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Research Paper

PERFORMANCE OF DOMESTIC REFRIGERATION SYSTEM WITH SUB COOLING BY USE OF ECO-FRIENDLY REFRIGERANTS

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There are various obstacles faced in working of different refrigerants due to their environmental impact (R 11, R12), toxicity (NH_3), Flammability (HC) and high pressure (CO_2); which makes them more hazardous than other working fluids according to safety and environmental issues. Performance analysis on a vapour compression refrigeration system with eco-friendly refrigerant of HC600a were done and their results were compared with R134a as possible alternative replacement. The performance of vapor compression refrigeration system of domestic refrigerator can be increased by using 150 cm length of a sub cooling coil for different refrigerants. The results obtained showed that the sub-cooler in the refrigeration system enhanced the system performance and an increase in sub-cooling reduces the compressors work input and increases the system refrigeration capacity. Also, an increase in the degree of sub-cooling, reduces the pressure ratio, and increases both the refrigerant mass flow rate and Coefficient of Performance (COP) of the system. The retrofitting of R600a in all conditions showed better performance than R134a. And also that if care is taken in flammable of R600a retrofitting gives better performance with R600a in domestic R134a systems.

Keywords: Compression refrigeration system, Refrigerant, COP, ODP, GWP

INTRODUCTION

Vapor compression Refrigeration system is an enhanced by air refrigeration system. The capacity of certain liquids to absorb giant quantities of heat as they vaporize is the basis of this system. Compared to melting solids (say ice) to find refrigeration effect, vaporizing liquid refrigerant has more advantages. To mention a few, the refrigerating effect can be started or stopped at will, the rate of cooling can be determined, the vaporizing temperatures can be governed by controlling the pressure at which the liquid vaporizes. Moreover, the vapor can be readily collected and condensed back into liquid state so that same liquid can be re-circulated over and over again to obtain refrigeration effect. Thus the vapor compression system employs a liquid refrigerant which evaporates and condenses

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readily. The system is a closed once the refrigerant never leaves the system.

The coefficient of performance of a refrigeration system is the ratio of refrigerating effect to the compression work; therefore the coefficient of performance can be increased by increasing the refrigerating effect or by decreasing the compression work.

The vapor compression refrigeration system is now-a-days used for all purpose refrigeration. It is generally used for all industrial purposes from a small domestic refrigerator to a big air-conditioning plant.

MATERIALS AND METHODS

Selection of Environment-Friendly Refrigerants: The range of possible alternative fluids is extensive; it includes Hydro-Fluorocarbons (HFCs), refrigerant mixtures, hydrocarbons, and natural fluids. Among these groups of alternatives, HFCs are the most useful. The possible environment-friendly refrigerants with zero ODP and lower Global Warming Potential (GWP) could be selected from derivatives of methane and ethane. In this work, full array of methane and ethane derivatives were considered and trade-off in flammability, toxicity and chemical stability concerning atmospheric lifetime with changes in molecular chlorine, fluorine and hydrogen content were carried out. Therefore, two promising alternative refrigerants (R134a and 600a) that contain no chlorine and that have short atmospheric lifetime were selected and investigated theoretically using sub-cooling coil.

Refrigeration System with Sub-cooling: Sub-cooling in refrigeration implies cooling the refrigerant in liquid state, at uniform pressure, to a temperature that is less than the saturation

temperature, which corresponds to condenser pressure. Degree of sub-cooling is the difference between the saturation temperature of the liquid refrigerant, corresponding to condenser pressure, and the temperature of the liquid refrigerant before entering to the expansion device. Figure 1 illustrates a refrigeration system with sub-cooling coil. The main components of the sub-cooling system include air-cooled condenser, evaporator, compressor, sub-coolling coil and expansion device.

Assumptions: The experimental analysis is based on the following relevant assumptions:

i. Pressure losses due to friction and pipelines are considered to be negligible.

ii. Heat losses to the surrounding through the system components are negligible.

iii. The compression process is assumed to be isentropic.

Figure 1: Vapour Compressor Refrigeration System with Sub Cooling Coil

COMPRESSOR

The low pressure and temperature vapor refrigerant from evaporator is drawn into the compressor through the inlet or suction valve A,

where it is compressed to a high pressure and temperature. This high pressure and temperature vapour refrigerant is discharged into the condenser through the delivery or discharge valve B.

CONDENSER

The condenser or cooler consists of coils of pipe in which the high pressure and temperature vapour refrigerant is cooled and condensed. The refrigerant, while passing through the condenser, gives up its latent heat to the surrounding condensing medium which is normally air or water.

COPPER COIL

By expanding the refrigerant very close to the saturated liquid line we can increase the refrigerating effect of the system. Hence to increase the COP we integrated a copper coil to the system in between the condenser and filter such that it always affected by water cooling.

RECEIVER

The condensed liquid refrigerant from the sub cooling coil is stored in a vessel known as receiver from where it is supplied to the evaporator through the expansion valve or refrigerant control valve.

EXPANSION VALVE

It is also called throttle valve or refrigerant control valve. The function of the expansion valve is to allow the liquid refrigerant under high pressure and temperature to pass at a controlled rate after reducing its pressure and temperature. Some of the liquid refrigerant evaporates as it passes through the expansion valve, but the greater portion is vaporized in the evaporator at the low pressure and temperature

EVAPORATOR

An evaporator consists of coils of pipe in which the liquid-vapor refrigerant at low pressure and temperature is evaporated and changed into vapor refrigerant at low pressure and temperature. In evaporating, the liquid vapour refrigerant absorbs its latent heat of vaporization from the medium (air, water or brine) which is to be cooled.

EXPERIMENTAL STUDIES

The vapor compression system is initially cleaned and the evacuation of the system is carried out with the help of a vacuum pump for nearly 30 min and then the refrigerant is charged into the system.

Initially the system is charged with refrigerants R-134a & R-600a and then the following tests were carried out.

1. Performance calculations test for existing system.

2. Performance calculations test for existing system with subcooling in air.

3. Performance calculations test for existing system with subcooling in water.

Performance calculations of domestic refrigerator using refrigerant R-134a for both existing system and new system with subcooling coil in air and water:

Performance calculations of domestic refrigerator using refrigerant R-600a for both existing system and new system with subcooling coil in air and water:

| **Table 1: Results Obtained for R-134a Refrigerant**				
S.No.	Parameters	Existing System	New System With Air Cooling	New System With Water Cooling
1.	Net refrigerating effect kJ/kg	180	187	196
2.	Coefficient of Performance (COP)	9.474	11.69	12.25
3.	Mass flow rate to obtainone TR kg/min	1.167	1.123	1.0714
4.	Work of CompressionkJ/kg	19	16	16
5.	Heat Equivalent of work of compression per TR kJ/min	22.173	17.968	17.1424
6.	Compressor Power KW	0.37	0.299	0.286
7.	Heat to be rejected in condenser kJ/kg	199	203	212
8.	Heat Rejection per TRkJ/min	232.23	227.97	227.14
9.	Heat Rejection Ratio	1.106	1.086	1.082

**Table 2: Results Obtained for R-600a Refrigerant**				
S. No.	Parameters	Existing System With No Load	New System With Air Cooling	New System With Water Cooling
1.	Net refrigerating effect Kj/kg	305	320	330
2.	Coefficient of Performance (COP)	10.167	12.8	13.2
3.	Mass flow rate to obtain one TR kg/min	0.688	0.656	0.6364
4.	Work of Compression kJ/kg	30	25	25
5.	Heat Equivalent of work of compression per TR kJ/min	20.656	16.4	15.9
6.	Compressor Power KW	0.344	0.273	0.265
7.	Heat to be rejected in condenser kJ/kg	335	345	355
8.	Heat Rejection per TR kJ/min	230.48	226.32	225.9
9.	Heat Rejection Ratio	1.098	1.077	1.076

RESULTS AND DISCUSSION

Effect on Refrigeration Effect of the System by Adopting Subcooling Coil Using Refrigerant R-134a

Figure1 shows the refrigeration effect for refrigerant R-134a for both existing and new system with subcooling coil in air and water.Net refrigeration effect is more with subcooling coil so coefficient of performance is increased with proposed system.
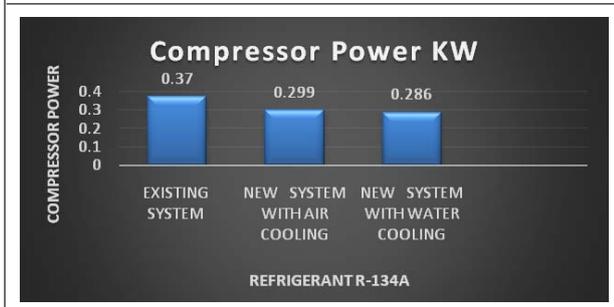
Figure 2: Net Refrigerating effect for refrigerant R-134a
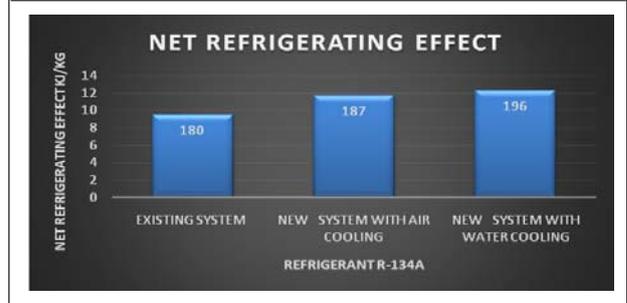
Effect on Coefficient of Performance of the System by Adopting Subcooling Coil using Refrigerant R-134a

Figure 2 shows the coefficient of performance for refrigerant R-134a for both existing and new system with subcooling coil in air and water. Net refrigeration effect is more with subcooling coil so coefficient of performance is increased with proposed system.

Figure 3: Coefficient of Performance for Refrigerant R-134a

Effect on Compressor Power by Adopting Subcooling Coil Using Refrigerant R-134a

Figure 3 shows the compressor power for refrigerant R-134a for both existing and new system with subcooling coil in air and water. Mass flow rate is less with subcooling coil so compressor power is decreased with proposed system.

**Figure 4: Compressor Power for Refrigerant R-134a**

Effect on Heat Rejection by Adopting Subcooling Coil Using Refrigerant R-134a

Figure 4 shows the heat rejection for refrigerant

R-134a for both existing and new system with subcooling in air and water.Subcooling is more with subcooling coil so heat rejection is increased with proposed system.
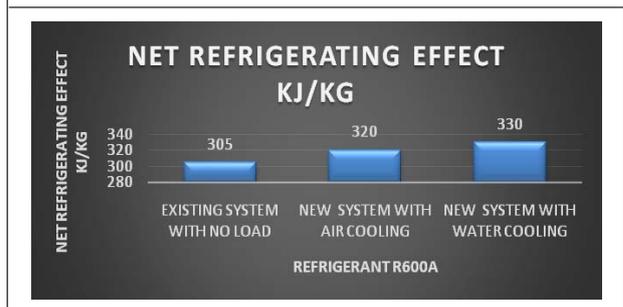
Figure 5: Heat Rejection for Refrigerant R-134a
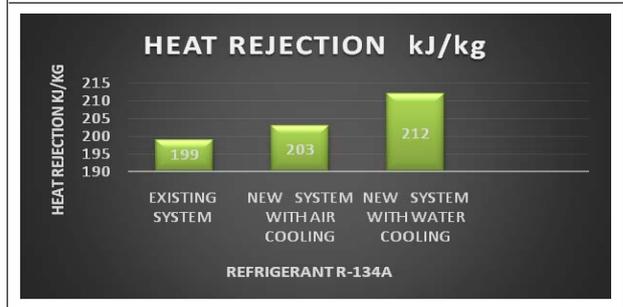
Effect on Refrigeration Effect of the System by Adopting Subcooling Coil Using Refrigerant R-600a

Figure 5 shows the refrigeration effect for refrigerant R-600a for both existing and new system with subcooling coil in air and water.Net refrigeration effect is more with subcooling coil so coefficient of performance is increased with proposed system.

Figure 6: Net Refrigerating Effect for Refrigerant R-600a

## Effect on Coefficient of Performance of the System by Adopting Subcooling Coil Using Refrigerant R-600a

Figure 6 shows the coefficient of performance for refrigerant R-600a for both existing and new system with subcooling coil in air and water.Net refrigeration effect is more with subcooling coil

so coefficient of performance is increased with proposed system.

Figure 7: Coefficient of Performance for Refrigerant R-600a
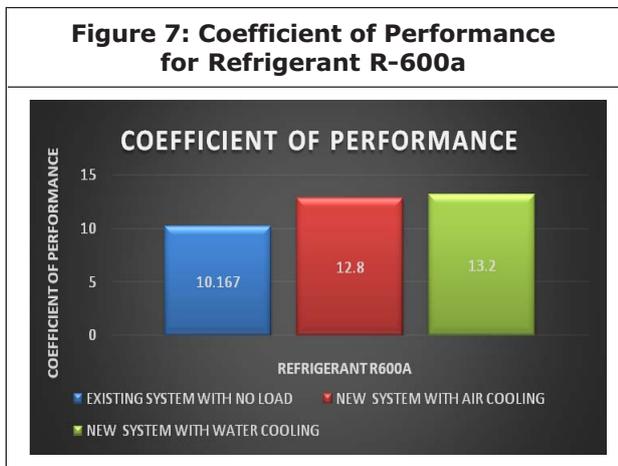
Effect on Compressor Power by Adopting Subcooling Coil Using Refrigerant R-600a

Figure 7 shows the compressor power for refrigerant R-600a for both existing and new system with subcooling coil in air and water. Mass flow rate is less with subcooling coil so compressor power is decreased with proposed system.

Figure 8: Compressor Power for Refrigerant R-600a
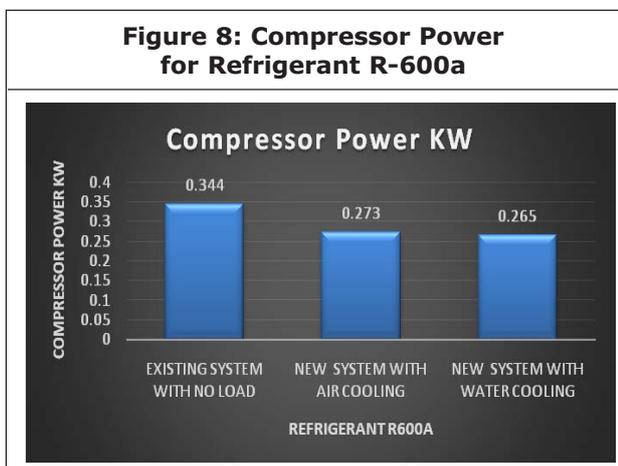
Effect on Heat Rejection by Adopting Subcooling Coil Using Refrigerant R-600a

Figure 8 shows the heat rejection for refrigerant R-600a for both existing and new system with subcooling in air and water. Subcooling is more with subcooling coil so heat rejection is increased with proposed system.

Figure 9: Heat Rejection for Refrigerant R-600a
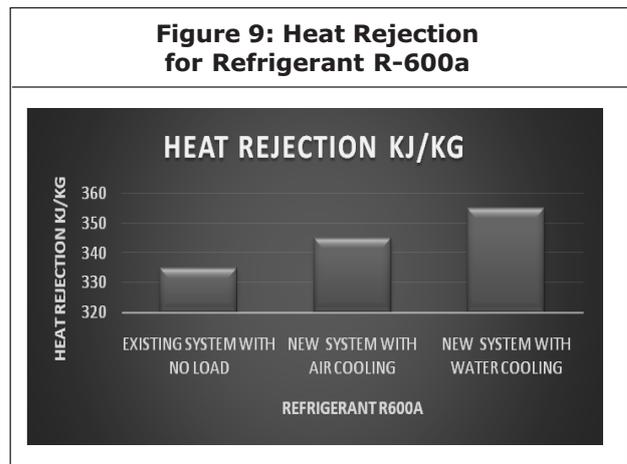
CONCLUSION

In present experimental setup is prepared for both existing and proposed system with R-134a and R-600a as refrigerants. In the proposed system with sub cooling coil of 150 cm length is used.

- In the proposed system with sub cooling coil the refrigeration effect is found to be more than the refrigeration effect of existing system. The percentage of increase in refrigeration effect using R-134a is 3.89%.

- In the proposed system with sub cooling coil the rerigeration effect is found to be more than the refrigeration effect of existing system. The percentage of increase in refrigeration effect using R-600a is 4.92%.

- In the proposed system the coefficient of performance is found to be greater than the coefficient of performance of existing system. The percentage of increase in COP using R-134a is 2.76%.

- In the proposed system the coefficient of performance is found to be greater than the coefficient of performance of existing system. The percentage of increase in COP using R-600a in no load condition is 3.03%.

- In the proposed system the compressor

power is found to be less than the compressor power of existing system. The percentage of decrease in compressor power using R-134a is 22.7%.

• In the proposed system the compressor power is found to be less than the compressor power of existing system. The percentage of decrease in compressor power using R-600a is 22.96%.

From the above discussions, it can be concluded that the performance of vapour compression refrigeration system of domestic refrigerator can be increased by using 150 cm length of a sub cooling coil for different refrigerants.

The retrofitting of R600a in all conditions showed better performance than R134a. And also that if care is taken in flammable of R600a retrofitting gives better performance with R600a in domestic R134a systems.

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