EXPERIMENTAL TEST ON THE REFRIGERATION SYSTEM WITH NEW DESIGN CONDENSER USING R-134a AND R-600a AS REFRIGERANTS

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ABSTRACT: Generally, the refrigeration works on the principle of Vapour Compression Refrigeration System (VCRS). Refrigeration has condenser which removes heat from the refrigerant and transfer the heat to the surroundings. The primary component of the condenser is typically the condenser coil, through which the refrigerant flows. The main objective of this project is to increase the coefficient of performance of the refrigeration system by designing the condenser coil with copper fins. The main purpose for adding fins to the plane condenser is to increase the surface area contact to the surroundings. The reason for selecting the copper as the material for the manufacturing of the condenser fins is that it has more heat transfer rate. The main objective of this paper is to compare the COPs of the refrigeration system of copper finned air-cooled condenser with both taking R-134a and R-600a as refrigerants.

Keywords: Vapour Compression Refrigeration System, copper fins, heat transfer rate, condenser, COP, R-134a and R-600a.

I. INTRODUCTION

Refrigeration is the process of the absorption of heat from where it is required space (i.e. evaporator section) plus its transfer to and rejection at a place where it is unobjectionable (i.e., condenser section). The domestic refrigerator is a device which works on "vapour compression refrigeration cycle". It is a home appliance called a 'fridge' used to keep food below the atmospheric temperature to reduce the bacteria effects on food. The domestic refrigerator has one reciprocating compressor, an air-cooled condenser, capillary tube as an expansion device and an evaporator.

Refrigeration is defined as the process of extracting the heat from the closed volume and maintaining the temperature in the closed volume very low when compared to the surrounding temperature.

Generally, there are two types of cycles for the refrigeration system. They are as follows:

a) Vapour Compression Refrigeration System

b)Vapour Absorption Refrigeration System

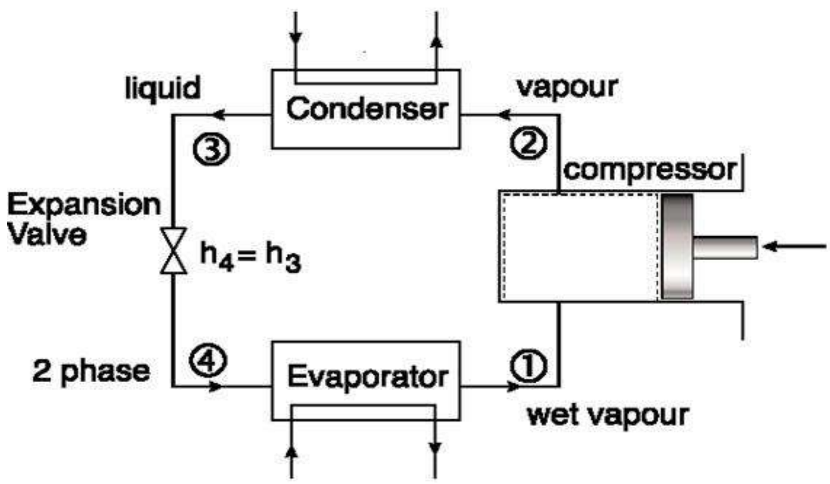

Fig.1 Simple Vapour Compression Refrigeration Cycle

A Domestic refrigerator works on upon Vapour compression Refrigeration cycle. The essential component of the cycles is the evaporator, the compressor, the condenser and the expansion device. The function of the compressor is to increase the pressure of the working fluid (called refrigerant) from the evaporator pressure to condenser pressure. And the function of the condenser is to reduce that high pressure working fluid from high to low pressure and temperature by the heat rejection process.

1-2 ISENTROPIC COMPRESSION

The refrigerant which is coming out from the evaporator will be compressed isentropic to generate more pressure and more temperature and refrigerant will be converted from liquid to vapour state, the refrigerant in the compressor will be compressed by the external power supply.

2-3 CONDENSATION

The refrigerant coming out from the compressor will be entered into the condenser and the refrigerant is condensed and converted to the liquid state so that the temperature and pressure decrease more due to the heat rejection. Heat rejection can be done by using forced or natural convection.

3-4 EXPANSION

The refrigerant which is coming out from the condenser will enter into the expansion so that the resulting slightly decreasing of temperature and pressure by remaining the enthalpy constant.

4-1 EVAPORATION

The low-temperature refrigerant that comes from the expansion valve will enter into the evaporator, extracts the heat from the evaporator to be cooled. Here the temperature and the pressure will increases and converts into the vapour state.

Most of the authors are doing research on the VCR System to improve the efficiency of the COP by changing the refrigerants as well as by the change of the components with different materials and different designs. [1], [2] & [3] have done their experimental studies and analysis on the design of the condensers with different materials. They also reviewed on adding different types of fins to the condenser coils of the VCR System to improve the COP. Authors [4] & [5] have reviewed on the Thermodynamic properties of refrigerants and alternative refrigerants to make eco-friendly.

II. EXPERIMENTALSET UP

The length and size of air conditioner condensers and evaporators have to be sized such that, the refrigerant is completely condensed before the condenser's exit, and the refrigerant is completely boiled before the evaporator's exit. Those two, depends mainly on the size of the compressor and refrigerant used. In this experiment, the condenser is designed with an eight tubes of finned type condenser so that the heat rejection will be more in the condenser section and the cooling will be quickly in the evaporation section by the change of the condenser design condensed and converted to the liquid state. In this, the condenser of the refrigeration system is newly designed by adding copper fins to the condenser coils. So that the pressure and temperature of the refrigerant will be decreased more due to the heat rejection. Heat rejection can be done by using forced or natural convection.

Fig .2 VCRS with new designed condenser

Equipment Dimensions:

Compressor:

Compressor Motor Type : RSCR
(Resistance Start Cap Run motor)
Rating : 230 V, 50Hz, 1 Phase
Refrigerants used : R-143a & R-600a

Condenser Dimensions:

Condenser Fins:

Fig.3Condenser Coils with Copper Fins

Material used for fins: Copper
Length of the fins : 250 mm
Fins diameter : 30 mm
No. of tubes finned : 8

Evaporator:

Length : 300 mm
Breadth : 300 mm
Height : 350 mm

Condenser Coil:

Material used for coil : Copper
Coil/tube length : 300 mm
Coil diameter: 10 mm
No. of coils : 8

III. EXPERIMENTAL PROCEDURE

The vapour compression uses a circulating liquid refrigerant as the medium which absorbs and removes heat from the space to be cooled and subsequently rejects that heat elsewhere. Fig.1 depicts a typical, single stage vapour compression system. All such systems have four components: a compressor, a copper finned type condenser, a thermal expansion valve and an evaporator. Circulating refrigerant enters the compressor in the thermodynamic state known as a saturated vapour and is compressed to a higher pressure, resulting in a higher temperature as well. The hot vapour is routed through acopper finned type condenser where it is cooled and condensed into a liquid by flowing through a coil or tubes with cool air flowing across the coil or tubes. The condensed liquid refrigerant, in the thermodynamic state known as a saturated liquid, is next routed through an expansion valve where it undergoes an abrupt reduction in pressure. That pressure reduction results in the adiabatic flash evaporation of a part of the liquid refrigerant. The cold mixture is then routed through the coil or tubes in the evaporator. A fan circulates the warm air in the enclosed space across the coil or tubes carrying the cold refrigerant liquid and vapour mixture. That warm air evaporates the liquid part of the cold refrigerant mixture. At the same time, the circulating air is cooled and thus lowers the temperature of the enclosed space to the desired temperature.

Notations:

P_1, P_2 = Low and High pressures respectively
T_1, T_2,T_3, T_4 = Suction , Discharge, Condenser and Evaporator temperatures respectively
h_1, h_2, h_3, h_4 = Enthalpies of the refrigerants
R.E = Refrigerating Effect
W.D = Work Done
m_r = Mass flow rate
C_w = Compressor Work
C.H.R = Condenser Heat Rejection

IV. TABLES & CALCULATIONS

TABLE 1: PRESSURE & TEMPERATURE VALUES OF R-134a

Loads	P_1	P_2	T_1	T_2	T_3	T_4
0	0.58	14.12	18.3	45.6	42.9	-9.3
2	0.88	14 90	15.6	46.8	42.3	-5.8
4	1.17	17.06	24.8	52.1	44.4	-4.9
6	1.27	18.04	22.9	54.6	46.6	-4.6
8	1.37	18.43	22.2	55.8	46.6	-3.5
10	1.47	19.80	23.8	58.2	47.6	-2.4

TABLE 2: ENTHALPY VALUES OF R-134a

Loads	h_1	h_2	h_3	h_4	COP
0	409	441	260	260	4.65
2	410	444	262	262	4.35
4	412	447	264	264	4.22
6	413	451	267	267	3.84
8	414	453	268	268	3.74
10	415	456	270	270	3.53

TABLE 3: REFRIGERATING EFFECT, WORK DONE, MASS FLOW RATE, COMPRESSOR WORK & CONDENSER HEAT REJECTION VALUES OF R-134a

Loads	R.E	W.D	m_r	C_w	C.H.R
0	149	32	1.40	44.80	181
2	148	34	1.41	47.94	182
4	148	35	1.41	49.35	183
6	146	38	1.43	54.34	184
8	146	39	1.43	55.77	185
10	145	41	1.44	59.04	186

TABLE 4: PRESSURE & TEMPERATURE VALUES OFR-600a

Loads	P_1	P_2	T_1	T_2	T_3	T_4
0	0.64	11.83	20.2	49.2	36.6	-4.3
2	0.82	12.61	18.6	50.4	37.8	-3.8
4	1.13	13.84	17.4	52.6	38.3	-3.1
6	1.41	14.46	15.5	53.8	39.8	-2.7
8	1.62	15.80	12.8	55.7	41.1	-2.2
10	1.90	17.45	11.6	56.2	42.4	-1.9

TABLE 5: ENTHALPY VALUES OF R-600a

Loads	h_1	h_2	h_3	h_3	COP
0	583	620	445	445	3.72
2	582	620	444	444	3.63
4	579	619	442	442	3.42
6	578	620	441	441	3.26
8	574	619	438	438	3.02
10	571	618	436	436	2.87

TABLE 6: REFRIGERATING EFFECT, WORK DONE, MASS FLOW RATE, COMPRESSOR WORK & CONDENSER HEAT REJECTION VALUES OF R-600a

Loads	R.E	W.D	m_r	C_w	C.H.R
0	138	37	1.52	56.24	175
2	138	38	1.52	57.76	176
4	137	40	1.53	61.20	177
6	137	42	1.53	64.26	179
8	136	45	1.54	69.30	181
10	135	47	1.55	72.85	182

Sample Calculation Part:

a) For load: 0 Kgs

From the TABLE 1

From the P-h chart of R-134a

Suction of compressor h_1 = 409 KJ/Kg

Discharge of compressor h_2 = 441 KJ/Kg

Condenser inlet h_3 = 260 KJ/Kg

Condenser outlet h_4 = 260 KJ/Kg

1) COP $= \frac{netrefrigeratingeffect}{workdone} = \frac{h1-h4}{h2-h1}$

Net refrigerating effect = $h_1 - h_4$ = 409 – 260 =149 KJ/Kg

Work done = $h_2 - h_1$ = 441 – 409 = 32 KJ/Kg

$$\therefore COP = \frac{149}{32} = 4.65$$

2) Mass flow rate (m_r) = $\frac{210}{netrefrigeratingeffect} = \frac{210}{h1-h4} = \frac{210}{149} = 1.40\ Kg/min$

3) Compressor work (C_W) = m_r * ($h_2 - h_1$) = 1.40 * (32) = 44.80 KJ/min

4) Heat rejection in condenser = $h_2 - h_3$ = 441 – 260 = 181 KJ/Kg

From the TABLE 4

From the P-h chart of R-600a

Suction of compressor h_1 = 583 KJ/Kg

Discharge of compressor h_2 = 620 KJ/Kg

Condenser inlet h_3 = 445 KJ/Kg

Condenser outlet h_4 = 445 KJ/Kg

1) COP $= \frac{netrefrigeratingeffect}{workdone} = \frac{h1-h4}{h2-h1}$
Net refrigerating effect = $h_1 - h_4$ = 583 – 445 =138 KJ/Kg

Work done = $h_2 - h_1$ = 620 – 583 = 37 KJ/Kg

$$\therefore COP = \frac{138}{37} = 3.72$$

2) Mass flow rate (m_r) = $\frac{210}{netrefrigeratingeffect} = \frac{210}{h1-h4} = \frac{210}{138} = 1.52\ Kg/min$

3) Compressor work (C_W) = m_r * ($h_2 - h_1$) = 1.52 * (37) = 56.24 KJ/min

4) Heat rejection in condenser = $h_2 - h_3$ = 620 – 445 = 175 KJ/Kg

V. GRAPHS

From the tabular values, the graphs between the Load Vs COP, Load Vs Compressor Work and Load Vs Condenser Heat Rejection are plotted below.

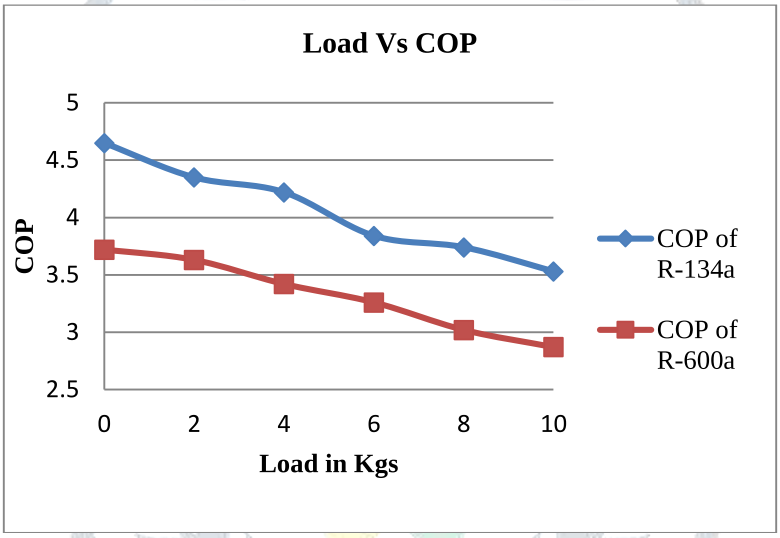

Fig.4 Load Vs COP

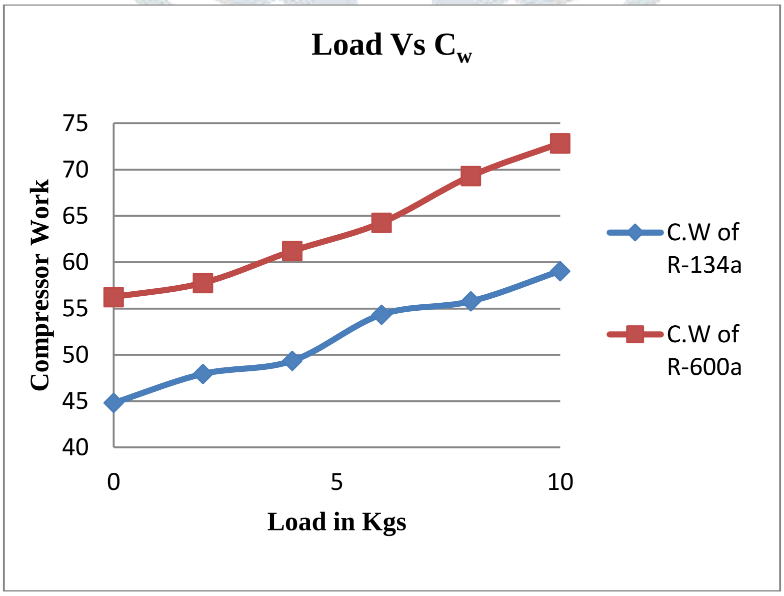

Fig.5 Load Vs Compressor Work

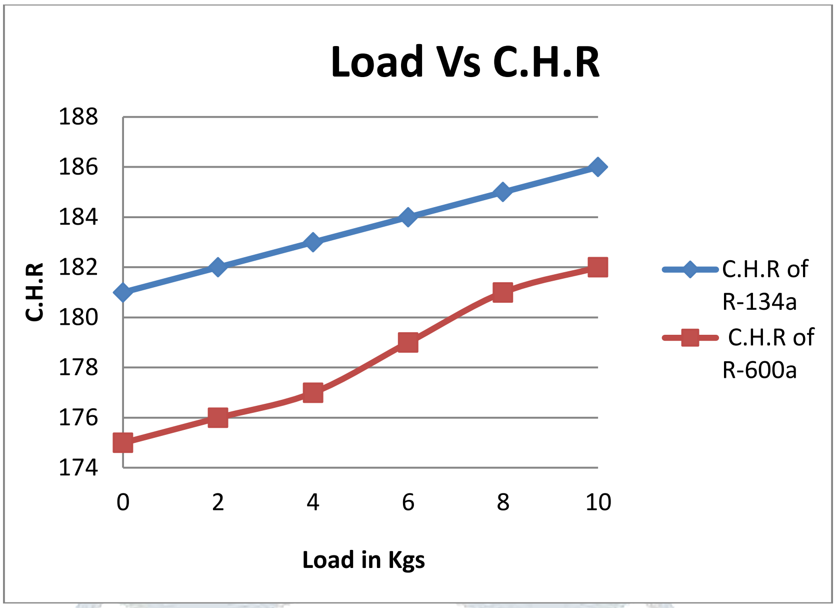

Fig.6 Load Vs Condenser Heat Rejection

VI. RESULT & CONCLUSION

Experimental performance data of a vapour compression refrigeration system with copper finned condenser coil with refrigerants R134a and R600a has been presented. While comparison of COP for copper finned condenser R-134a and copper finned condenser R-600a gives nearest values of performance but copper finned condenser with R134a gives optimum and highest COP.

From Fig. 4, 5 & 6 the effect of changing the copper finned condenser with both R-134a and R-600a the following conclusions are noted as follows:

1. Comparing the Refrigerating Effect of the two refrigerants, the Refrigerating System of the R-134a has more than that of the R-600a.
2. Comparing the Compressor Work of the two refrigerants, the Refrigerating System of R-134a has less than that of the R-600a.
3. Comparing COP of the two refrigerants without load, the Refrigerating System of R-134a has more than that of the R-600a.
4. Comparing the Mass flow rate of the two refrigerants, the Refrigerating System of R-134a has less than that of the R-600a.
5. Comparing the heat rejection in the condenser, the refrigerating system of the R-134a has more than that of the R-600a.

Finally, it is concluded that the copper finned condenser of the Refrigerating System with R-134a as refrigerant is recommended for the domestic refrigerator.

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