International Journal of Advance Research in Science and Engineering
Volume No.07, Special Issue No.05, March 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

Performance Evaluation of Heat Pump Test Rig

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ABSTRACT

A heat pump is a device that transfers heat energy from a source of heat to a destination called a "heat sink".The heat energy rejected from the condenser coil is used to heat the water or space. From the calculations obtained, we can compare the theoretical COP and actual COP. Also we can plot the tempertaure vs entropy and pressure vs enthalpy graph. Paper describes about the calculation of the heat pumps that are used for purposes of heating.

Keyword: heat sink, COP, entropy, enthalpy.

I. INTRODUCTION

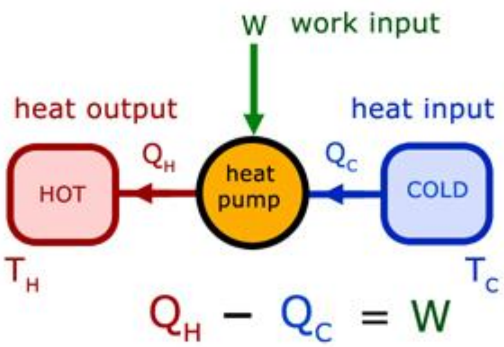

Fig. 1 Block Diagram of Heat Pump

A mechanical heat pump basically uses a volatile condensing and evaporative fluid known as 'refrigerant'. In the first stage, it compresses the fluid making it hotter and highly pressurized before sending it to condenser. The condenser rejects the heat which can be stored to heat the space or water. Later it passes through an expansion valveand then to the evaporator where it gains the heat or absorbs the heat from the space or surrounding providing a refrigerating effect. [5]

Many have debated over the usage of the refrigerants causing hazard to the environment. R134a is an ideal refrigerant 'as it has low GWP and low ODP. Also, use of hermetically sealed compressor has avoided the mixing of oil with the refrigerant[2].According to simulation research, Chenet al. proposed that R134a was superior to R22 with respect to the system performance. R134a refrigerant, which is widely used in current automobile air conditioning systems, is one of the controlled substances in the Kyoto protocol (1997). [3]

The COP of the heat pump is given by the ratio of heating effect to its compressor work. The output energy is 4 times the average input energy.When working medium reaches its temperature upto13 ºC it goes to compressor and there its pressure and temperature rises from 2.71 bar to 7.77 bar and 13 ºC to 58 ºC[4]

Because the energy consumed will always generate an amount of heat, calculating the COP for heating and cooling is different, i.e., when calculating the COP for heating efficiency, the heat given out from the energy consumedis added to the change in heat, whereas cooling efficiency is calculated by this principle, the heat generated fromthe energy consumed is not included.[5]

II.LITERATURE REVIEW

J. Perko, V. Dugec, D. Topic, D. Sljivac, Z.Kovac (2011) in their paper “Calculation and design of heat pump” have dealt with the calculation of the theoretical COP of the heat pump. The authors have plotted the temperatures with respect to their pressure on a T-S chart. The refrigerant used is Freon-12. Hence, by plotting the values the theoretical COP comes round about 3.43.

Prof. Jignesh K. Vaghela (2016) in his paper “Comparative evaluation of an automobile air - conditioning system using R134a and its alternative refrigerants” has stated the advantages of R134a refrigerant over the conventional CFC refrigerant. He has also discussed the various drawbacks of other CFC refrigerant. Also he found out that the COP of R134a refrigerant is 6.3% more than that of R12, R1234yf and R290.

Opeyemi Bamigbetan, Trygve M. Eikevik, Petter Nekså, Michael Bantle in their paper “Review of Vapour Compression Heat Pumps for High Temperature Heating using Natural Working Fluids” have reviewed the heat pumps working at higher temperature than the conventional heat pump. The working temperature for these types of heat pump is 80-85^{o}C. They have also discussed the need of using the natural fluids as refrigerant so as to reduce the harmful emissions of the synthetic refrigerants.

III. METHODOLOGY

Fig.2. Experimental Setup of Heat Pump

3.1. Components& Specifications.

3.1.1 Hermetically Sealed Compressor:

Capacity: ¼ Ton, 230 V AC.

Evaporating Temperature: 0^0c

Condenser Temperature : 58^0c

Suction Pressure: 2.04 bar

Discharge Pressure: 7.77 bar

3.1.2 Tube Type Condensers:

Normal dia.of condenser pipe is 3.6 mm

Thickness of the pipe = 0.3 mm

3.1.3 Tube Type Evaporator:

Material: Copper

No.of coils: 8

Minimum temperature: 0-10°C

3.1.4 Capillary Tube:

Inner diameter = 4 mmOuter diameter=7 mm

Material = Copper

3.1.5 R-134a Refrigerant:

Boiling Point	-14.9°F or -26.1°C
Freezing Point	-103.3°C
Ozone Depletion Level	0
Solubility In Water	Medium Soluble

IV CALCULATIONS

4.1 Theoretical COP

From P-h chart of R-134a,

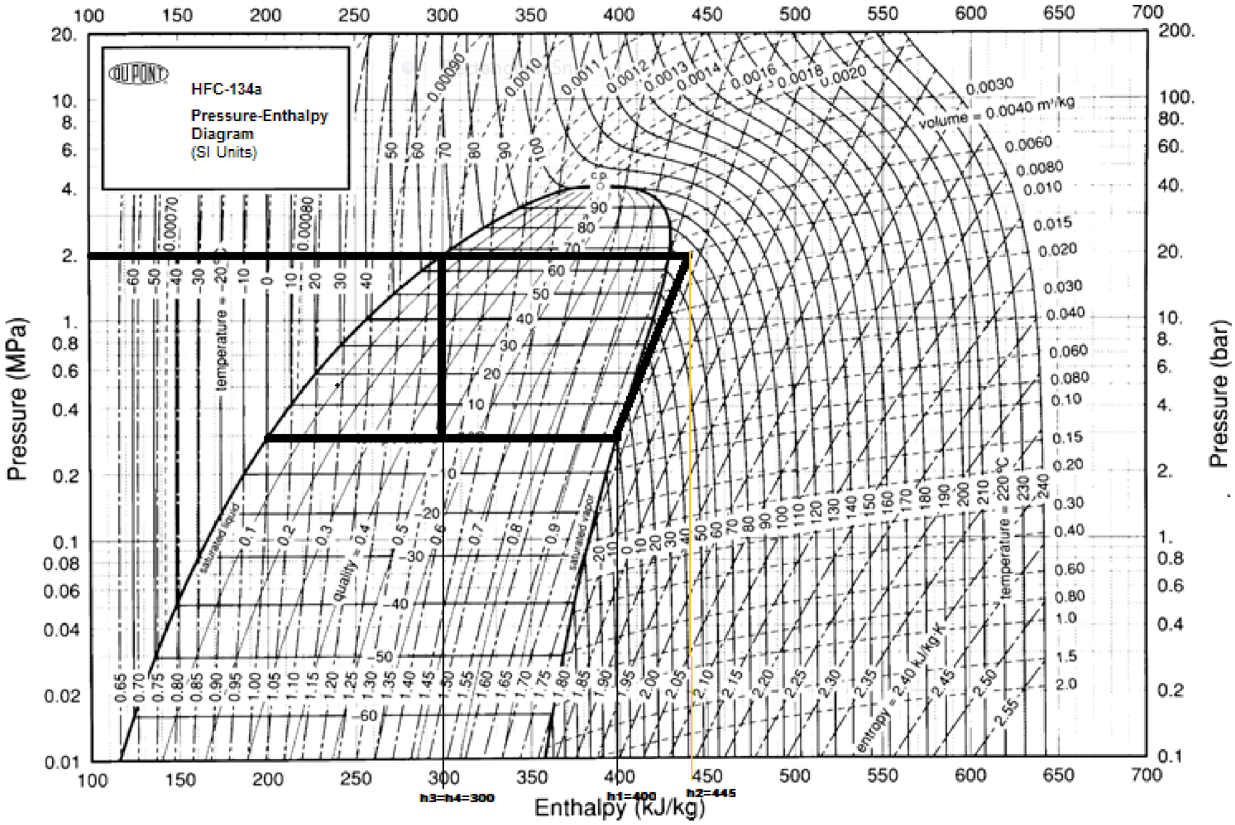

Fig.3. P-h chart of R-134a

- h_1= 400 KJ/kg (Enthalpy after evaporation).
- h_2=445 KJ/kg (Enthalpy after compression).
- h_3=300 KJ/kg (Enthalpy after condensation).
- h_4=300 KJ/kg (Enthalpy after expansion).

Therefore, COP = Condenser Work/ Compressor Work

= $(h_2-h_3)/(h_2-h_1)$

=3.23

4.2 Overall Heat Transfer Coefficient

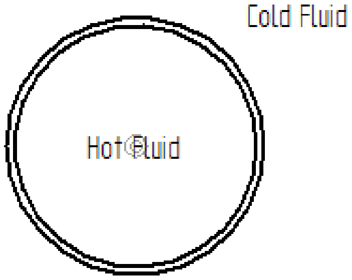

Fig.4. Copper Tube

The overall heat transfer coefficient 'U' is dominated by the smaller convection coefficient,since the inverse of a large number is small.

- Convection=1/hiAi

hi=inside heat transfer coeff. Of copper tube

=17 w/m^2 K

=1/17($\pi * 0.005$)

Ri=3.744 K/w

- Thermal conductivity=385 w/Mk
- Heat Transfer Coeff.(inside)=17 w/m^2 K ,
- Heat Transfer Coeff.(outside)=13.1 w/m^{2}K
- Conduction= x/KA

X= 0.3mm =0.0003m

K= 385 w/mK

A=π(Do-Di) =$\pi(0.0053 - 0.0050)$=9.42*10^{-4}

- Conduction=0.0003/385*9.42*10^{-4}

8.26*10^{-4} k/w

Now,

- 1/UA= 3.744 8.26x 10^{-4} + 3.744

1/UA= 7.488 k/w

UA= 0.1335 W/K

- Q=U*A*LMTD

3.517= (0.1335)*A*(26.00)

A=1.013 m^2

- Normal dia.of condenser pipe is 3.6 mm
- Thickness of the pipe = 0.3 mm

V. CONCLUSION & FUTURE SCOPE

After studying the vapor compression cycle, we have found out the theoretical COP of the system on a P-h chart. For Validation of theoretical values, experimentation is to be done on heat pump test rig by taking trial on it under varying conditions.

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