IOSR Journal of Engineering (IOSR JEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
PP 21-27

Design and Fabrication of Multipurpose Refrigeration Cycle

Mahalingesh Bagali #1, Dr. V. Mariappan *2, Parashuram Nandi #3, G.Shruti#4
#13&4Assistant Professor,# 2Professor, & Principal,
Mechanical Engineering Department, Agnel Institute of Technology and Design
Assagao, Bardez-Goa,
Email:[1]mahalingesh.b@gmail.com,[2]vm@aitdgoa.edu.in, [3]nps@aitdgoa.edu.in, [4]gs@aitdgoa.edu.in

Abstract: *This research targets to satisfy various needs to bring in customer satisfaction in an economical way. In the multi-purpose refrigeration system, both coolingandheating is done instantaneouslyby using single vapour compression refrigeration arrangement. This arrangementhasthe waste heat recovery system from the compressor for heating effect. In a normal VCR cycle, the refrigerant comes at the exit of the compressor releases heat while entering in to the condenser. The Paper proposed utilizes this waste heat for the heating purpose.*

It will be used for all simple vapour compression refrigeration systems. The idea can be stretched for uses in air conditions, freezers, water coolers and small scale refrigeration plants. This paper will lead to hybrid coolingandheatingapplication with same vapour compression refrigeration system.

Keywords: *Refrigeration, vapour compression refrigeration systems, waste heat*

I. Introduction

The refrigeration system is known to the man, since the middle nineteenth century. The inventor, of the time developed a few stray machines to achieve some pleasure. But it paved the way by inviting the attention of scientist for proper studies and research. They were capable to form a reasonably reliable device by the end of the nineteenth century for the refrigeration jobs. But with the advent of efficient rotary compressors and gas turbines, the scientist of refrigeration reached its present height. Hebrews, Greeks, and Romans placed large amounts of snow into storage pits dug into the ground and insulated with wood and straw.

Brewing was the first activity in the northern states to use mechanical refrigeration extensively, beginning with an absorption machine used by S.Liebmann's Sons brewing company in Brooklyn, New York in 1870.

However, as time went on, ice, as a refrigerant agent, became health problem. Says Bern Nagengast, co-author of Heat and Cold: Mastering the Great Indoors (published by the American Society of Heating, Refrigeration and Air-conditioning Engineers), "Good sources were harder and harder to find. By the 1890s natural ice become a problem because of pollution and sewaged damping. "Signs of a problem were first evident in the brewing industry. Soon the meatpacking and dairy industries followed with their complaints. Refrigeration technology provided the solution ice, mechanically manufactured, and giving birth to mechanical refrigeration. Carl(Paul Gottfried) von Linde in 1895 set up a large plant for the production of liquid air. Six years later he developed a method for separating pure liquid oxygen from liquid air that resulted in widespread industrial conversion to processes utilizing oxygen(e.g in steel manufacture)

II. Literature Review

M. Y. Taib and A. A. Aziz, has conducted analysis of performance on a domestic refrigerator. The Co-efficient of performance (COP) is found to be 2.75 and refrigeration capacity ranges from 150W to 205W. Besides, Test rig development method has been presented in this work. The correct data from the experiment is produced from reliable test rig [1].

SanmatiMirji, has designed multipurpose hot chamber from waste heat from domestic refrigerator. Themultipurposesystemismade as an extrafragment of the refrigerator. It uses the heat which producedfrom the refrigerator. The extreme temperature of chamber found as high as 50 ºC and nearby 40 ºC average temperature was found. The main advantage of the invention was to keep cooked food warm for a sufficiently long duration before consumption as well as warming the food removed from the refrigerator before consumption. It will use thedomesticrefrigeratorgenerated waste heat and no need to have any additional electric energy. [2]

Romdhane ben slama, has made a system which can recuperatewasteheat from the refrigeratorcondenser. In the currentworkconventional condenser is used which is of air-cooled type and is substituted by another heat exchanger to warm the water. In the results we come to know that system can produce warm water of temperature up to 60ºC. This paper also analyzed the importance of economic of the waste heat recovery system from the energy efficient point of view [3].

M. M. Rahman et al. has developed a heat recovery system which can recuperate heat from a split air conditioning system. In this system heating tan is designed in such a way that it can hold 60litercapacity. And the copper tube transmitting refrigerant is not submerged in water. Two cylindrical chambers are provided in the heating recovery tank. Water is filled in the inner chamber, and is coiled with the hot refrigerant carrying tube at the external surfaces. It was found that compressor efficiency is improved because of using heat recovery systemandwarm water is supplied continuously for domestic purpose. This system rejectsa lesser amount of heat to the atmosphere so it is safer in ecological aspects [4].

M. BalaKumaran, has improved the performance of a Refrigeration System by utilizing waste heat from Condenser. The Design for waste heat recovery was tested with different refrigerant R-242 and R-236me. R-242 refrigerant gave a increase in waste heat recovery. This paper undertook the evaluation based on study in to the Co-efficient of performance (COP)Improvement of a Domestic Refrigerator of Air Cooledtype and het is recovered from Condenser in terms of its current status, the researches, originality and background. This work has great significant for rising new technologies relates to heat recovery from a domestic refrigerator, in order to get the cooling at low energy cost, no harmful effect to the atmosphere and also it is a low initial cost. So this area needsmoreattention and many more work has to be done [5].

ShreyasGolegaonkar, has performed Experimental Analysis of Heating and Cooling Effect in DomesticRefrigeration System. Investigationalarrangement consists of 165 L capacity refrigerator system. The system is retrofitted with a water storage tank having the total capacity of 20 L. 10 liter volume of water is used for testing purpose. A water in tank is kept ideal till water temperature is increased to 40^0C or above. The maximum temperature achieved in the water tank ataverage load is 40°C. Theoretical Co-efficient of performance (COP) of the systems is achieved more when run with HRU than the system run with air cooled condenser. We can achieve more actual overall Co-efficient of performance (COP) of the systems when run with HRU than the system run with air cooled condenser. The power usage is decreased as compare to conventional system and also it increases as the temperature of water in water tank goes above 38^0C but it is less than the cost ofenergy required to heat 100 liter water up to 42^0C. Recovery of heat from the condenser reduces the heat load to atmosphere and it makes atmospherecomfortable. Electric energy Consumption is decreasedwith the use of water cooled (HRU) condenser instead of air cooled [6].

A. M. Vibhute, has performed experiment on waste heat recovery in domestic refrigerator. In proposed work air cooled condenser is replaced by condenser coil. It is detected that without using waste heat recovery domestic refrigerator gives Co-efficient of performance (COP) 1.1 and waste heat recovery it gives Co-efficient of performance (COP)1.22. So from calculations we come to know that 10.91% more Co-efficient of performance (COP)canimproved by heat recovered in insulated box where temperature is increased by 18^oC [7].

P. Sathiamurthi and PSS. Shrinivasan,deliberated in his research on WHR from an air conditioning unit that the energy can be recovered and used without losing comfort level. They have also exposed that this type of system is economically viable. Energy consumption in the system and environmental pollution can still further be reduced by designing and employing energy saving equipment's [8].

R.A Clark et al.described the design, construction, and testing of an integrated heat recovery system which was designed both to enhance the performance of a residential refrigerator and simultaneously to provide preheated water for an electric hot water heater. The particular opportunity investigated in that study was to preheat the supply water for a hot water system using refrigerator condenser waste heat. An economic analysis revealed that a savings of 18.3 % on the water heater operating cost was possible [9]

Patil and Dange, performed modification of a domestic 190-liter refrigerator to recover the waste heat by installing a water tank containing the condenser coils of refrigerator. Experiment showed that maximum temperature increment was up to 40 ^{o}C. But major drawback with this type of arrangement was that it had no mobility and cannot be used for domestic purposes [10].

III. Experimental Setup

Refrigerator is a common household item used to preserving food. It works on the simple physics principle "The evaporation cause cooling". In fact, the refrigerator does not truly cool stuffs it eliminates heat from the stuff. The important component of the refrigerator is Compressor, Evaporator, Condenser, Expansion device, Refrigerant. The refrigerant which is used in the refrigerator is a liquid such as Ammonia,Freon or CFC will turn to vapour at small temperature. The refrigerant which is there in the heat exchanger coil inthe refrigerator absorbs the heat and which leads refrigerant to vaporize. Then the vapour is compressed by the compressor. This leads to increase the pressureand temperature of the refrigerant. The coil of the heat exchanger outside the refrigerator permits the refrigerator to liberate the heat of pressurization. As it chills the refrigerant condenses back into liquid flows through expansion valve. The liquid refrigerant enters the expansion valvewhererefrigerantconverts from high pressure zone to low pressure zone, so it expands and evaporates. In evaporation it absorbs heat from the coil of heat exchanger inside the refrigerator making it cold. This process mainlyeliminates heat from inside cabin refrigerator and dissipates it to anotherplace that is outside the refrigerator.

The place from where the heat is removed becomes cold and such place known as refrigerator is used for food preserving. The place where the heat is dissipated is however not used by the refrigerator. The heat dissipated by the refrigerator is the waste heat of the refrigerator.

The compressor of refrigerator works round the clock, round the year with intermediate stoppage when the temperature inside the refrigerator is below the set point. The compressor uses electrical energy which is converted to mechanical energy to compress the refrigerant. Since all the electrical energy can't be converted to mechanical energy due to limited conversion efficiency, some energy will be converted to heat energy. This is the also the waste heat generated by the refrigerator. There are many a times to make use of waste heat generated by the refrigerator is used for domestic water heating. The modified system result in energy saving due to non-usage of electricity for keeping food warm, moisture removal from wet clothes and cost saving by combing the both utilities(refrigeration and moisture removal) in one system.

WORKING PRINCIPLE OF MULTIPURPOSE REFRIGERATION SYSTEM

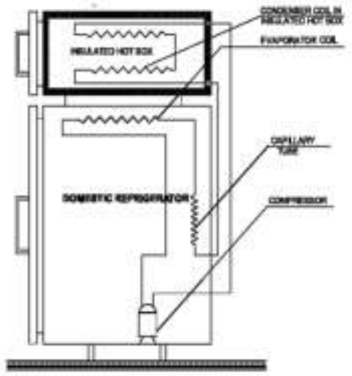

Fig. 1. Block diagram for multipurpose refrigeration system.

In the schematic drawing accompanied by the specifications, fig. 1, describes the multipurpose refrigerator with a warm chamber for the waste heat of the domestic refrigerator. Accordingly the present invention provides a multipurpose warming Apparatus utilizing the waste heat of domestic refrigerator which comprises a warm chamber housing the condenser tubes of the domestic refrigerator The refrigerant which will be used in this Apparatus will be R134a. When compressor is started it draws the low pressure vapour from the evaporator and compresses it isentropically to high pressure, hence the vapour temperature also increase.

Hot vapour from compressor to condenser, where it is cooled, rejects heat, and hot vapour gets converted into liquid. This heat which is rejected is passed on to the heat box by means of natural convection and stored. The liquid phase refrigerant is then passed from the expansion valve which reduces pressure of liquid, thus liquid gets converted into vapour of low dryness fraction. Finally low pressure, low temperature refrigerant passes through the evaporator, it absorbs its latent heat from the cold chamber and gets converted into vapour.

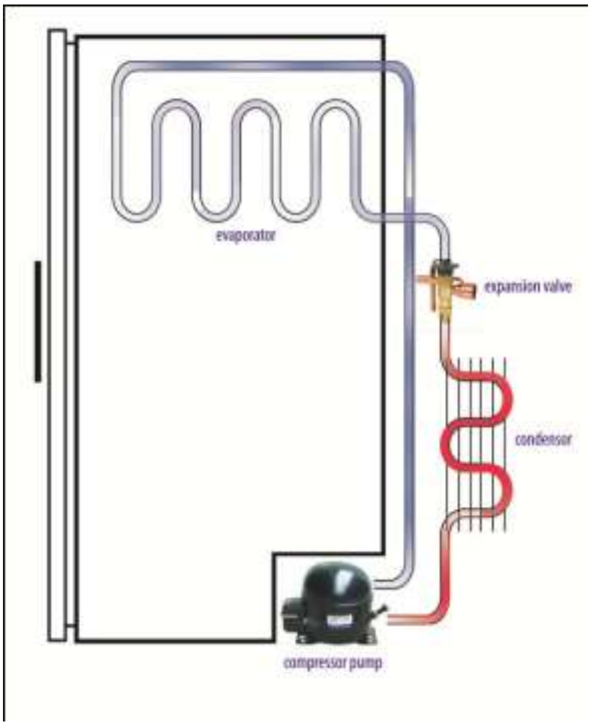

Fig. 2. Domestic Refrigerator Components

It has 4 main components: compressor, condenser, evaporator, and throttling device. Of these components, the throttling device is the one that is responsible for the production of the cold liquid. So we will first analyze the throttling device in a detailed way and move on to the other components.

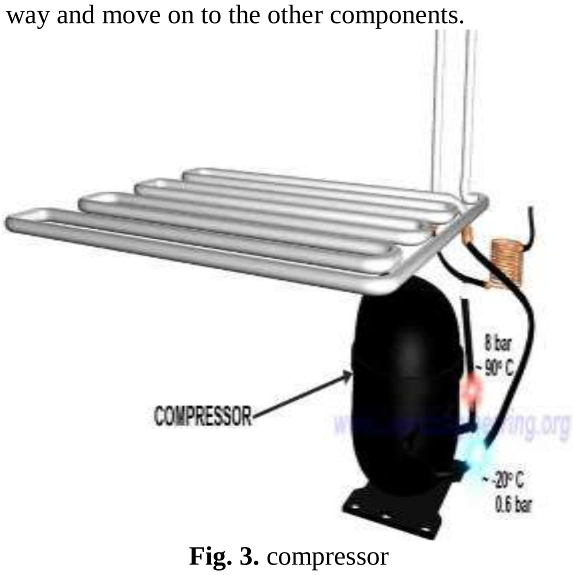

Fig. 3. compressor

A compressor is introduced for this purpose. The compressor will raise the pressure back to its initial level. But since it is compressing gas, along with pressure, temperature will also be increased. This is unavoidable. Now the refrigerant is a high-pressure vapour. To convert it to the liquid state, we must introduce another heat exchanger.

The throttling device obstructs the flow of liquid; cold liquid is produced with the help of this device. In this case, the throttling device is a capillary tube. The capillary tube has an approximate length of 2 m and an inside diameter of around 0.6 mm, so it offers considerable resistance to the flow. For effective throttling at the inlet, the refrigerant should be a high-pressure liquid. The throttling device restricts the flow, which causes a tremendous pressure drop. Due to the drop in pressure, the boiling point of the refrigerant is lowered, and it starts to evaporate. The heat required for evaporation comes from the refrigerant itself, so it loses heat, and its temperature drops. If you check the temperature across the throttling device, you will notice this drop. It is wrong to say that the throttling is a process. We know only the end points of throttling, that is, the states before and after throttling. We don't know the states in between, since this is a highly irreversible change. So it is correct to call throttling a phenomenon instead of a process.

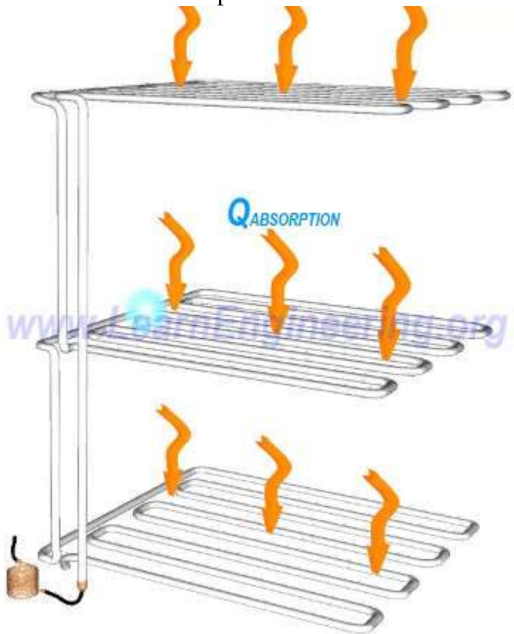

Fig. 4. Evaporator

Evaporator - Heat Absorption Process

The next stage is simple: this cold liquid is passed above the body or object that is to be cooled. At the end the refrigerant absorbs the heat. During the heat absorption process, the refrigerant more evaporates and converts into pure vapour. A proper heat exchanger is essential to carry the cold refrigerant over the body. This type of heat exchanger is known as an evaporator.

So we have produced the required refrigeration effect. If we can return this low-pressure vapour refrigerant to the condition before the throttling process (that is the high-pressure liquid state), we will be able to repeat this process. So first step, let's raise the pressure.

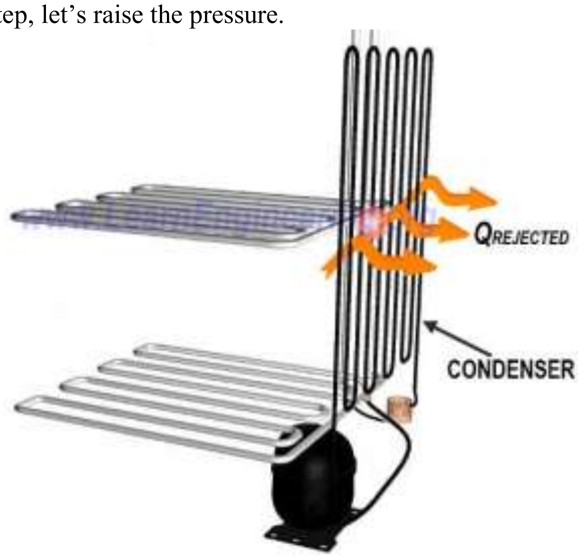

Fig. 5. Condenser

Condenser

This is a heat exchanger which is fitted externaltothe refrigerator, and the refrigerant temperature is greater than a surrounding temperature. So heat will disperse to the atmospheres. The vapor is condensed to liquid, and the temperature is returned to a common level. So the refrigerant is back to its initial state again: a high-pressure liquid. We can repeat this cycle over and over for continuous refrigeration. This cycle is known as the vapor compression cycle. Refrigeration technology based on the vapor compression cycle is the most commonly used one in home and industrial applications.

IV. Evaporator Design

i) Evaporator temperature: It should be decided according to the requirement. When it is to be used for cooling of certain liquid, the evaporator temperature can be kept around 5 K below the temperature of the cooling fluid. Sometimes evaporator is used to dehumidify the conditioned or process air. Under such situation the evaporator temperature should be kept below apparatus dew point temperature.
(ii) After going through the desirable properties of refrigerants, it is decided to select R-134a as the refrigerant.
(iii) Refrigeration effect: The inlet temperature of refrigerant entering the evaporator is fixed as -2^0C and outlet temperature is 18^0C. Let h1 be the enthalpy of vapour leaving the evaporator and $h_4$is the enthalpy of the vapour entering the evaporator.
The refrigerant flow rate through the system is found from $m= Q_D/q_C= Q_D / (h_1-h_4)$ 1.1

Where
Q_D = cooling load =180W = 0.18KW = 10.8 kg/min
Q_C = refrigeration effect
m= 0.06 kg/min
(iv)Tube selection:The following factors are considered during selection of a tube:
(a) The pressure drop should be quite low.
(b) A cheap material should be used.
(c) Workability, should be easily shaped and brazed or soldered if necessary
Wall thickness from the simple expression:
t = pd/(2f) 1.2
Where P=Maximum Pressure
d=Diameter of pipe
f=hoop stress
t=0.13mm
(v) Surface area of the evaporator is obtained from:
$A = Q_D / (\Delta T_m \times U)$ 1.3
Where ΔT_m = log mean temp difference
U = overall heat transfer coefficient
$LMTD = [(T_4-T_L) – (T_1–T_L)] / \ln [(T_4-T_L) / (T_1–T_L)]$ 1.4
LMTD: 33.305K
Considering overall heat transfer coefficient, U = 16 W/m^2k
$A = Q_D / (\Delta T_m \times U)$ 1.5
A= 0.3378 m^2
(vi) Length of the pipe or tube:
After knowing the surface of the evaporator, the pipe length L_P is calculated as:$L_p = A /(л \times d)$ 1.6
L_p = 10.75m
(vii) No of turns is found out by: $N_P = L_P$ / perimeter
N_P = 8.26 turns
In the design of condenser, the four factors are of great importance,
(i) Heat transfer and pressure drop characteristics,
(ii) Working pressure,
(iii) Type of fluid,
(iv) Manufacturing ease and after service or maintenance.
(i)The heat transfer rate for condenser is obtained by,
$Q_h=m(h_2-h_4)$ 1.7
Where h_2=enthalpy of refrigerant coming out of compressor
h_4=enthalpy of refrigerant from condenser
Q_h=180W
(ii)Tube selection
t=pd/(2f) 1.8
Where p=max pressure
d=diameter of pipe
f=hoop stress
t=1.24mm
(iii)Surface area of condenser is obtained from:
$A=Q_h/(\Delta T\times U)$ 1.9
A=0.4911m^2

(iv)Length of the pipe or tube

L_p=A/(л×d) 2.0

L_p=16.42m

V. Conclusions

The project "design and fabrication of multipurpose refrigeration system" is based on the way to increase the thermal efficiency of VCRs systems by using the waste heat given out to the atmosphere for heating purpose without increase in additional input power supply. The expected temperature in the heating compartment is predicted up to the range of 35°C to 45°C.Using the sophisticated design information and tools the related refrigeration system will be developing practically.

The system is cheap in initial as well as running cost as it is not need additional input power energy for the heating effect; it has no moving parts in the system so maintenance cost is also very small. This project has great significance aimed atemergent new technologies related to heat regaining from all domestic refrigerators, to get cooling at low energy cost, no harmful effect to environment. Besides, the refrigerator this system can be utilized as conventional refrigerator by maintaining the door of the cabin open in circumstance of nonappearance of heat sink. The system is most suitable for domestic use such as keeping food warm, moisture removal in case of wet clothes, fermentation of curd and other applications.

References

[1]. ShreyasGolegaonkar, RanjeetKadam, "Experimental Analysis of Heating and Cooling Effect in Household Refrigeration System" ISSN: 2321-8169 Volume: 5 Issue: 6.

[2]. M. BalaKumaran, T.Sivasubramaniyan, "Improving the Performance of a Refrigeration System by Utilizing Waste Heat from Condenser" ISSN: 2348-2079 Volume-5 Issue-2.

[3]. M. M. Rahman , Adrian Ng, "An Environmental Friendly and Cost Effective Way of Water Heating through the Recovery of Waste Heat from Split Air Conditioning System" ORGANIZED BY UNIVERSITI TENAGA NASIONAL, BANGI, SELANGOR, MALAYSIA; 28-30 AUGUST 2006.

[4]. Tanmay Patil, NiteshMedhane, "A Review On Recovering Waste Heat From Condenser Of Domestic Refrigerator" IJSRM Volume 3 Issue3 Pages 2409-2414(2015).

[5]. SanmatiAnnarayMirji, "MULTIPURPOSE WARM CHAMBER FROM THE WASTE HEAT OF DOMESTIC REFRIGERATOR" Pub. No.: US 2006/0179860 A1 Pub. Date: Aug. 17, 2006

[6]. Abhijith M S , Anoop M O, "A REVIEW ON COMBINED UNIT OF REFRIGERATION AND WATER HEATER" International Journal of Scientific & Engineering Research, Volume 7, Issue 4, April-2016

[7]. Romdhane Ben Slama, "THERMODYNAMIC HEAT WATER BY THE CONDENSER OF REFRIGERATOR" Int. Symp. on Convective Heat and Mass Transfer in Sustainable Energy April 26 – May 1, 2009, Tunisia.

[8]. M. Vibhute , Avinash M. Patil, "Waste heat recovery in Domestic Refrigerator" International Engineering Research Journal (IERJ), Special Issue Page 131-133, ISSN 2395-1621.

[9]. R.S. KHURMI & J.K. GUPTA, "Textbook of refrigeration and air-conditioning (M.E.)", S.CHAND publications.