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Experimental Investigation on Domestic Refrigerator Providing Subcooling by using Eco Friendly Refrigerant

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ABSTRACT

Domestic refrigerators using different refrigerants such as R11, R12, NH_3, CO_2, etc. The major problems facing these refrigerants are environmental impact, toxicity, flammability, and high pressure, making them more dangerous than other refrigerants according to environment and safety issues. Present R134a refrigerant using in domestic refrigerators because of their thermal properties, but it may be harmful to human health. So, isobutane (R600a) is a better replacement of R134a because it is ecofriendly than all other refrigerants. The current work focuses on increasing the vapor compression refrigeration system's performance by providing a 150 cm length of a subcooling coil for different (R134a and R600a) refrigerants. The results showed that the refrigeration system's sub-cooler enhanced system performance by reducing the compressors' work input and increasing refrigeration capacity. R600a showed better performance than R134a refrigerant at all conditions but took care of R600a refrigerant because of its explosive nature.

1. INTRODUCTION

Most domestic refrigerators in India used R-134a as a refrigerant because of its good thermo physical and thermodynamic properties. R-134a refrigerant major disadvantage is high global warming potential (GWP). The major problems facing this refrigerant is environmental impact, toxicity, flammability, and high pressure, making them more dangerous than other refrigerants according to environment and safety issues. Hydrofluorocarbons better alternative to chlorofluorocarbons (CFC) replacement because it has global potential, but it less than CFC. Present refrigerators are primary energy consuming domestic appliance in household purpose [1-6].

Ching-Song et al. [7] conducted experiments on a domestic refrigerator by using a mixture of isobutane and propane as a refrigerant. It reduced the 4.4% of energy consumption and 40% of weight contrasted with R134a. The faster change of cabin temperature and also ON time ratio by using hydrocarbon mixture as a refrigerant in domestic refrigerator correlated with R134a [8]. Sattar et al. [9] investigated the effects of different hydrocarbons as refrigerants used in a domestic refrigerator. The results revealed that R290 refrigerant not as a replacement of R134a because it operated at high temperature. R600a refrigerant better alternative of replacement of R134a because it has desirable characteristics of discharge temperature, operating pressure and mass flow rate. Joybari et al. [10] investigated the effects of a domestic refrigerator with different refrigerants. The result revealed that the optimum condition of total exergy destruction was 45.05% of R600a refrigerant of the household refrigerator.

Previous studies reported that R600a refrigerant showed better performance than R134a in household refrigerators. The main objective of this work is to investigate the effects of R134a and R600a as refrigerants used in a domestic refrigerator by providing subcooling with existing and new system with air and water cooling.

2. MATERIALS AND METHODS

Refrigerants of R-134a and R-600a bought from Tulsi Refrigerants, Secunderabad, Telangana. Table 1 illustrates the properties of refrigerants.

2.1 Experimental Setup

Figure 1. illustrated the experimental setup of the vapor compression refrigeration system with a subcooling coil. The VCR system's main components are the compressor, condenser, subcooling coil, throttle valve, and evaporator.

The compressor compresses the low-pressure gas refrigerant into high pressure liquid refrigerant. This high-pressure liquid refrigerant is entering into the condenser. It releases the heat into the atmosphere, and high-pressure low temperature liquid refrigerant enters into the subcooling coil. It further decreases the temperature of the liquid refrigerant, and it enters into the throttle valve. It reduces the pressure of the liquid refrigerant, and it enters into the evaporator. The evaporator absorbs the heat, and it converts lower pressure liquid refrigerant into lower pressure gas refrigerant, and it enters the compressor. This cycle repeats with all refrigerants.

Table 1: Properties of refrigerants

REFRIGERANT	R600a	R134a
Name	Isobutane	1.1.1.2-Tetra-flouro-ethane
Formula	$(CH_3)_3CH$	CF_3-CH_2F
Critical temperature (˚C)	135	101
Molecular weight (Kg/kmol)	58.1	102
Normal boiling point (˚C)	-11.6	-26.5
Pressure at -25˚C in bar (absolute)	0.58	1.07
Liquid density at -25˚C (Kg/L)	0.60	1.37
Vapor density at t_0-25/+32˚C (Kg/m^3)	1.3	4.4
Volumetric capacity at -25/55/32˚C in KJ/m^3	373	658
Enthalpy of vaporization at -25˚C in KJ/Kg	376	216
Pressure at +20^{0}c in bar (absolute)	3.0	5.7

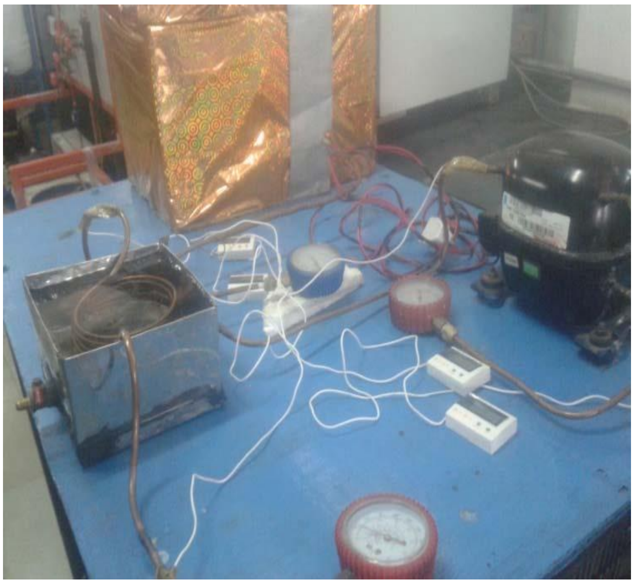

Figure 1. Vapour Compressor Refrigeration System with Sub Cooling Coil

The copper tube of 150 cm length and 1/4" inch diameter used as a subcooling coil by providing subcooling in the VCR system. Figure 2 illustrates the subcooling coil used in this system.

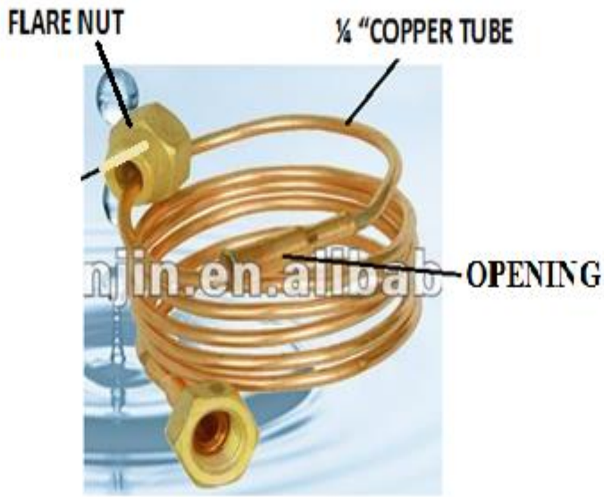

Figure 2. Subcooling Coil

3. RESULTS AND DISCUSSION

The current work focuses on increasing the vapor compression refrigeration system's performance by providing a 150 cm length of a subcooling coil for different (R134a and R600a) refrigerants. Table 2 illustrated the results of using R-134a refrigerant with different systems. Table 3 showed the results of using R-600a refrigerant with different systems.

3.1 Net Refrigeration Effect

Figure 3 shows the refrigeration effect for refrigerants R-134a and R600a for existing and new systems with subcooling coil in air and water. The net refrigeration effect increases with subcooling compared to the existing system because subcooling reduces the liquid's flashing during evaporation and increases its refrigeration effect. From figure 3, It showed that high refrigeration effect by using R-600a refrigerant contrasted with R-134a.

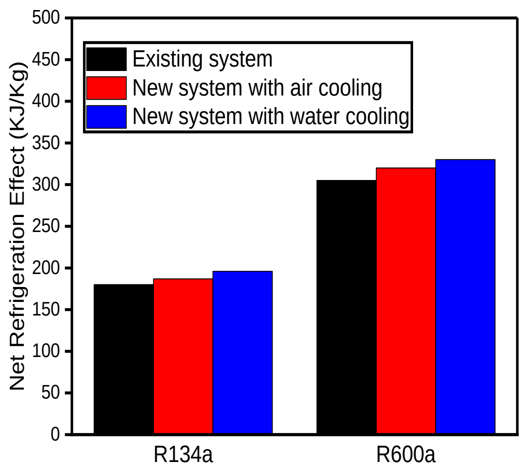

Figure 3. Net refrigerating effect of different refrigerants

Table 2: Effects of using R-134a refrigerant with different systems

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 obtain 1 TR (Kg/min)	1.167	1.123	1.0714
4.	Work of Compression (KJ/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 TR (KJ/min)	232.23	227.97	227.14
9.	Heat Rejection Ratio	1.106	1.086	1.082

Table 3: Effects of using R-600a refrigerant with different systems

S. No.	Parameters	Existing System	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 1 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

3.2 Compressor Power

Figure 4 shows the compressor power for refrigerants R-134a and R600a for both existing and new systems with subcooling coil in air and water. The mass flow rate is less with the subcooling coil, so compressor power decreased with the proposed system. Figure 4 showed less compressor power by using R-600a refrigerant with different systems contrasted with R-600a.

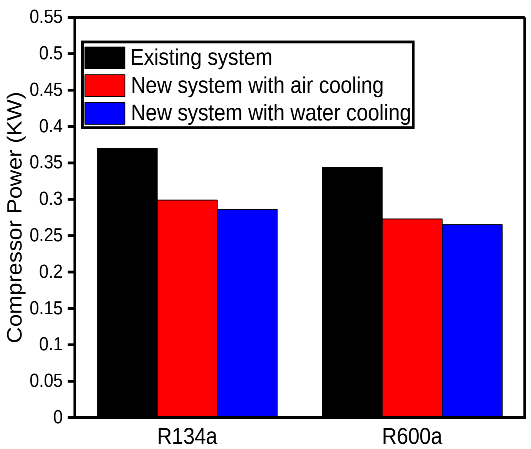

Figure 4. Compressor power of different refrigerants

3.3 Compressor Power

Figure 5 shows the coefficient of performance of both existing and new systems with subcooling coil in air and water with different refrigerants. The net refrigeration effect is more with the subcooling coil, so the coefficient of performance increased with the proposed system. Figure 5 showed a high coefficient of performance by using R-600a refrigerant with different systems contrasted with R-600a.

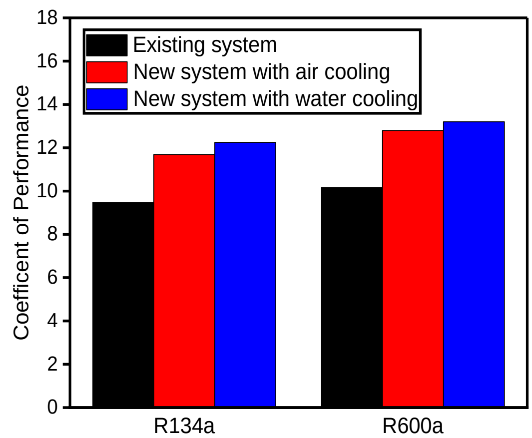

Figure 5. Coefficient of performance of different refrigerants

3.4 Heat Rejection

Figure 6 shows the heat rejection of both existing and new systems with subcooling in air and water with different refrigerants. Subcooling is more with a subcooling coil, so heat rejection increased with the proposed system. Figure 6 showed high heat rejection by using R-600a refrigerant with different systems contrasted with R-134a.

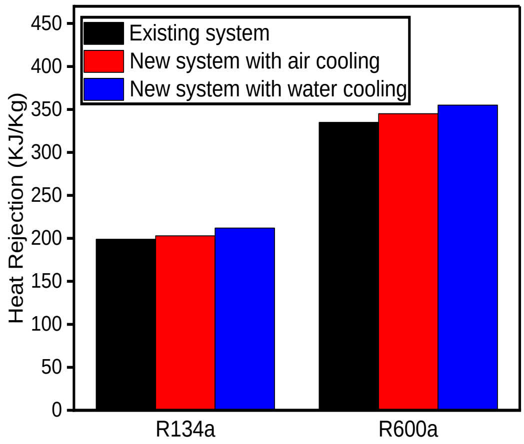

Figure 6. Heat rejection of different refrigerants

4. CONCLUSION

The current work focuses on increasing the vapor compression refrigeration system's performance by providing a 150 cm length of a subcooling coil for different (R134a and R600a) refrigerants. The outcomes revealed that the net refrigeration effect increases with subcooling compared to the existing system because subcooling reduces the liquid's flashing during evaporation and increases the system's refrigeration effect. The refrigeration effect increased by using R-600a refrigerant contrasted with R-134a. High coefficient of performance by using R-600a refrigerant with different systems contrasted with R-134a because of net refrigeration effect is more with subcooling coil, so the coefficient of performance increased with the proposed system. Less compressor power using R-600a refrigerant with different systems contrasted with R-600a because the mass flow rate is less with the subcooling coil, so compressor power decreased with the proposed method. High heat rejection using R-600a refrigerant with different systems contrasted with R-134a because subcooling is more with subcooling coil, so heat rejection increased with the proposed system. It concluded that R600a showed better performance than R134a refrigerant at all conditions but took care of R600a refrigerant because of its explosive nature.

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