Design & Fabrication of Vapour Compression Refrigeration System Test Rig

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Abstract: ***Refrigeration is the process of removing heat from a substance under controlled condition. Process consist of reduction of heat and maintaining the temperature of body below the general temperature of its surrounding. Refrigeration is a device which is used for cooling of food product in domestic and commercial application. For utilization of heating and cooling purpose used of vapour compression refrigeration system (VCRS) is done. The paper focus on determining the value of coefficient of performance (COP) of the refrigerator by using refrigerant. Refrigerant is substance or mixture used for absorbing heat from the environment and provide refrigeration or air conditioning when combine with other components and subsequently reject that heat from the system. They are usually in fluid state. But in most cycle it undergoes phase transition from a liquid to gas and back again. VCRS consist of four stages i.e. (expansion, compression, condensation and evaporation) which helps to carry heat medium for refrigeration. COP has to be calculate for finding good refrigerant in refrigeration system. Refrigerant should have low boiling point, high critical temperature, and high latent heat of vaporization which makes these properties as a good refrigerant. Determination of the value of COP is done on VCRS by using refrigerant in normal temperature and pressure condition.***

Keywords: Refrigerant, COP, VCR System

1. Introduction

The Test-rig consists of a hermetic compressor, an air-cooled condenser, a capillary tube (Thermo-static Expansion Valve) and a water cooled evaporator. In addition to these four major components, the test-rig also consists of several other components such as manual shut-off valves, sight glass, filter, dryer, solenoid valve etc. Pressure gauges are installed to measure the condenser and evaporator pressures. Similarly thermo-couples are provided at the inlet and exit of evaporator, compressor and condenser to facilitate measurement of the refrigerant temperature temperatures at these points using suitable thermometers. The test-rig uses*R134a* as refrigerant. The household refrigerator works on vapour compression refrigeration cycle. The refrigerant vapour is compressed by means of compressor to a pressure at which temperature obtained at the end of compression will be more then atmosphere so that at this high temperature it will reject heat to atmosphere and will get condensed. The condensate is then allowed to pass through a capillary so that the pressure and temperatures and lowered. Capillary device acts as a throttling unit. At low pressure and temperature refrigerant is supplied to the evaporator where load is kept, it absorbs the heat and refrigerant get converted into gaseous phase.

2. Description of Components

2.1 Hermetically Compressor

The hermetically sealed reciprocating compressor is widely used for the refrigeration and air conditioning applications. In all the household refrigerators, deep freezers, window air conditioners, split air conditioners, most of the packaged air conditioners, the hermetically sealed reciprocating compressor is used. The hermetically sealed reciprocating compressor is very easy to handle, and requires low maintenance. Compressor is a mechanical device that increases the pressure of a gas by reducing its volume. Compressors are similar to pumps: both increase the pressure one fluid and both can transport the fluid through a pipe. In the setup, the compressor is designed to isentropically compress the refrigerant.

Figure 2.1: Hermetically Compressor

2.2 Condenser

A refrigerator condenser is one of the main operating components that make up the cooling system on a standard refrigerator. It consists of a series of copper tubes that overlap in a grid or coiling pattern. On most models, the condenser is located at the back of the unit, though some may be installed on the bottom or along one side of the unit. While its size can vary, it often covers at least half of the area of the refrigerator wall, and some even cover the entire wall of the unit.Combined with the evaporator unit within the fridge, the condenser removes heat from inside the refrigerator and transfers it to the outside of the unit. A series of copper tubes or pipes connect the two devices, and liquid refrigerant passes through these tubes to travel from one to the other. As the refrigerant passes through the evaporator, it collects heat energy from within the refrigerator or freezer, leaving the inside of the unit cold enough for food storage. The extra heat energy warms the refrigerant, causing it to transform into a gaseous material. This gaseous refrigerant then travels down to the condenser.As the refrigerant passes into the condenser, a fan blows air onto the copper tubes. This cools the refrigerant inside, and the excess heat energy is exhausted into the room. Once the heat leaves the refrigerant, it transforms back into a liquid, then travels back into the evaporator to repeat this cooling cycle.To maximize the operating life of a refrigerator, owners must perform routine maintenance tasks, which include cleaning the refrigerator condenser coils. By keeping these coils free of dirt and debris, owners will often find that the unit is less likely to break down. A clean unit is also able to operate more efficiently, which may result in lower utility costs.Before attempting to clean the coils, users should unplug the unit or switch off the electrical breaker to reduce the risk of injury. The refrigerator should then be pulled away from the wall to allow access to the unit. Some coils are covered by a plate or panel, which typically slides or snaps off by hand. Once the condenser is exposed, users can clean the coils with a vacuum hose attachment or a stiff brush. It's important to work carefully during this task to avoid bending or damaging the tubes.

Figure 2.2: Condenser

2.3 Evaporator

A refrigerator condenser is one of the main operating components that make up the cooling system on a standard refrigerator. It consists of a series of copper tubes that overlap in a grid or coiling pattern. On most models, the condenser is located at the back of the unit, though some may be installed on the bottom or along one side of the unit. While its size can vary, it often covers at least half of the area of the refrigerator wall, and some even cover the entire wall of the unit.Combined with the evaporator unit within the fridge, the condenser removes heat from inside the refrigerator and transfers it to the outside of the unit. A series of copper tubes or pipes connect the two devices, and liquid refrigerant passes through these tubes to travel from one to the other. As the refrigerant passes through the evaporator, it collects heat energy from within the refrigerator or freezer, leaving the inside of the unit cold enough for food storage. The extra heat energy warms the refrigerant, causing it to transform into a gaseous material. This gaseous refrigerant then travels down to the condenser.As the refrigerant passes into the condenser, a fan blows air onto the copper tubes. This cools the refrigerant inside, and the excess heat energy is exhausted into the room. Once the heat leaves the refrigerant, it transforms back into a liquid, then travels back into the evaporator to repeat this cooling cycle.To maximize the operating life of a refrigerator, owners must perform routine maintenance tasks, which include cleaning the refrigerator condenser coils. By keeping these coils free of dirt and debris, owners will often find that the unit is less likely to break down. A clean unit is also able to operate more efficiently, which may result in lower utility costs.Before attempting to clean the coils, users should unplug the unit or switch off the electrical breaker to reduce the risk of injury. The refrigerator should then be pulled away from the wall to allow access to the unit. Some coils are covered by a plate or panel, which typically slides or snaps off by hand. Once the condenser is exposed, users can clean the coils with a vacuum hose attachment or a stiff brush. It's important to work carefully during this task to avoid bending or damaging the tubes.

Figure 2.3: Evaporator

3. Technical Description of Components

3.1 Compressor

Low pressure, low temperature vapors refrigerant form the evaporator it sucks into the compressor through the suction valve.The low pressure and low temperature vapors refrigerant compress at high pressure and temperature deliver to the condenser by delivery valve.

3.2 Condenser

Condenser consist of coil of pipe in which high pressure and temperature vapors refrigerant from compressor is cool and condense at constant pressure and the mixture of liquid vapors is formed .This mixture is collected into vessel called receiver.

3.3 Copper Tube

Copper tube is most often used for supply of hot and as refrigerant line system copper offers a high level of corrosion resistance. Use to copper tubing for supply of hot and cold water and as refrigerant.
Size: -Copper tube size
Outer diameter of copper tube $(D_o) = 6\ mm$
Inner diameter of copper tube $(D_i) = 5\ mm$
Thickness of copper tube $(t_c) = 1\ mm$

3.4 On-Off Switch

On off switch for compressor condenser fan, temperature meter. The most familiar form of switch is a manually operated electromechanical device with one or more sets of electrical contacts, which are connected to external circuits. Each set of contacts can be in one of two states: either "closed" meaning the contacts are touching and electricity can flow between them, or "open", meaning the contacts are separated and the switch is non-conducting. The mechanism actuating the transition between these two states (open or closed) can be either a "*toggle*" (flip switch for continuous "on" or "off") or "*momentary*" (push-for "on" or push-for "off") type.

3.5 MCB (Miniature Circuit Breakers)

MCB are the electromechanically device which proceed an electrical circuit from and overcurrent and electrical circuit from and overcurrent in an electrical circuit may result from short circuit overload faculty design .An MCB meter temperature to as fuse since. It does not require replacement and overload is detected. MCB can be easily reset and thus offers impressed operational safety and grater convene without refrigeration operating case.

3.6 Temperature Meter

It is measuring the refrigeration temperature frees temperature for the high and low.Measure the temperature of evaporator and inlet of condenser and outlet of the condenser. Its measure the temperature of ice box.T_1And measure the temperature of inlet of condenser $T_2$and measure the temperature of outlet of condenser.

3.7 Pressure Gauge Meter High And Low

A pressure gauge is a mechanical instrument designed to measure the internal pressure and/or vacuum of a vessel or system. Trerice Pressure Gauges are offered in a variety of styles, sizes, and wetted part materials to meet the demands of standard and special applications.

3.7.1 Low pressure gauge: Low pressure gauge is mechanical device which used measure the pressure of before of compressor.

3.7.2 High pressure gauge: Low pressure is mechanical device which used measure the pressure of after of compressor.

3.8 Electric Meter

It is the device that measure the amount of electric energy consumed by a residence a business or an electrically power device. Pulses of energy meter of compressor.An electricity meter, electric meter, electrical meter, or energy meter is a device that measures the amount of electricenergy consumed by a residence, a business, or an electrically powered device Electricutilities use electric meters installed at customers' premises to measure electric energy delivered to their customers for billing purposes. They are typically calibrated in billing units, the most common one being the kilowatthour [kWh]. They are usually read once each billing period.

4. Working Principle of VCC

Refrigerant flows through the compressor, which raises the pressure of the refrigerant. Next the refrigerant flows through the condenser, where it condenses from vapor form to liquid form, giving off heat in the process. The heat given off is what makes the condenser "hot to the touch." After the condenser, the refrigerant goes through the expansion valve, where it experiences a pressure drop. Finally, the refrigerant goes to the evaporator. The refrigerant draws heat from the evaporator which causes the refrigerant to vaporize. The evaporator draws heat from the region that is to be cooled. The vaporized refrigerant goes back to the compressor to restart the cycle.

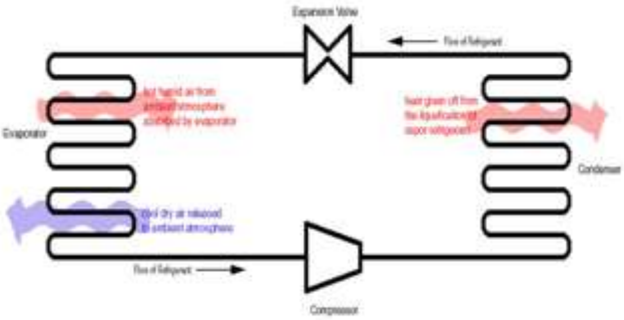

Figure 4: Working Principle of VCC

5. Working

The schematic diagram of the arrangement is as shown in Fig. The lowtemperature, low pressure vapor at state B is compressed by a compressor to high temperature and pressure vapor at state C. This vapor is condensed into high pressure. Vapor at state D in the condenser and then passes through the expansion valve. Here,the vapor is throttled down to a low pressure liquid and passed on to an evaporator,where it absorbs heat from the surroundings from the circulating fluid (being refrigerated) and vaporizes into low pressure vapor at state B. The cycle then repeats.

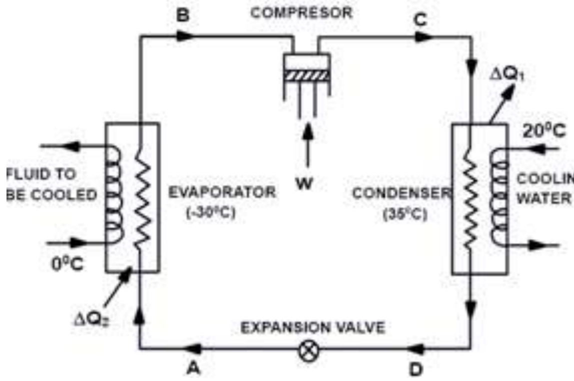

Figure 5.1: Working

Figure 5.2: Working diagram ofRefrigeration Test Rig

6. P-h Diagram

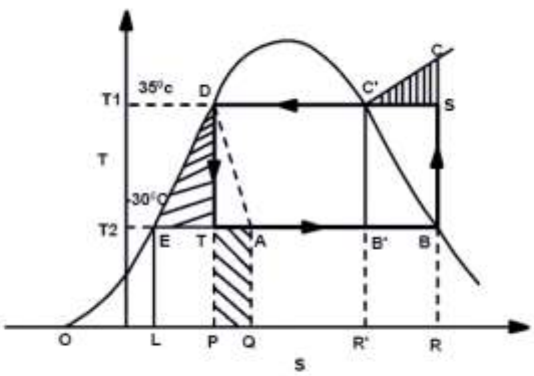

Figure 6: P-h Diagram

7. T-S Diagram

In vapor compression cycle, de-superheating between C and C' is at constant Pressure rather than constant temperature. Therefore, more work has to besupplied to the compressor. There is an equivalent amount of increase in theMagnitude of heat rejected.In vapor compression cycle, no work is done by the system during the throttlingProcess. Hence, the network supplied to the cycle increases further by area EDT. As compared to the reversed Carnot cycle. Because,{(Area RSDO – Area RBEO) – Area EDT} = Area

BSDT, in vapor compression cycle, there is a loss of refrigeration effect equivalent toArea PQAT due to increase in entropy during the irreversible throttling expansion.The effect of all these deviations is to increase the compression work required or to decrease the refrigeration effect and therefore the COP of the vaporCompression cycle will be less than that of reversed Carnot cycle.

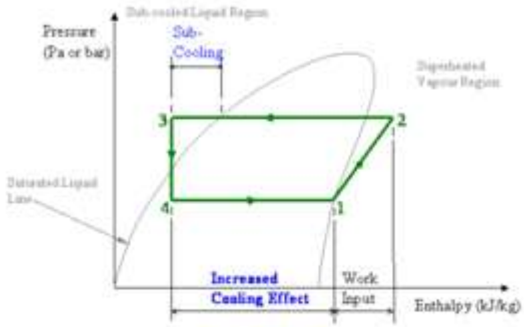

Figure 7: T-S Diagram

8. Advantages

- Very mature technology.
- Relatively inexpensive.
- Can be driven directly using mechanical energy
- (Water, car/truck motor) or with electrical energy.
- Efficient up to 60% of Carnot's theoretical limit

9. Disadvantages

- The initial cost is higher.
- The leakage of refrigerant is difficult to avoid.

10. Application

- **Domestic refrigeration**: - Appliances used for keeping food in dwelling units.
- **Commercial refrigeration**: -Holding and displaying frozen and fresh food in retail outlets.5
- **Industrial refrigeration**:- Large equipment, typically 25 kW to 30 MW, used for chemical processing, cold storage, food processing, building and district heating and cooling.
- **Transport refrigeration**:-Equipment to preserve and store goods, primarilyfoodstuffs, during transport by road, rail, air and sea.

11. COP of Vapor Compression Cycle

COP $=\frac{\text{Heat extracted at low tempreature}}{\text{Wrok Supplied}}$ Heat extracted at low temperature = Heat transfer during the process A-B =refrigerating effect.

$$q_{2=(h_B - h_A)}$$

Work of compression = w = $(h_C - h_B)$(adiabatic compression).

So, COP = $\left\{\frac{(h_B - h_A)}{(h_C - h_B)}\right\}$

Now, heat rejected to the condenser,

$= q_{1=W+q_2}$

$=(h_C - h_B)+(h_B - h_A)$

$=(h_C - h_A)=(h_C - h_D)$

12. Observations Table

Sr. no.	Description	Symbol	Reading
1.	Evaporator pressure	P_e	4.8 bar
2.	Condenser pressure	P_c	8.8 bar
3.	Evaporator Inlet Temperature	t_{ei}	18.8^0 C
4.	Evaporator outlet Temperature	t_{eo}	19.8°C
5.	Condenser Inlet Temperature	t_{ci}	41.8°C
6.	Condenser outlet Temperature	t_{co}	88.8°C
7.	Temperature of water	t_w	18°C
8.	Time for 10 revolutions or pulses of energy meter of compressor	T_c	7^0 C
9.	Time For 10 of Energy Water.	T_n	6^0 C

13. Calculations

Carnot COP

Carnot Cycle Cop = $\frac{T_2}{T_1 - T_2}$

Carnot Cycle Cop = $\frac{276}{376.5-276}$

Carnot Cycle Cop = 2.74

Theoretical COP

= (Theoretical Refrigerating Effect) / (Theoretical Compressor Work)

$=(h_{ei} - h_{eo})/(h_{ci} - h_{eo}) = \frac{h_4 - h_1}{h_2 - h_2}$

$Therortecal\ COP = \left(\frac{498.77-406}{556.7-498.7}\right) = 1.60$

$Therortecal\ COP = 1.60$

Actual COP

Actual COP

= (Actual Refrigerating Effect) = Heat Produced by Water

R.E$_{act}$ $= \frac{\mathbf{10}}{\boldsymbol{N_h}} \times \frac{\mathbf{3600}}{\boldsymbol{T_h}}$

R.E$_{act}$$=\frac{10}{6900} \times \frac{3600}{5}$

R.E$_{act}$= 0.803

Actual COP $=\frac{R.E_{act}}{W}$

Actual COP = $\frac{0.803}{1.4}$

Actual COP = 0.5735

14. Result

- Carnot COP = 2.74
- Theoretical COP = 1.60
- Actual COP = 0.5735

15. Conclusion

Performance evaluation of vapour compression refrigeration system (VCRS) by using R134a refrigerant was studied, based on the experimental setup, the effect of different working parameters. R134a is one of the important refrigerants used in refrigeration system. The result obtained showed that as discharge temperature and energy increase while the coefficient of performance COP should be increase, highest COP of system is Carnot COP and actual COP is less than theoretical COP can be obtain.

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