International Engineering Research Journal

Effect of condenser subcooling on performance of VCR system

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Abstract

Heat is the energy and energy saving is the important for the protection of global environment. so it is necessary to find possible ways to save the energy through the different medium in order to increase the performance of system to make it as compatible. Themain objectiveofthispaperistostudy "WasteHeatrecoverysystemfordomesticrefrigerator".An attempt has been made toutilize wasteheat from condenser ofrefrigerator. This heatcan be used fornumberofdomesticandindustrialpurposes.In minimumconstructional,maintenanceand running cost,thissystem ismuch usefulfor domesticpurpose.Itisvaluable alternative approach to improve overall efficiency and reuse the waste heat. The study has shown that such asystem is technically feasible and economically viable.

Keywords:*COP, Refrigeration effect, subcooling, Waste heatrecovery .*

1. Introduction

The increase in surrounding temperature due to climatic condition affect the performance of refrigeration and AC system and results in reducing the cooling capacity, increase in power consumption leads to detoriate the ability of comfort. Before we discussing the subccoling of refrigerant, it is necessary to understand what refrigeration is. Refrigeration is the removal of heat or transmission of heat from one part of system to another. Subcooling in refrigeration implies that cooling the refrigerant in liquid state at uniform pressure, to temperature that is less than the saturation temperature which corresponds to condenser pressure. Refrigeration is improved when a liquid refrigerant is subcooled by circulation of cold water in heat exchanger i.e condenser. Due to this characteristics, design of condenser needs to change for getting better liquid subcooling.
Therefore the present study has one of the alternative approach for the performance improvement of refrigerator and AC system, with minimal cost.

2. Literature Review

Useofwasteheatrecoveryfromthermalsystemisnotanew techniquealtogether.Thefocusis placed onaneedtodevelopeffective,lesscostlyandmaintenance-freeauxiliaryintegratedwith mainsystemtoachievewasteheatrecovery.If thisideaisimplementedatsystemdesignlevel, then therewould beconsiderable saving ofenergy.
Stinson et al.[1] conducted research in dairy refrigeration by recovering the heat fromcondenser. They found out that by using the water cooled condenser COP of the system is enhanced by 10% to 18%. They also found that increase in condenser pressure reduces COP, and inclusion of heat recovery heat exchanger reduces head loss.
Clark et al. [2] carried out experimentation on 18 ft3 domestic refrigerator. They used watercooled condenser and regular air cooled condenser in parallel. Following are the findings of this research: (i) rise in temperature of cooling water is 350C in 100 hours of continuing operation, (ii) 18% - 20% energy savings for hot water, and (iii) no deterioration of the refrigerant performance.
Milind V. Rane et al. [3] developed sensible heat recovery unit and carried out experiments.Waste heat recovered is utilized for water heating. Their findings are: (i) chiller cooling capacity enhanced by 30% and COP by 20%, (ii) fuel saving reported 81liters HSD/day, annual savings of Rs. 10 Lakh/year, (iii) Reduction in CO2 Emissions 450 ton in 4 years, and (iv) simple payback of 3 to 6 months.
Gustavo POTTKER et. al.[4] a theoretical and experimental analysis of the effect of condensersubcooling on the performance of vapor-compression systems. It is shown that, as condenser subcooling increases, the COP reaches a maximum as a result of a trade-off between increasing refrigerating effect and specific compression work. The thermodynamic properties associated with the relative increase in refrigerating effect, i.e. liquid specific heat and latent heat of vaporization, are dominant to determine the maximum COP improvement with condenser subcooling. Refrigerants with large latent heat of vaporization tend to benefit less from condenser subcooling. For a typical AC system, numerical results indicate that the R1234yf would benefit the most from condenser subcooling in comparison to R410A, R134a and R717 due to its smaller latent heat of vaporization. On the other hand, the value of COP maximizing subcooling does not seem to be a strong function of thermodynamic properties.

Experimental results comparing R1234yf and R134a confirmed the trends observed during the numerical study. For a given operating condition, the system COP increased up to 18% for R1234yf and only 9% for R134a.

AmitPrakash [5] To improve the coefficient of performance, it is to require that compressorwork should decrease and refrigerating effect should increase. Modifications in condenser are meant to increase degree of sub-cooling of refrigerant which increased refrigerating effect or more cooling water is required in condenser. The purpose of a compressor in vapor compression system is to elevate the pressure of the refrigerant, but refrigerant leaves the compressor with comparatively high velocity which may cause splashing of liquid refrigerant in the condenser tube, liquid hump and damage to condenser by erosion. It is needed to convert this kinetic energy to pressure energy by using diffuser. By using diffuser power consumption is less for same refrigerating effect so performance is improved.

3.Problem Description and Objectives

Vaporcompression refrigerationsystemisusedindomesticrefrigeration,food processingand coldstorage, industrialrefrigerationsystem, transportrefrigeration andelectroniccooling.So improvement of performance of system is too important for higher refrigerating effect or reduced power consumptionforsamerefrigeratingeffect.Manyeffortshavetobedonetoimprovethe performanceofVaporCompressionrefrigerationsystem. Toimprovethecoefficient of performance,itistorequirethatcompressorworkshoulddecreaseandrefrigeratingeffect shouldincrease. It is only possible by subcooling refrigerant by either water or air. Modificationsincondenserarenecessary. Thedilemmathatindustry isfacing regardingCFCphase-outandtheproblemsassociated withCFCalternativespresentlyunder development. Thechallenge**of**replacingR-11andR-12presents**a**greatdilemmato manufacturersofhomerefrigerator/freezerssinceR-12isavery popularworkingfluidforthis application.Toxicity isanother issuewithusing nonCFCrefrigerant.

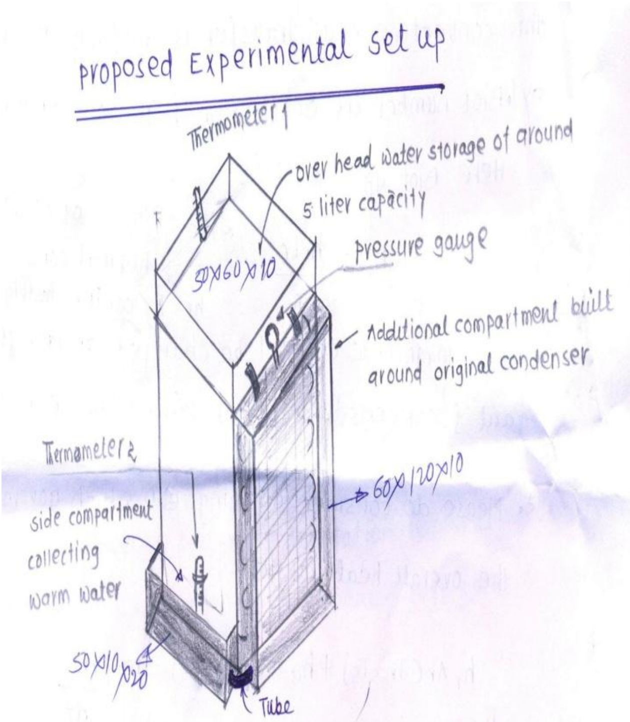
4.Methodology and Experimental Setup

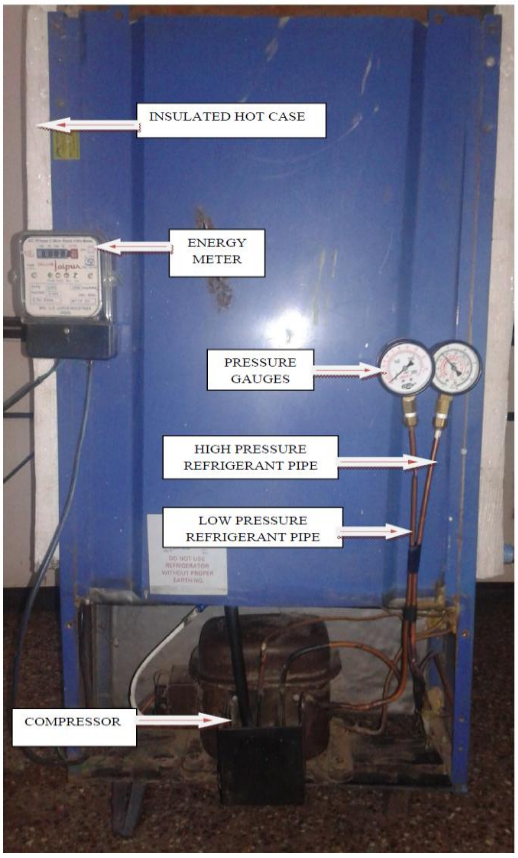
4.1.Methodology

- Optimize the use ,distribution and operation of refrigeration system.
- Examine waste heat streams in refrigeration system.
- Quantify potential value of this heat.
- Examine uses for the Waste heat.
- Quantify useable heat and its value.
- Design heat recovery system.
- Develop and Implement project.
- Result and Analysis

4.2.Experimental Setup

Photograph shows the assembly of hot case, energy meter, temperature sensor and load kept in the evaporator of the refrigerator





5.Experimental Method (Apparatus and Procedure)

The present research used 165 liters household refrigerator working on vapor compression cycle includes four major equipment as Compressor, condense, capillary tube, and evaporator, with a cabinet made over the original condenser
In which cold water is store and dummy load of water is kept in evaporator and evaporator main cabin. With the variation of load in evaporator the system performance is analyzed.

5.1Idea Behind The Project

Due to the presence of subcooled liquid, the two phase heat transfer area would decrease relative to the condition without subcooling. As result saturation temperature would be rise in condenser which would increase the specific compression work, on the other hand the temperature at outlet of condenser decreases with the increase in enthalpy as results of this COP of the system increases.

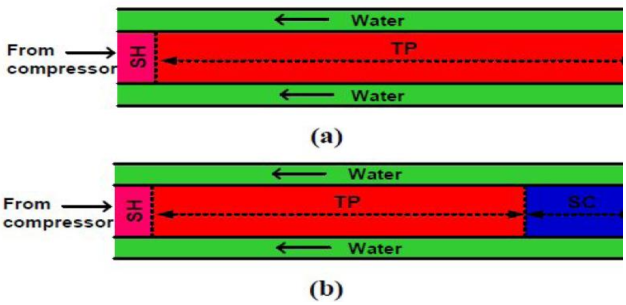


Fig.1 Schematic of water cooled condenser with and without subcooling

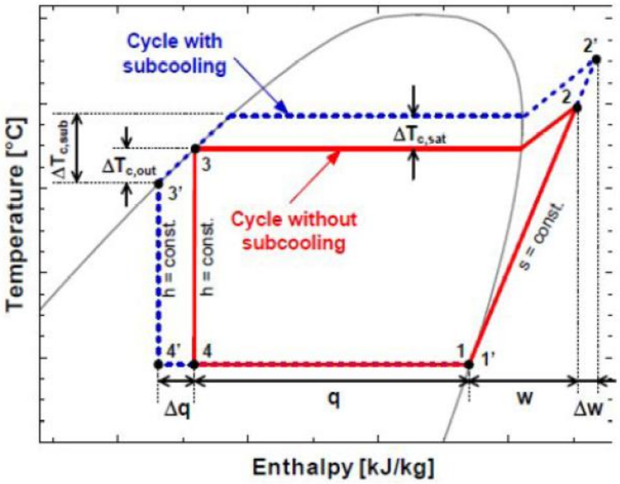


Fig.2 T-s diagram with and without subcooling

6.Experimental Results

6.1. COP of the system calculated on the theoretical data provided by the refrigerator manufacturing company (GODREJ).

For Refrigerator of 165 liters capacity, given data from Kirloskar Ltd manual follows-
Refrigerator cooling capacity:(PROVIDED BY GODREJ)
=76 kcal/hr
= 76×4.187×1000/3600
= 88.392 W
Power required running the compressor
= 1/8 HP
= 1/8×746
= 93.25 W

The coefficient of performance (COP)

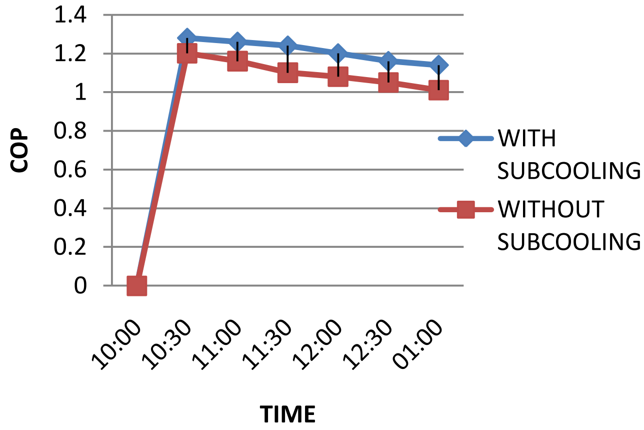
$$=\frac{\text{REFRIGERATION EFFECT}}{\text{WORKSUPPLIED}}$$

$$=\frac{88.5}{93.2}$$

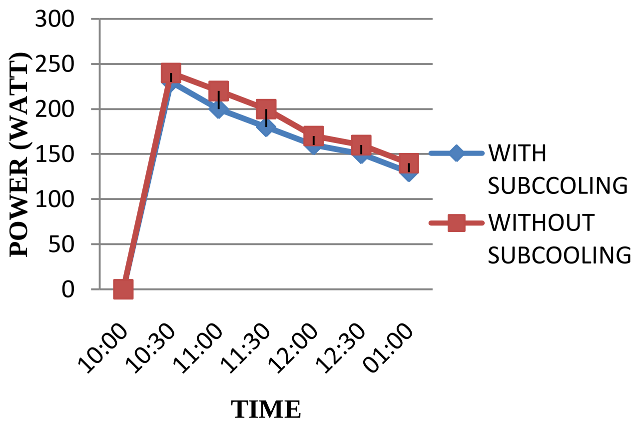
=0.948

6.2 Experimental COP of the system

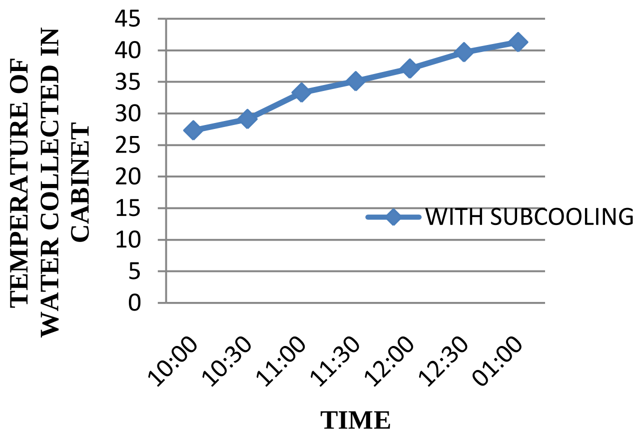
OPERATING CONDITION:
Water kept in evaporator = 5 kg
Water kept in evaporator main cabin = 15 kg



As shown in above fig, the refrigerating effect keeps decreasing as the temperature difference between the refrigerant and article placed is decreased. The COP of system remains almost constant though, it decrease little bit. Average COP is in case with subcooling is 1.04.Somewhat higher thanWithout hot case.



As shown in above fig, Power consumption of refrigerator is somewhat more than that of refrigerator with hot case similar to the case by changing load in other cases without hot case.



As shown in above fig .Same trend of graph showing increasing the temperature of water in outside compartment. It is shown that as the load on refrigerator increases, heat rejected by condenser also increases and as result of this temperature of water in outside compartment also increase. The maximum temperature achieved in this case is 41.3

6.3 Calculations for increased rate of waste heat

Heat Recovery Achieved, Q = Heat Absorbed By Water
Given data-
Mass of water in the outside compartment, M = 10 kg

Specific heat of water, Cp = 4.187 KJ/Kg K

Initial temperature of water = 27.3 °C

Final temperature of water = 41.3 °C

Time required for reading Δt = 180 min
Q = 10 x 4.187 x (41.3–27.3)/180 X60

= 3.74 J/s

Heat recovery achieved Q = Heat Absorbed by Water

= 3.74 W

6.4 Result and discussion

From experimental results it can be concluded that with time the energy consumption of the refrigerator decreases for certain time and then it remain constant. The refrigerating effect keeps decreasing as the temperature difference between the refrigerant and article placed is decreased. The C.O.P. remains almost constant though it decreases a little bit. With hot case, as if we add up heating effect in desired effect, then the COP is increased also otherwise it is almost little bit more than the unit with the hot case. Thus the hot case has not bad effect on the refrigerator. Here with use of hot case, we can keep some food stuff, is hot condition, also temperature of food/milk, etc can be increased without change in taste, so amount of electrical energy used for hot case, as in case of conventional system, can be saved.
The same procedure is followed to show different behavior of the system by changing the different loading condition as mentioned below and results obtTained

CASE 1:
Water kept in evaporator = 3 kg
Water kept in evaporator main cabin = 15 kg

CASE 2:
Water kept in evaporator = 3 kg
Water kept in evaporator main cabin = 20 kg

CASE 3:
Water kept in evaporator = 5 kg
Water kept in evaporator main cabin = 15 kg

The following result shows the comparison between COP of modified setup and waste heat recovery at various operating conditions.

CASE 1: Average COP with and without hot case is obtained as 1.211 and 0.9625 respectively. Waste heat recovery achieved is 3.48 watt

CASE 2: Average COP with and without hot case is obtained as 1.132 and 0.9542 respectively. Waste heat recovery achieved is 4.16 watt

CASE 3: Average COP with and without hot case is obtained as 1.041 and 0.9548 respectively waste heat recovery achieved is 3.74 watt

The result show that modified setup gives better instantaneous efficiency as compared to normal setup. It is shown from results obtain in three different cases as load on refrigerator increases, the power consumption of refrigerator increases and COP decrease a little bit but the temperature of water in outside compartment increases.

Conclusion

A theoretical and experimental study about the effect of condenser subcooling on the performance of vapor compression system has been presented. This study showed that, as condenser subcooling increases, the COP undergoes a maximum as a result of a trade-off between increasing refrigerating effect, due to the reduction of the condenser exit temperature, and increasing specific compression work, due to the increase in the condensing pressure. "Waste heat recovery system" is an excellent tool to conserve available energy. An attempt is made to recover the waste heat from 165 L refrigerator used for domestic purpose. As indicated in this paper, recovered heat can be utilized as food and snacks warmer, water heater, grain dryer. So one can save lot of time and energy also

Future Scope

Now a day saving & regeneration of energy is become a very needful issue due to energy crisis. Cost of fuel is increasing day by day so anybody is providing any equipment for energy saving or regeneration then he will get a lot of future scope, help & research facilities to work for it by any government of developing countries. Worldwide attempts are being made to phase out the production and consumption of chlorofluorocarbons, as these chemicals are responsible for

Depletion of stratospheric ozone layer. Refrigeration, A/C and heat pumps sectors are one of the principal users of these chemicals. Due to the environmental concerns ozone depletion potential (ODP) and global warming potential (GWP) of the existing refrigerants, industry and researchers in this field are investigating long-term solutions.

According to that, following are few recommendations for the future work.

1. A design optimization of refrigeration system such as condenser coil modification and arrangement of hot case around the refrigerator can be made.
2. Application of this type of techniques in air conditioning system can be studied.
3. Change of different refrigerant and optimizing the performance of system can be studied.

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