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Experimental study of eco-friendly refrigerants in vapour compression system with different diameters capillary

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ABSTRACT

In this paper, an experimental study was conducted on the performance of capillary tube for different eco-friendly refrigerants R290 and R404A. The coefficient of performance of both refrigerants for different diameters of capillary tubes (1.25mm, 1.50mm, 1.75mm, and 2mm) has to be compared. Bare tube coil evaporator, Hermetic sealed compressor, and Air cooled condenser, capillary tubes are the devices used in the vapour compression refrigeration system. The work shows that the coefficient of performance of different capillary tubes of diameter 1.25mm, 1.50mm, 1.75mm. 2mm in equal time intervals are drawn. The actual results showed that the C.O.P for refrigerant R290 is high in 1.50mm than other capillary tube diameters in equal intervals of time in the vapour compression refrigeration system.

Keywords: C.O.P-coefficient of performance, q-Refrigeration effect, w-compressor work done, m-mass of the refrigerant, specific heat capacity, T-Temperature, t-Time, Ec-Energy meter constant, n-number of revolutions, P-pressure, h-enthalpy.

1. INTRODUCTION

Vapour Compression Refrigeration System: Vapour Compression Refrigeration system is used for domestic refrigeration, food processing, and cold storage. Vapour Compression Refrigeration cycle is approximately a Rankine cycle run in reverse. A working fluid (refrigerant) is pushed through the system and undergoes state changes (from liquid to gas and back). The latent heat of vaporization of any refrigerant is used to transfer large amounts of heat energy, and changes in pressure are used to control when the refrigerant expels or absorbs heat energy.

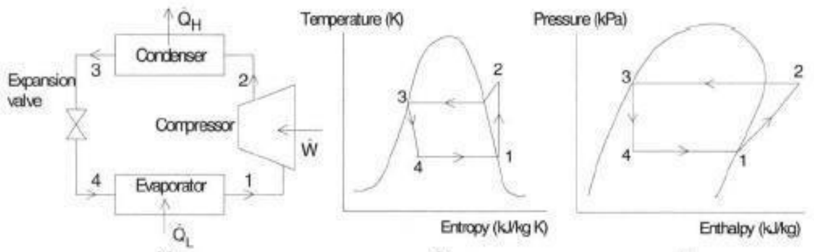

Figure.1. Processes Involved In VCRS

Processes Involved In VCRS:
Process 1-2: Isentropic Compression in Compressor
Process 2-3: Constant Pressure Heat Rejection in Condenser
Process 3-4: Isenthalpic Expansion in expansion Device
Process 4-1: Constant Pressure Heat Absorption in Evaporator

Refrigerants: The refrigerant is a heat carrying medium during the refrigeration cycle. Desired properties of ideal refrigerants are Low boiling and freezing point, a High latent heat of vaporization, Nonflammable, Nonexplosive and Nontoxic, Low cost, High COP, Ozone friendly and high thermal conductivity. Refrigerants are of the primary or secondary kind. Primary refrigerants are of halocarbon, a zeotropic, zeotropic, inorganic, hydrocarbon refrigerants. Secondary refrigerants are of brines used in chemical plants, dairies, food processing units, ice plants, meat packing, etc.

Physical properties of refrigerants are corrosive property, stability, viscosity, thermal conductivity. Chemical properties of refrigerants are flammable, toxic, solubility, miscibility. Thermodynamic properties of refrigerants are boiling and freezing temperature, COP, power requirement, latent heat of vaporization. Environmental and safety properties of refrigerants are ozone depleting potential, global warming potential, total equivalent warming index.

2. EXPERIMENTAL SETUP AND PROCEDURE

The experimental setup used for the study is as shown in the figure below. Domestic Refrigerator is selected, working on vapour compression refrigeration system. Pressure and temperature gauges were installed at each entry and exit components. The vapour at low temperature and pressure enter the compressor where it is compressed isentropically and subsequently its temperature and pressure increase considerably. The vapour after leaving the compressor enters the condenser where it is condensed into high-pressure Liquid and from condenser it passes through the expansion valve here it is throttled down to a lower pressure and a lower temperature. Through expansion valve, it finally passes onto evaporator where it extracts heat from the surrounding to be cooled.

The setup consists of the following components.

Compressors: The working fluid is isentropically compressed to a superheated state and then moved to the condenser. Hermetic sealed type compressor used in the setup. In hermetic compressors, the motor and the compressor are enclosed in the same housing to prevent refrigerant leakage. The housing has welded connections for refrigerant inlet and outlet and power input socket. As a result of this, there is virtually no possibility of refrigerant leakage from the compressor. The COP of the hermetic compressor based systems is lower than that of the open compressor based systems since a part of the refrigeration effect is lost in cooling the motor and the compressor.

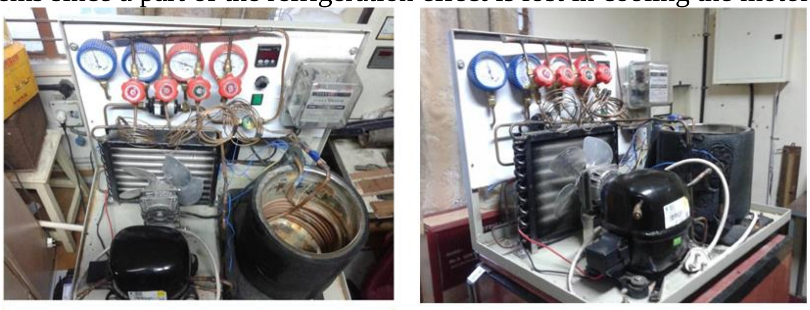

Figure.2.Compressors

Condenser: Condenser function is to remove the heat of hot vapor refrigerant discharged from the compressor. The heat has removed by condenser tubes and condenser cooling medium. Factors affecting the condensing capacity are material, amount of contact, temperature difference. Air cooled condenser had used in the refrigeration system. Forced convection type condensers use the fan or a blower for the circulation of air over the condenser surface to maintain temperature. These condensers have fins on the surface of condenser tube for good heat transfer.

Evaporator: The evaporator is used to absorb heat from the surrounding location or medium which is to be cooled using refrigerant. The refrigerant boils or evaporates and in doing so absorbs heat from the substance being refrigerated. It is used as a low-pressure side device. The evaporator is used to change the liquid phase of the refrigerant to the vapour phase. The temperature of the boiling refrigerant should be low in evaporator than surroundings then heat flows to the refrigerant .factors affecting the heat transfer capacity are material, temperature difference, the velocity of refrigerant, thickness of evaporator coil wall, little contact surface area.

Expansion Device: The expansion device is known as metering device or throttling device. It reduces the high-pressure liquid refrigerant to low pressure liquid refrigerant before being fed to evaporator.it maintains the pressure difference between the low and high-pressure sides of the system. The flow of refrigerant has controlled according to the load on the evaporator. Capillary tube has used in the refrigeration system. Inside diameter of the tube varies about 0.5mm to 2.25 mm and the length varies from 0.5m to 5m. Some Other measuring and controlling instruments have used in the system, that were an electrical switch, thermometer, energy meter, pressure gauges, etc..

Procedure: Fill the refrigeration system with R404A refrigerant. Fill the evaporator with Fresh Water (4.5 liters). Check the pressure gauge and temperature measuring devices for getting the correct values during the experiment. Switch on the power supply and the compressor to start the experiment. Note down the temperature of water initially. Now note the temperature was reading for every 10 min up to 40 min. Note down the pressure gauge readings and temperature readings for every 10 min of the reading. Now values are tabulated, and calculations have made, and finally COP is found for R404A. Similarly, follow the same procedure for R290 and calculations are made, and COP has identified. With the help of pressure gauge readings, p-h graphs are drawn

Method of Calculation:

1. T1, P1 –before compression
2. T2, P2 – after compression
3. T3, P3– before expansion valve
4. T4, P4 – after expansion valve

T1, T2, T3, T4 are temperatures in Celsius. P1, P2, P3, P4 are pressures in psi.

Actual COP = q/w

q = actual refrigeration effect

w = compressor work done Actual

Refrigeration Effect: q= m.cp.T/t kJ/s (OR) kW

where, m=mass in kg.

Cp-constant value -4.187 KJ /kg k

T- T initial – T final –temperature of water in degrees. T-Time in seconds.

Actual compressor work done: w= 1* n * 3600 kJ/s   Ec * t

Where: n- n revolutions.

t- Time for n revolutions in a second
Ec- energy meter constant -750 rev/kWh
Theoretical cop of the refrigeration system: Theoretical cop = (h1-h4)/(h1-h2)
where: h1 - h4 = refrigeration effect .
h1 - h2 = compressor work done.

Thus, the theoretical cop is calculated from the pressure enthalpy chart of the refrigerants used in the refrigeration system.

3. RESULTS

The experiments have been conducted, and the coefficient of performance of various refrigerants for various capillary tube diameter are calculated. The key observations have been represented in the form of graphs comparison of Coefficient of Performance of Refrigerants R290 and R404A in capillary tube diameter of 1.25mm in the vapour compression refrigeration system. The graph of C.O.P versus time for refrigerants R290 and R404A of 1.25mm capillary tube diameter is shown in the figure 3.

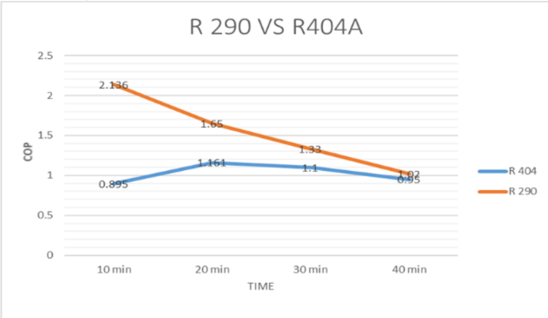

Figure.3.C.O.P vs Time for refrigerants R290 and R404A of 1.25mm capillary Tube diameter

From the above graph, the performance of refrigerant R290 is more than R404A in equal time intervals of 1.25 mm capillary tube in the vapour compression refrigeration system. Comparison of Coefficient of Performance of Refrigerants R290 and R404A in capillary tube diameter of 1.50mm in the vapour compression refrigeration system. The graph of C.O.P versus time for refrigerants R290 and R404A of 1.50mm capillary tube diameter is shown in figure 4.

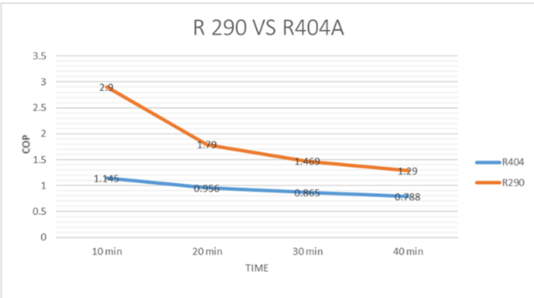

Figure.4.C.O.P vs Time for refrigerants R290 and R404A of 1.50mm capillary Tube diameter

From the above graph, the performance of refrigerant R290 is more than R404A in equal time intervals of 1.50 mm capillary tube in the vapour compression refrigeration system. Comparison of Coefficient of Performance of Refrigerants R290 and R404A in capillary tube diameter of 1.75mm in the vapour compression refrigeration system. The graph of C.O.P versus time for refrigerants R290 and R404A of 1.75mm capillary tube diameter is shown in figure 5.

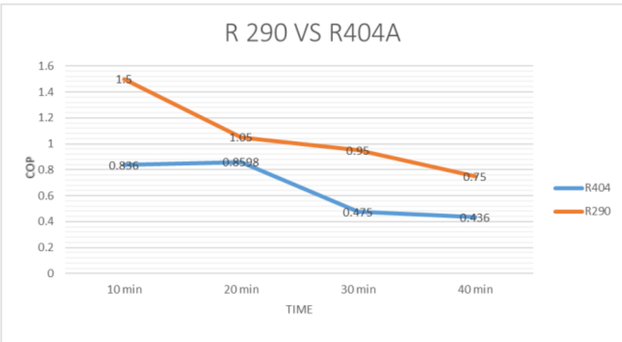

Figure.5.C.O.P vs Time for refrigerants R290 and R404A of 2mm capillary Tube diameter

From the above graph, the performance of refrigerant R290 is more than R404A in equal time intervals of 2.00 mm capillary tube in the vapour compression refrigeration system.

4. CONCLUSION

Comparison of Coefficient of Performance of Refrigerant R290 in capillary tube diameter of 1.25mm, 1.5mm, 1.5mm, 2mm in equal intervals of time intervals in the vapour compression refrigeration system.

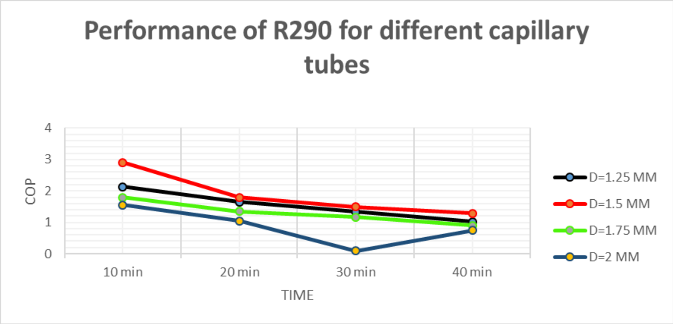

Figure.6.C.O.P vs. TIME graph for different diameters of capillary tube for refrigerant R290 in the refrigeration system

From the above graph, the coefficient of performance of different capillary tubes of diameter 1.25mm, 1.50mm, 1.75mm. 2mm in equal time intervals are drawn. The COP for refrigerant R290 is high in 1.50mm than other capillary tube diameters in equal intervals of time in the vapour compression refrigeration system.

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