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# Performance Test On Refrigerator By Using Inorganic Refrigerants

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**ABSTRACT**

A vapour compression refrigeration system in which a suitable working substance termed as refrigerant is used .It condences and evaporates at temperature and pressure closed to atmospheric condition the refrigerant used for the purpose are ammonia, carbon dioxide and sulphur dioxide. Refrigerator consist five major parts-compressor, condenser, receiver, expansion valve, evaporator. The refrigerant used , does not leave the system but it circulated through the system alternately condensing and evaporating. In evaporation the refrigerant absorbs its latent heat from the brine(salt water) which is used for circulating it around the cold chamber , while condensing it give out its latent heat to the circulating water of the cooler. The vapour compression refrigeration system is a latent heat pump as it pump its latent heat from brine deliver to cooler. The vapour compression refrigeration system is now adays used for all purpose refrigeration. It is generally used for all industries purpose from a domestic refrigerator to abig air conditioning plant.

In our project work, we have calculated the values of C.O.P of in organic refrigerants, those are carbon dioxide, sulphur dioxide and ammonia. After that we compare the values of C.O.P.



Vapour compression refrigeration systems are the most commonly used among all refrigeration systems. As the name implies, these systems belong to the general class of vapour cycles, wherein the working fluid (refrigerant) undergoes phase change at least during one process. In a vapour compression refrigeration system, refrigeration is obtained as the refrigerant evaporates at low temperatures. The input 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. Vapour compression refrigerationsystems 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 vapour 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 vapour compression cycles.

This limit is set by a completely reversible cycle.

The use of CFCs is now beginning to be phased out due to their damaging impact on the protective tropospheric ozone layer around the earth. The Montreal Protocol of 1987 and the subsequent Copenhagen agreement of 1992 mandate a reduction in the production of ozone depleting Chlorinated Fluorocarbon (CFC) refrigerants in a phased manner, with an eventual stop to all production by the year 1996. In response, the refrigeration industry has developed two alternative refrigerants; one based on Hydro-chloro Fluorocarbon (HCFC), and another based on Hydro Fluorocarbon (HFC). The HCFCs have a 2 to 10% ozone depleting potential as compared to CFCs and also, they have an atmospheric lifetime between 2 to 25years as compared to 100 or more years for CFCs (Brandt, 1992).

Synthetic refrigerants that were commonly used for refrigeration, cold storage and air conditioning applications are: R 717 ($NH_3$), R 744 ($CO_2$), R 764 ($SO_2$), etc. However, these refrigerants have to be phased out due to their Ozone Depletion Potential (ODP). The synthetic replacements for the older refrigerants are: R-134a (HFC-134a) and blends of HFCs. Generally, synthetic refrigerants are non-toxic and non-flammable. However, compared to the natural refrigerants the synthetic refrigerants offer lower performance and they also have higher Global Warming Potential (GWP). As a result, the synthetic refrigerants face an uncertain future. The most commonly used natural refrigerant is ammonia. This is also one of the oldest known refrigerants. Ammonia has good thermodynamic, thermo-physical and environmental properties. However, it is toxic and is not compatible with some of the common materials of construction such as copper, which somewhat restricts its application. Other natural refrigerants that are being suggested are hydrocarbons (HCs) and carbon di-oxide (R-744). Though these refrigerants have some specific problems owing to their eco-friendliness, they are being studied widely and are likely to play a prominent role in future.

Prior to the environmental issues of ozone layer depletion and global warming, the most widely used refrigerants were: R 11, R 12, and R 22. Of these, R 11 was primarily used with centrifugal compressors in air conditioning applications. R 12 was used primarily in small capacity refrigeration and cold storage applications, while the other refrigerants were used in large systems such as large air conditioning plants or cold storages. Among the refrigerants used, except ammonia, all the other refrigerants are synthetic refrigerants and are non-toxic and non-flammable. Though ammonia is toxic, it has been very widely used due to its excellent thermodynamic and thermo-physical properties. The scenario changed completely after the discovery of ozone layer depletion in 1974. Since ozone layer depletion could lead to catastrophe on a global level, it has been agreed by the global community to phase out the ozone depleting substances (ODS). As a result except ammonia, all the other refrigerants used in cold storages had to be phased-out and a search for suitable replacements began in earnest.

**Tabulation For Refrigerant $SO_2$**

| Temp.of water | | Energ-y reading meter | Temperature($^oc$) | | | | Pressure gauge | | C.O.P therotical | C.O.P actual | Comp. work | Actual Cooling effect |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $T_1$ | $T_2$ | watt | $T_1$ | $T_2$ | $T_3$ | $T_4$ | psi | | | | KJ/Kg | KJ/Kg |
| 30 | 20 | 200 | 14.4 | 14.4 | -15 | -15 | 55 | 12.1 | 4.57 | 2.91 | 72 | 210 |
| | | 200 | 13.5 | 13.5 | -10 | -10 | 70 | 25 | 3.91 | 2.91 | 72 | 210 |
| | | 200 | 10 | 10 | -5 | -4 | 80 | 34 | 4.20 | 2.91 | 72 | 210 |
| | | 200 | 5 | 4 | -2 | -2 | 98 | 38 | 4.45 | 2.91 | 72 | 210 |

Calculation for refrigerant $SO_2$

1. Absolute pressure ($P_1$) =Pressure gauge × 0.07+1.013

   = (55× 0.07 + 1.013 )

   = 4.863 bar

2. Absolute pressure ($P_3$) = (Pressure gauge × 0.07+1.013 )

   =( 12.1× 0.07 + 1.013 )

   =1.86 bar

3. At Temperature

   $T_1 = T_2$ = 14.45 $^oC$

   $T_3 = T_4$ = - 15 $^oC$

   From refrigeration chart

   $h_1$ = 203.67 KJ/kg , $h_2 = h_{f2}$ =43.82 KJ/ kg

   $h_4$ = 175 KJ/ kg

   Theoretical C.O.P = $h_4 – h_{f2} / h_1 - h_4$

   = (175 – 43.82) / (203.67 – 175)

   = 4.57

4. Actual cooling effect = $mc_p$ ( $T_1$ – $T_2$ )

   =5 × 4.2 (30 -20)

   = 210 KJ/Kg

5. Actual compressor work = 3600 × 0.02

   = 72 KJ/kg

6. Actual C.O.P = ( Actual cooling effect / actual compressor work )

= ( 210/72 )

= 2.91

**Tabulation For Refrigerant $CO_2$**

| Temp.of water | | Energy reading meter | Temperature(°c) | | | | Pressure gauge | | C.O.P therotic al | C.O.P actual | Comp. work | Actual Cooling effectr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $T_1$ | $T_2$ | watt | $T_1$ | $T_2$ | $T_3$ | $T_4$ | psi | | | | KJ/Kg | KJ/Kg |
| 30 | 20 | 200 | 25 | 25 | -5 | -5 | 61 | 15.5 | 3.57 | 1.94 | 108 | 210 |
| | | 200 | 20 | 21 | -4 | -3 | 70 | 20 | 2.91 | 1.94 | 108 | 210 |
| | | 200 | 15 | 16 | -1 | -2 | 80 | 35 | 3.06 | 1.94 | 108 | 210 |
| | | 200 | 10 | 11 | 0 | 0 | 115 | 70 | 3.58 | 1.94 | 108 | 210 |

Calculation for refrigerant $CO_2$

1. Absolute pressure ($P_1$) =Pressure gauge × 0.07+1.013

   = (61× 0.07 + 1.013 )

   = 5.29 bar

2. Absolute pressure ($P_3$) = (Pressure gauge × 0.07+1.013 )

   =( 15.5× 0.07 + 1.013 )

   =2.09bar

3. At Temperature

   $T_1 = T_2 = 25$ °C

   $T_3 = T_4 = -5$ °C

   From refrigeration chart

   $h_1$ = 237.83 KJ/kg , $h_2 = h_{f2}$ =164.77 KJ/ kg

   $h_4$ = 221.83 KJ/ kg

Theoretical C.O.P = $h_4 - h_{f2} / h_1 - h_4$

= (221.83 – 164.77) / (237.83 – 221.83)

= 3.57

4. Actual cooling effect = $mc_p$ ( $T_1 - T_2$ )

   =5 × 4.2 (30 -20)

   = 210 KJ/Kg

5. Actual compressor work = 3600 × 0.03

   = 108 KJ/kg

6. Actual C.O.P = ( Actual cooling effect / actual compressor work )

= ( 210/108 ) = 1.94

**Tabulation For Refrigerant $NH_3$**

| Temp.of water | | Energy reading meter | Temperature(°c) | | | | Pressure gauge | | C.O.P Thero-tical | C.O.P actual | Comp. work | Actual Cooling effectr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $T_1$ | $T_2$ | watt | $T_1$ | $T_2$ | $T_3$ | $T_4$ | psi | | | | KJ/Kg | KJ/Kg |
| 25 | 20 | 200 | 30 | 30 | -5 | -5 | 65 | 20 | 1.68 | 1.45 | 72 | 105 |
| | | 200 | 25 | 24 | -3 | -3 | 70 | 25 | 1.62 | 1.45 | 72 | 105 |
| | | 200 | 20 | 19 | -2 | -2 | 80 | 35 | 1.65 | 1.45 | 72 | 105 |
| | | 200 | 15 | 15 | 0 | 0 | 90 | 40 | 1.57 | 1.45 | 72 | 105 |



Calculation for refrigerant $NH_3$

1. Absolute pressure ($P_1$) =Pressure gauge × 0.07+1.013

   = (65× 0.07 + 1.013 )

   = 5.563 bar

2. Absolute pressure ($P_3$) = (Pressure gauge × 0.07+1.013 )

   =( 20× 0.07 + 1.013 )

   =2.413bar

3. At Temperature

   $T_1 = T_2 = 30$ °C

   $T_3 = T_4 = - 5$ °C

   From refrigeration chart

$h_1$ = 270.56 KJ/kg , $h_2 = h_{f2}$ =170.76 KJ/ kg

$h_4$ = 230.87 KJ/ kg

Theoretical C.O.P = $h_4 – h_{f2} / h_1 - h_4$

= (230.87 – 170.76) / (270.56 – 230.87)

= 1.68

4 Actual cooling effect = $mc_p$ ( $T_1$ – $T_2$ )

=5 × 4.2 (25 -20)

= 105 KJ/Kg

5 . Actual compressor work = 3600 × 0.02

= 72 KJ/kg

6 .Actual C.O.P = ( Actual cooling effect / actual compressor work )

= ( 105/72 )

= 1.45

**CONCLUSION**

1. For refrigerant $SO_2$ (R-764)

   Theoretical C.O.P = 4.57

   Actual C.O.P =2.91
2. For refrigerant $CO_2$ (R-744)

   Theoretical C.O.P = 3.57

   Actual C.O.P =1.94
3. For refrigerant $NH_3$ (R-717)

   Theoretical C.O.P = 1.68

   Actual C.O.P =1.45

As for testing of C.O.P we realised that the C.O.P of $NH_3$ are much lower than another two inorganic refrigerant. So, that's wise $NH_3$ has more cooling efficiency . Hence it is most common and widely used in large and commercial reciprocating compression system where toxicity is secondary.

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