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PERFORMANCE OF VCRS SYSTEM WITH HEAT EXCHANGER AND PHASE CHANGE MATERIAL

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ABSTRACT

The applications of refrigeration have been increasing in this modern world, so it is very necessary to update the technologies in refrigeration system. The COP of the refrigeration system (VCRS) can be increased by increasing the refrigeration effect or by reducing the work done by the compressor. In this work the capillary tube of refrigeration system is wound around the evaporator outlet to make a heat exchanger there by increasing the COP of the system by the effect of sub-cooling. The additional advantage added to this project is the phase change material (potassium chloride). By using the phase change material in the evaporator the temperature change in refrigeration system during absence of electricity is protected.

KEYWORDS: *Refrigeration, Cop, VCRS, Heat Exchanger and PCM*

I. INTRODUCTION

In this modern world almost all the refrigeration systems are based on the vapour compression refrigeration system cycle. The four processes that involved in vcrs system are constant pressure heat addition, isentropic compression, constant pressure heat rejection and isenthalpic expansion.

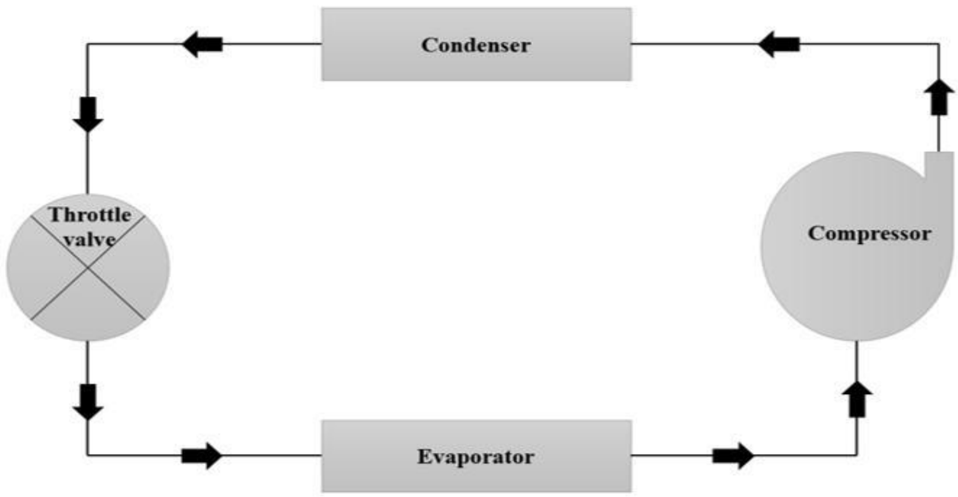

Figure 1 Simple Refrigeration Cycle

Figure 1 shows the simple refrigeration cycle. Initially the refrigerant enters the compressor as a gas under low pressure and having a low temperature. Then, the refrigerant is compressed adiabatically, so the fluid leaves the compressor under high pressure and with a high temperature. The high pressure and high temperature gas condenses in the condenser and the refrigerant leaves the condenser as high pressure liquid. The high pressure liquid refrigerant is then passed to capillary tube which causes it to expand. When the refrigerant is forced through throttle, its pressure is reduced. As a result refrigerant now has low pressure and low temperature. The low pressure and low temperature refrigerant enters the evaporator, which is in contact with cold reservoir. Because a low temperature is maintained, the refrigerant is able to boil at a low temperature. So the liquid absorbs the heat from the cold reservoir, it evaporates and enters into the compressor. And the cycle repeats.

SUB- COOLING

Refrigeration is nothing but the extraction of heat, or the transmission of heat by mechanical methods, from one location to another. Sub-cooling in refrigeration implies that cooling the refrigerant in liquid state at uniform pressure to a temperature less than saturation temperature, which corresponds to condenser pressure. This can be achieved by incorporating a heat exchanger in the VCRS system.

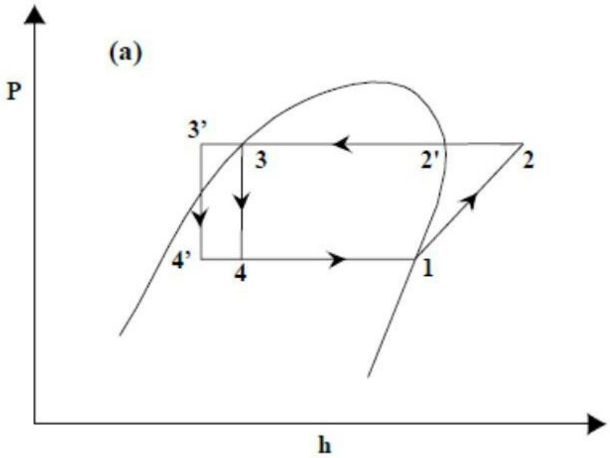

Figure 2 Effect of sub- cooling from 3-3'

HEAT EXCHANGER

Heat exchangers are the devices that are used to transfer the heat from one to another. These are widely used in space heating, refrigeration, air conditioning, chemical plants etc. parallel flow and counter flow are the two flow types used in heat exchanger. In parallel flow arrangement the 2 fluids flow in same direction, they move in opposite direction in counter flow arrangement.

POTASSIUM CHLORIDE

Potassium Chloride is a metal halide salt composed of potassium and chloride. It is odourless and has a white colourless vitreous crystal appearance. The solid dissolves readily in water and its solution have a salt like taste. KCL is used as a fertilizer in medicine, scientific applications and food processing. It occurs naturally as the mineral sylvite and in combination of sodium chloride as sylvinite.

Table 1. Properties of potassium chloride

Chemical formula	KCL
Solubility	Soluble in water, glycerol and alkalies
Melting point	770 c
Acidity	~7
Density	1.984 g/cm^3
Molar mass	74.5513 g/mol

PROPOSED METHOD FOR IMPROVING THE CO-EFFICIENT OF PERFROMANCE OF THE VCRS SYSTEM

As we all know in refrigeration cycle along the capillary tube the refrigerant has high temperature than that of evaporator outlet pipe temperature. The capillary tube is rotated along the length of the evaporator outlet pipe and then connected to evaporator inlet. A heat exchanger like set up takes place in the cycle. Heat exchange takes place between the capillary tube and evaporator outlet pipe. The refrigerant coming from the capillary tube undergoes sub-cooling and increases the refrigeration effect in the evaporator. Similarly the refrigerant in evaporator outlet pipe undergoes super heating and enters into compressor. By the effects of sub-cooling and super heating the co-efficient of performance of the refrigeration system can be increased.

In evaporator one of the phase change material named potassium chloride is added by mixing with water. Potassium chloride freezes in the evaporator when the temperature in the evaporator reaches less than -2 degree. When there is a power loss or when the system is turned off this pcm which is already freeze, helps in protecting the temperature rise in evaporator.

II. EXPERIMENTAL WORK

In this work a simple heat exchanger setup is made in the VCRS system as shown in below figure without adding any external devices.

Figure3 Heat Exchanger like set up

From figure 3along the capillary tube the refrigerant has high temperature than evaporator outlet pipe temperature. So the capillary tube is rotated along the evaporator outlet pipe with a length of 24cm to make the heat exchanger. Thus the capillary tube temperature is reduced (sub cooled) and the same manner the refrigerant temperature entering into the compressor can be increased.

Figure 4 Complete set up with Heat Exchanger

Figure 4shows the complete VCRS system with heat exchanger containing compressor, condenser, capillary tube and evaporator. The refrigerant used in this system is R-134a. Today almost all the domestic refrigerants are using R-134a, so the same refrigerant is used here.

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Table 2. Specifications of Heat Exchanger

Evaporator outlet pipe diameter	1 cm
Length of heat exchanger	24 cm
Material	Copper

Table 3. Readings for the VCRS system with Heat Exchanger

Compressor inlet temperature	14.7
Compressor outlet temperature	72
Condenser temperature	37.2
Evaporator temperature	-3
Low pressure (P1)	3 bar
High pressure (P2)	13 bar

SAMPLE CALCULATIONS

From P-H chart of R-134a at pressure (P1) and temperature (T1), the enthalpy is given as

h_1= 615kj/kg

From P-H chart of R-134a at pressure (P2) and temperature (T2), the enthalpy is given as

h_2= 660kj/kg

From P-H chart of R-134a at pressure (P2) and temperature (T3), the enthalpy is given as

h_3= 460kj/kg

From P-H chart of R-134a at pressure (P1) and temperature (T4), the enthalpy is given as

h_4= 400kj/kg

Refrigeration effect = h_1-h_4 = 615 – 400 = 215 kj/kg

Compressor work = h_2-h_1 = 660 – 615 = 45 kj/kg

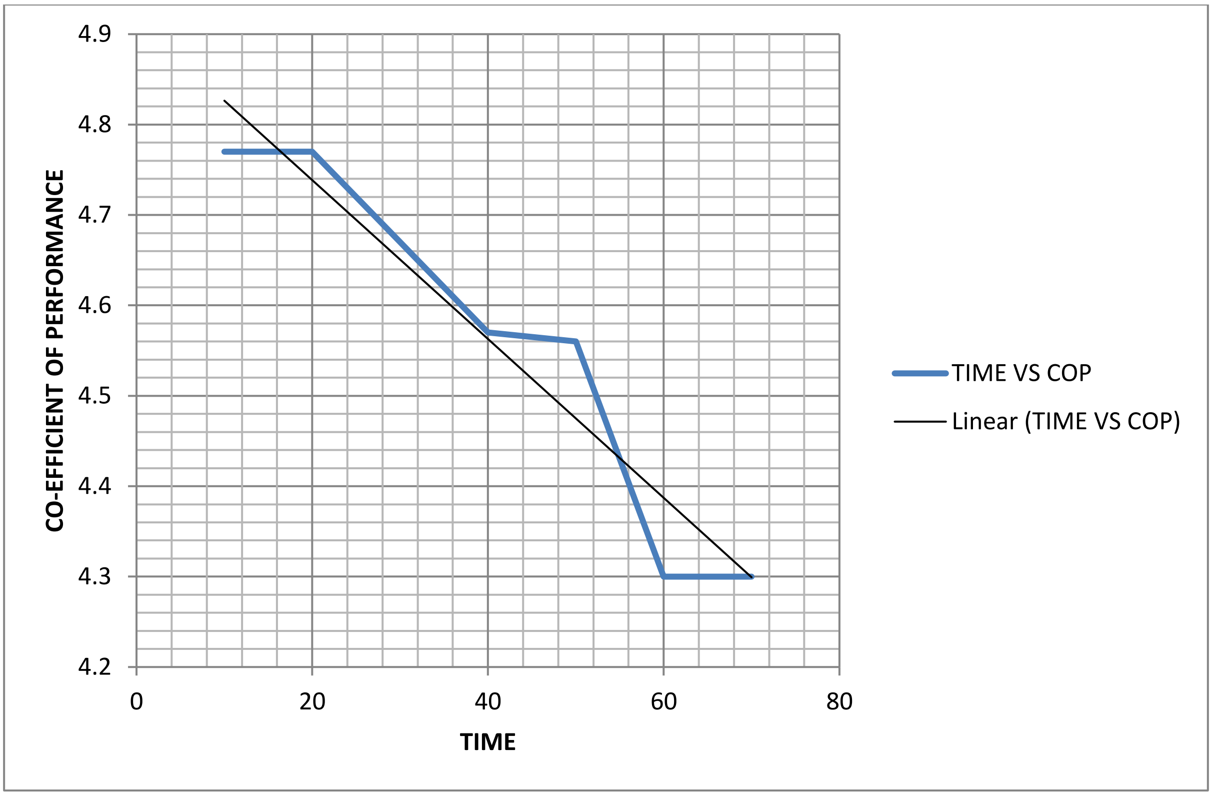
Co-efficient of performance (COP) = refrigeration effect / compressor work

= 215 / 45

= 4.77

Table 3. Co-efficient of Performance for different time period

Time in Mins	**Compressor Inlet Temp (T1) in degrees**	**Compressor Outlet Temp (T2)**	**Condenser Temp (T3)**	**Evaporator Temp (T4)**	**Pressure (P1) in bar**	**Pressure (P2) in bar**	**COP**
10	14.7	72	37.2	-3	3	13	4.77
20	14.7	72.4	37	-3.1	3	13	4.77
30	14.5	73	37	-3.1	3	13	4.67
40	14.6	74.2	36.8	-3.2	3	13	4.57
50	14.7	74.8	36.8	-3.2	3	13	4.56
60	14.6	75.1	36.5	-3.2	3	13	4.3



Graph1 Time vs COP

Graph 1 shows the relationship between time and cop. Readings are taken for every 10 minutes upto more than an hour to understand the co- efficient of performance. There is only a slight variation in cop which shows the effective performance of the system.

Table 3. Readings for the VCRS system without Heat Exchanger set up

Compressor inlet(t_1) in degrees	14
Compressor outlet(t_2)	75
Condenser temperature(t_3)	40
Evaporator temperature(t_4)	2.5
Low pressure (p_1)	3.2 bar
High pressure(p_2)	12.8 bar

From P-H chart of R-134a at pressure (p_1) and temperature (t), the enthalpy is given as

h_1= 610kj/kg

From P-H chart of R-134a at pressure (p_2) and temperature (t_2), the enthalpy is given as

h_2= 665kj/kg

From P-H chart of R-134a at pressure (p_2) and temperature (t_3), the enthalpy is given as

h_3= 460kj/kg

From P-H chart of R-134a at pressure (p_4) and temperature (t_4), the enthalpy is given as

h_4= 410kj/kg

Refrigeration effect = h_1-h_4 = 610 – 410 = 200 kj/kg

Compressor work = h_2-h_1 = 665 – 610 = 55 kj/kg

Co-efficient of performance (COP) = refrigeration effect / compressor work

= 200 / 55

= 3.63

By this we can conclude that by incorporating heat exchanger like set up in vcrs system we can improve the co-efficient of performance of the system.

III. WORKING OF PHASE CHANGE MATERIAL IN EVAPORATOR

As we all know that there is a temperature rise in evaporator when the VCRS system is turned off or may be power loss. To protect the temperature rise for a certain period, this phase change material is used. Here the phase change material used is potassium chloride. Basically the availability of potassium chloride in market is in powdered form (looks like salt). We can't use the powdered potassium chloride directly into the evaporator. So a solution is prepared by mixing it with water in the ratio of 5:1. 1250 ml of water is used to prepare solution for 250 grams of potassium chloride.

Figure 5 Magnetic Stirrer

Figure 5 shows the magnetic stirrer which is also known as magnetic mixer used for preparing a solution (potassium chloride and water). It is a laboratory device that employs a rotating magnetic field to cause a stir bar immersed in liquid to spin very quickly, thus stirring it.

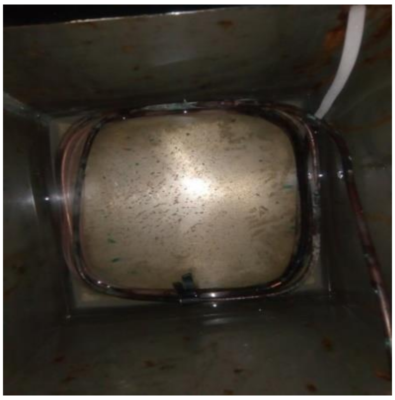


Figure 6 Solution in evaporator

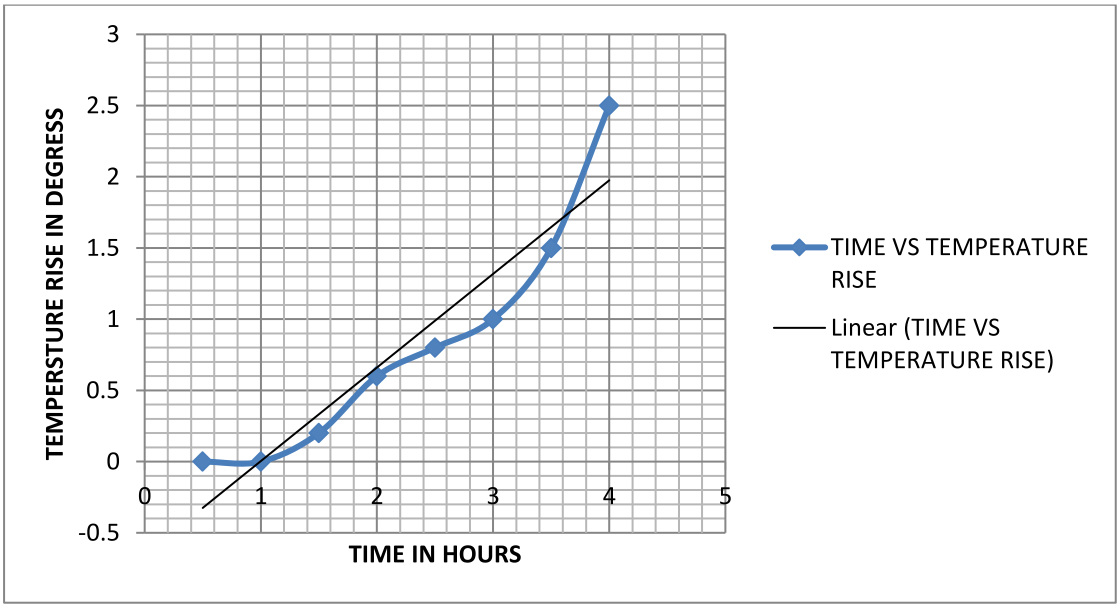
From **figure 6,** once the solution is prepared it is poured into the evaporator. Make sure that the evaporator coils is completely immersed in the PCM for the better results. As the solution is mixed with 5:1 ratio the freezing point of the solution reduces. So anything less than -2 degree evaporator temperature, the solution undergoes partial freezing. The solution freezes and cools because of low evaporator temperature. Once the solution freezes the VCRS system is turned off. When the system is turned off the solution which is already freeze in the evaporator protects the temperature rise in evaporator for a period of 4 to 5 hrs.

Figure 7 Freezing of pcm in evaporator

Table 3. Temperature rise in evaporator when the system is turned off

Time in hrs	Temperature rise in degrees
0.5 hr	0
1 hr	0
1.5 hr	0.2
2 hrs	0.6
2.5 hrs	0.8
3 hrs	1
3.5 hrs	1.5
4 hrs	2.5

If we observe the table 3 readings the temperature rise in first one hour is almost zero that indicates the importance of pcm. After some time period 4 to 5 hrs, the evaporator temperature starts to increase. However these readings were taken under no load conditions. If there is a load in evaporator may be values differ slightly.



Graph2 Time vs Temperature rise

Graph 2 shows the relationship between the time and temperature rise in evaporator. It clearly indicates that there is only 2.5 degrees increase in temperature for 4 hrs which is very much useful for domestic and medical applications.

IV. RESULTS

By incorporating this heat exchanger like set up in refrigeration system the co-efficient performance can be increased more than the systems that have not this set up. Phase change material (kcl) is very effective in protecting the temperature rise in evaporator when there is power loss. For 4 hours there is only 2.5 degree rise in temperature.

V. CONCLUSION

Now we can conclude that by using the heat exchanger of this type improves the co-efficient of performance of the refrigeration system with the effect of sub-cooling. Many projects have done on this work but in this work heat exchanger is designed without adding any external devices. Another advantage added in this work is a phase change material called potassium chloride helps in protecting the temperature rise in the evaporator when there is a power loss or when the system is turned off.

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