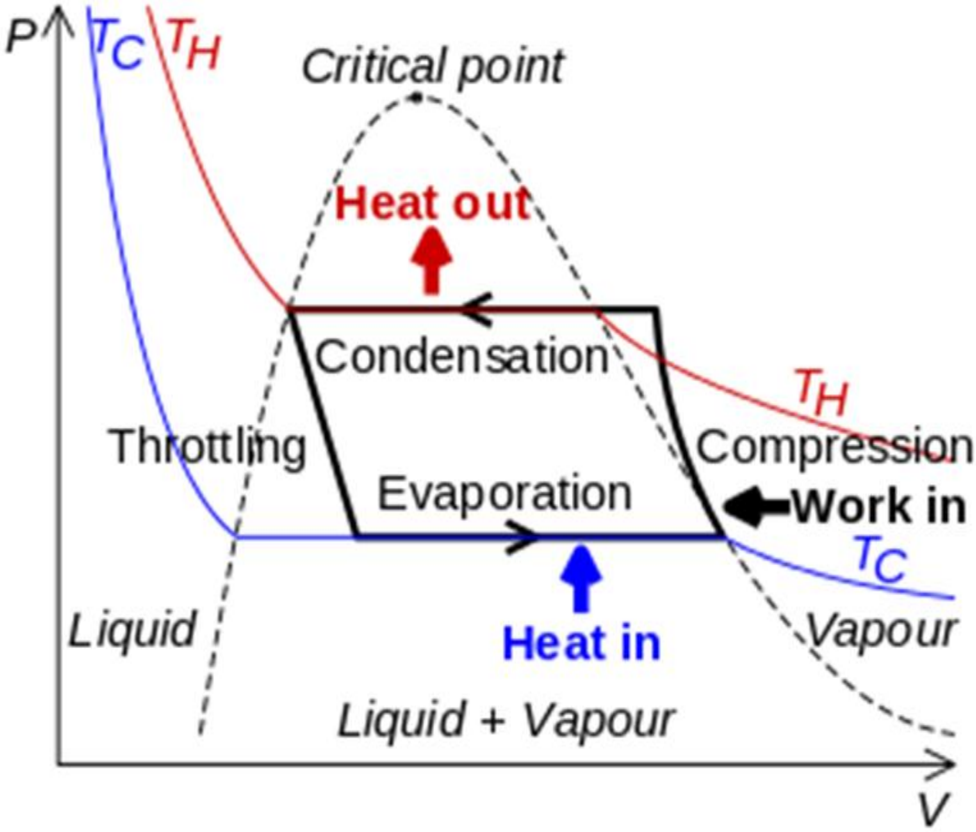

Fig.1

Vapor compression refrigeration cycle one of the many refrigeration cycles and is the most widely used method for air-conditioning of buildings and automobiles. It is also used in domestic and commercial refrigerators, large-scale warehouses for chilled or frozen storage of foods and meats, refrigerated trucks and railroad cars, and a host of other commercial and industrial services. Oil refineries, petrochemical and chemical processing plants, and natural gas processing plants are among the many types of industrial plants that often utilize large vapor-compression refrigeration systems. So improvement of performance of system is too important for higher refrigerating effect or reduced power consumption for same refrigerating effect. Many efforts have to be done to improve the performance of VC refrigeration system.

In 1805, American inventor Oliver Evans described in detail, but never built, a refrigeration system based on the vapor compression refrigeration cycle. An American living in Great Britain, Jacob Perkins, improved upon the design proposed by Oliver Evans and obtained the first patent

In 1842, an American physician, John Gorrie, designed the first system for refrigerating water to produce ice. He also conceived the idea of using his refrigeration system to cool the air in the rooms of a Florida hospital used for treating yellow fever and malaria patients. His system compressed air, then partially cooled the hot compressed air with water before allowing it isentropically expand while doing part of the work required to drive the air compressor.

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CAD MODEL:

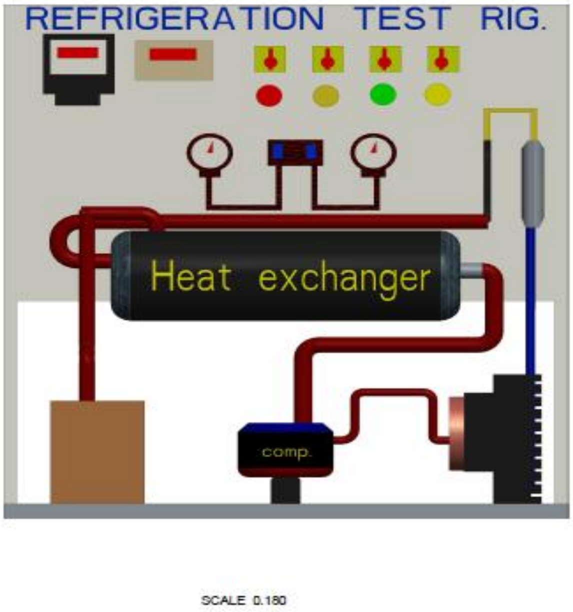

Fig 5

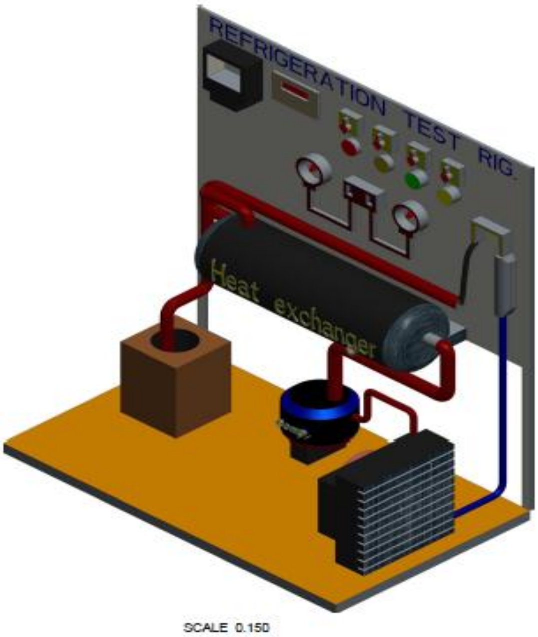

Fig 6

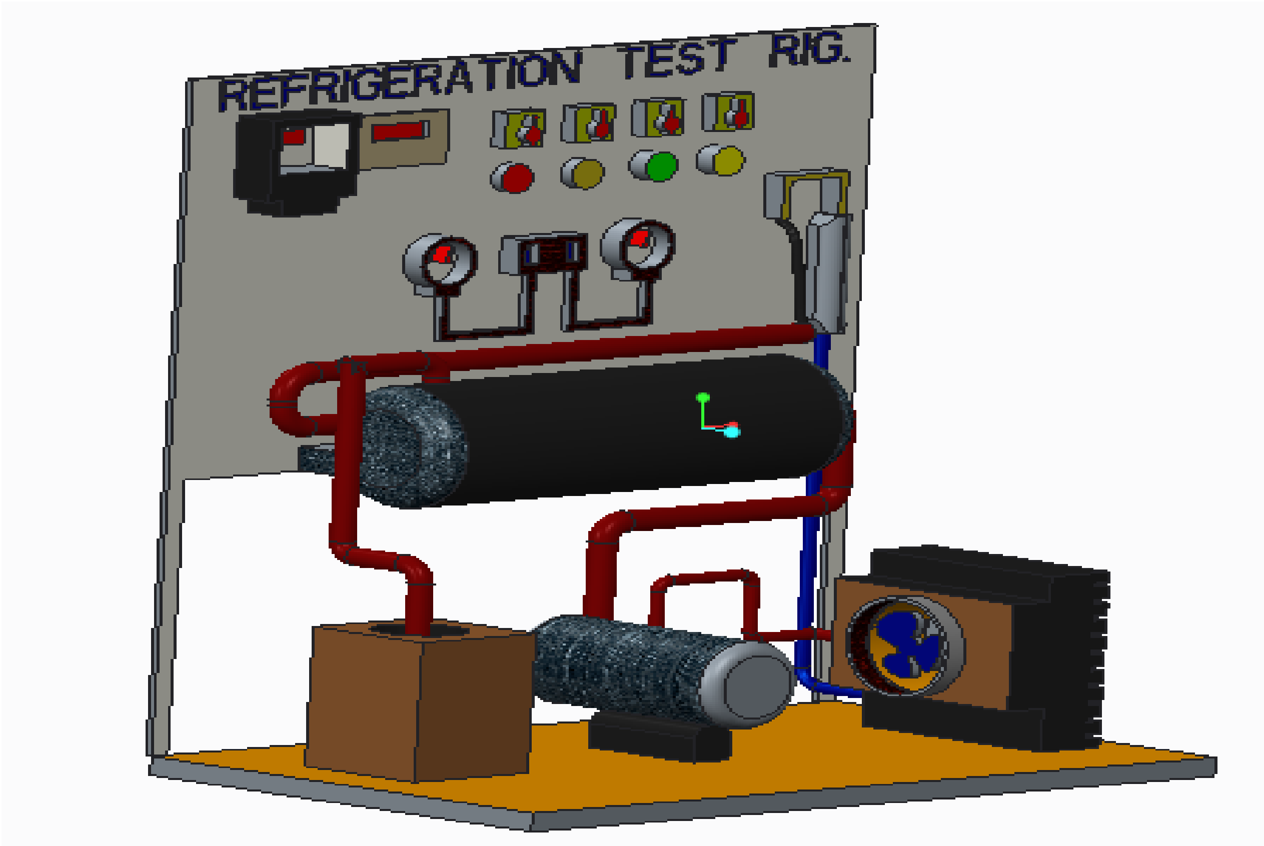

Fig 7

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II. METHODOLOGY

A vapor compression cycle with dry saturated vapor after compression is shown on T-s diagrams in Figures.(a) and (b) respectively. At point 1, let T_1, p_1 and s_1 be the temperature, pressure and entropy of the vapor refrigerant respectively. The four processes of the cycle are as follows:

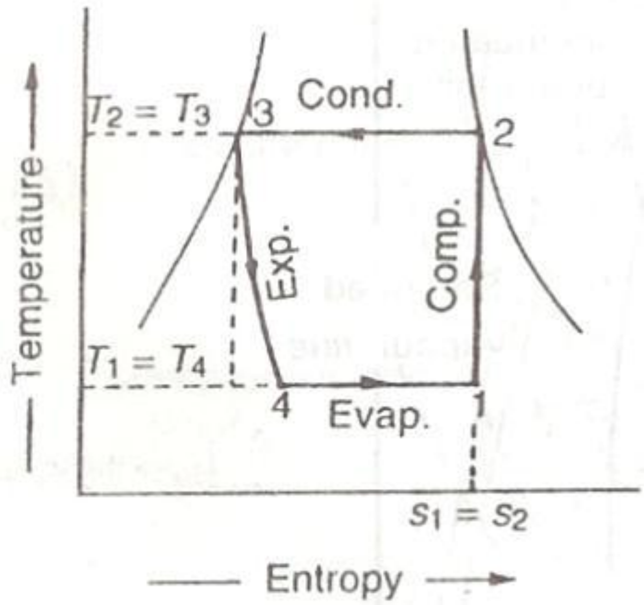

Fig 8 T-s Diagram

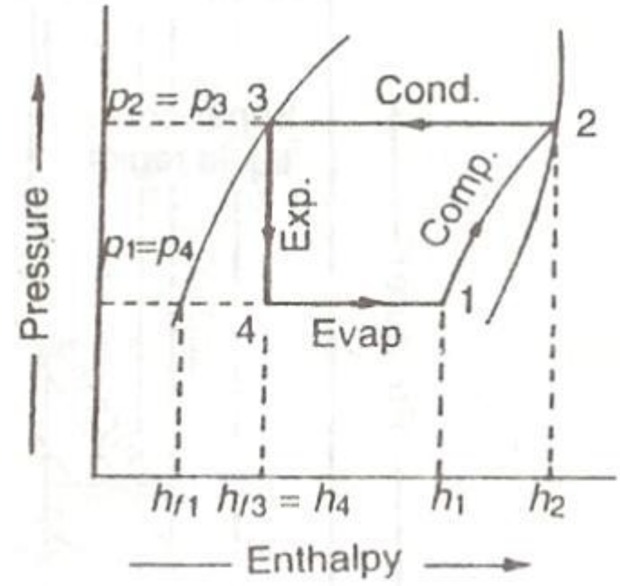

Fig 9 p-h Diagram

Compression Process

The vapor refrigerant at low pressure $p1$ and temperature$T1$ is compressed isentropically to dry saturated vapor as shown by the vertical line 1-2 on the T-s diagram and by the curve 1-2 on p-h diagram. The pressure and temperature rise from $p1$ to $p2$ and $T1$ to $T2$ respectively.

The work done during isentropic compression per kg of refrigerant is given by

$w = h2 - h1$

where$h1$ = Enthalpy of vapor refrigerant at temperature $T1$, i.e. at suction of the compressor, and

$h2$ = Enthalpy of the vapor refrigerant at temperature $T2$. i.e. at discharge of the compressor.

Condensing Process

The high pressure and temperature vapor refrigerant from the compressor is passed through the condenser where it is completely condensed at constant pressure p_2 and temperature T_2 as shown by the horizontal line 2-3 on T-s and p-h diagrams. The vapor refrigerant is changed into liquid refrigerant. The refrigerant, while passing through the condenser, gives its latent heat to the surrounding condensing medium.

Expansion Process

The liquid refrigerant at pressure $p_3 = p_2$ and temperature $T_3 = T_2$, is expanded by throttling process through the expansion valve to a low pressure $p_4 = p_1$ and Temperature $T_4 = T_1$ as shown by the curve 3-4 on T-s diagram and by the vertical line 3-4 on p-h diagram. Some of the liquid refrigerant evaporates as it passes through the expansion valve, but the greater portion is vaporized in the evaporator. We know that during the throttling process, no heat is absorbed or rejected by the liquid refrigerant.

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Impact Factor : 2.015

Vaporizing Process

The liquid-vapor mixture of the refrigerant at pressure $p_4 = p_1$ and temperature $T_4 = T_1$ is evaporated and changed into vapor refrigerant at constant pressure and temperature, as shown by the horizontal line 4-1 on T-s and p-h diagrams. During evaporation, the liquid-vapor refrigerant absorbs its latent heat of vaporization from the medium (air, water or brine) which, is to be cooled, This heat which is absorbed by the refrigerant is called refrigerating effect and it is briefly written as *RE*. The process of vaporization continues up to point 1 which is the starting point and thus the cycle is completed.

We know that the refrigerating effect or the heat absorbed or extracted by the liquid-vapor refrigerant during evaporation per kg of refrigerant is given by

$RE = h1 - h4 = h1 - hf3$

where$hf3$ = Sensible heat at temperature $T3$, i.e. enthalpy of liquid refrigerant leaving the condenser.

It may be noticed from the cycle that the liquid-vapor refrigerant has extracted heat during evaporation and the work will be done by the compressor for isentropic compression of the high pressure and temperature vapor refrigerant.

Coefficient of performance, C.O.P. = (Refrigerating effect) / (Work done)

$= (h_1 - h_4) / (h_2 - h_1)$

$= (h_1 - h_{f3}) / (h_2 - h_1)$

Effect of Suction Pressure

The suction pressure (or evaporator pressure) decreases due to the frictional resistance of flow of the refrigerant. Let us consider a theoretical vapor compression cycle 1-2-3-4 when the suction pressure decreases from $p_s$to $p_{s'}$ as shown on p-h diagram in Figure.

It may be noted that the decrease in suction pressure:

(a) Decreases the refrigerating effect from $(h1 - h4)$ to $(h_1^1 - h_4^1)$, and

(b) Increases the work required for compression from $(h2 - h1)$ to $(h_2^1 - h_1^1)$.

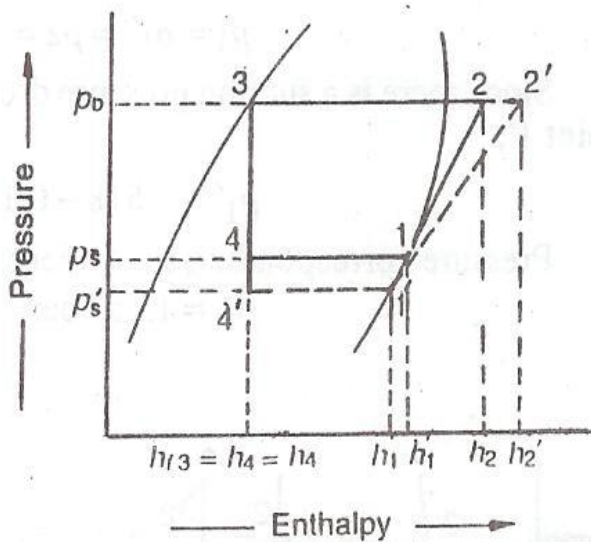

Fig. 10 Effect of Suction Pressure

Since the C.O.P, of the system is the ratio of refrigerating effect to the work done, therefore with the decrease in suction pressure, the net effect is to decrease the C.O.P. of the refrigerating system for the same refrigerant flow. Hence with the decrease in suction pressure the refrigerating capacity of the system decreases and the refrigeration cost increases.

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Impact Factor : 2.015

Effect of Discharge Pressure

In actual practice, the discharge pressure (or condenser pressure) increases due to frictional resistance of flow of the refrigerant. Let us consider a theoretical vapor compression cycle l-2-3-4 when the Discharge pressure increases from p_D to $p_{D''}$ as shown on p-h diagram in Figure resulting in increased compressor work and reduced refrigeration effect.

III. OBSERVATION AND CALCULATION

t_1 = temperature after compression
t_2 = temperature after condensation
t_3 = temperature after expansion
t_4 = temperature after evaporation
t_5 = Water temperature at outlet
t_6 = Water temperature at inlet

1. Compressor works at room temperature:

OBSERVATION TABLE:

For Refrigerant R134a , Tetrafloroethane , CH_2FCF_3 .

Table 1 Observations when Compressor works at room temperature

Reading in every 15 min	Temperature (t_1) °C	Temperature (t_2) °C	Temperature (t_3) °C	Temperature (t_4)°C	Temperature (t_5)°C	Temperature (t_6) °C
1	38	31	-1	34	-1	20
2	41	32	-1	39	-1	17
3	43	32	-1	42	-1	13
4	45	34	-1	44	-1	12

Table 2

Reading no.	Suction Pressure (bar)	Discharge pressure (bar)	Suction temperature °C	Discharge temperature °C	Rotameter reading (LPH)	Electric meter reading (KW/hr)
1	1.72369	7.92897	-16.67	20	1.8	6.0
2	1.72369	8.204	-17.78	20.56	2	6.1
3	1.72369	8.237	-18	21	2	6.2
4	1.72369	8.567	-18.67	22	2.1	6.2

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Calculaion of COP for average value of temperature:

Since the system operates at condensor temperature 40°C and evaporator temperature -1°C
Therefore,

At $t_c = 40^oC$

$h_3 = 26.41$ kJ/g $p_c = 1.0166$MPa

$C_p = 1.145$ kJ/kg K$h_g = 419.43$ kJ/kg

$s_g = 1.711$ kJ/kg
At $t_e = -1^oC$

$h_1 = 398.60$ kJ/kg $p_e = 0.29280$MPa

$s_1 = 1.7271$ kJ/kg K $C_p = 0.906$ kJ/kg K

For discharge temperature

$s_1 = s_2 = s_g + C_p \ln(T_2/T_c)$

$T_2 = 317.44$ K
$t_2 = 44.44\ ^oC$

For discharge enthalpy,

$h_2 = h_g + C_p(t_2 - t_c)$

$h_2 = 424.51$ kJ/kg

COP = q_0 / W

$q_0 = h_1 - h_3 = (398.60 - 256.41)$ kJ/kg

$q_0 = 142.19$ kJ/kg

$W = h_2 - h_1 = (424.44 - 398.60)$ kJ/kg

W = 25.80 kJ/kg

COP = (142.19 / 25.80)

COP = 5.4

1 With cooling of compressor

Table 3 Observations when Compressor is Cooled

Reading in every 15 min	**Temperature (t_1) °C**	**Temperature (t_2) °C**	**Temperature (t_3) °C**	**Temperature (t_4)°C**	**Temperature (t_5)°C**	**Temperature (t_6) °C**
1	39	41	6	44	-1	21
2	40	43	6	48	-1	17
3	41	43	5	49	-1	16
4	42	43	4	54	-1	13
5	42	43	4	54	-1	11

Table 4

Calculaion of COP for average value of temperature:

Since the system operates at condensor temperature 41°C and evaporator temperature 5°C
Therefore,

At $t_c = 41^oC$

$h_3 = 259.41$ kJ/g $p_c = 1.0722$MPa

C_p =1.163kJ/kg Kh_g = 420.28kJ/kg

s_g = 1.7103 kJ/kg

At $t_e = 5^oC$

h_1 = 402.06 kJ/kg p_e = 0.36198MPa

s_1 = 1.7240 kJ/kg K C_p = .925 kJ/kg K

For discharge temperature

$s_1 = s_2 = s_g + C_p \ln(T_2 / T_c)$

T_2 = 317.72K
t_2 = 44.72 °C

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Impact Factor : 2.015

For discharge enthalpy,

$h_2 = h_g + C_p(t_2 – t_c)$

h_2 = 424.6 kJ/kg

COP = q_0 / W

$q_0 = h_1 – h_3$ = (402.06 - 259.41) kJ/kg

q_0 = 142.65 kJ/kg

W = $h_2 – h_1$ = (424.6 – 402.60) kJ/kg

W = 22 kJ/kg

COP = (142.65 / 22)

COP = 6.4

IV. CONCLUSION & RESULT

By conducting the experiment it is seen that the COP is slightly increased. So we can say that decrease in compressor temperature will increase the cop of the system. It means that decrease in compressor temperature, the difference of condenser and evaporator temperature it decreased and thus the COP is increased.

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