International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-2, July 2019

Development of Multi use Refrigeration System

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Abstract: ***Conservation of energy is the important factor from global point of view. Waste heat recovery has become significantly necessary and instant effort should be made to conserve this waste energy. Presently the refrigerator system rejects a lot of heat through condenser. This heat can be used for a variety of useful purposes. A multiuse refrigeration setup has been developed in which, both heating and cooling will be done simultaneously with the help of single vapour compression refrigeration cycle. It has a waste heat recovery system from the compressor for heating effect. Here without disturbing refrigeration cycle, the waste heat energy is used for useful work. The study has shown that such a system is technically feasible and economically viable. This concept has a scope of applications in variety of products such as air conditioners, freezers, water coolers and small scale refrigeration plants. This project leads to hybrid heating and cooling application with same vapour compression refrigeration system.***

Index Terms: ***Waste heat; refrigerator; condenser; heating; refrigeration cycle; vapour compression.***

I. INTRODUCTION

Refrigeration is a process of absorbing heat from one location and rejection to another location in controlled conditions. Refrigeration has many applications, such as: household refrigerators, industrial freezers, cryogenics, and air conditioning. Heat pumps may use the heat output of the refrigeration process, and also may be designed to be reversible, but are otherwise similar to refrigeration units [1].

This is a modified refrigeration system which does four processes such as heating of water, cooling of water, cooling of air and heating of air. All these processes are carried out with the use of a single compressor. This system uses the process of waste heat recovery in which normal refrigeration system incorporates a water heating system, air cooling system and air heating system in addition to the water cooling system[3]. In this simple system heat lost from the condenser is used to heat water and remaining heat used to heat water and cold refrigerant after cooling water is further used to cool the air. For the heat recovery from the domestic refrigeration system some modification are made. As seen in the regular refrigeration system, a lot of heat energy is generated in the condenser unit. The condenser heat is recovered and is splited into two parts for heating water and air. A part of heat is transferred to the water there by increases the temperature of the water. The remaining heat is used to heat the air. The evaporator unit is also split into two parts for cooling water and air. After passing through expansion valve the pressure and temperature decreases [2]. The heat is absorbed by the refrigerant, thereby reduces the water temperature. Remaining heat present in the refrigerant is used to cool the air by absorbing the heat from air. This system utilizes all the waste heat to do multiple tasks.

II. WORKING OF BASIC REFRIGERATION SYSTEM

A Basic refrigeration system is a system which removes heat from the area to be cooled through a liquid medium called as refrigerant. The removed heat is rejected to some other place or the surrounding environment. These systems have four components namely a condenser, a compressor, an evaporator and a throttle or expansion valve. The compressor is charged with a gas and is connected to two other units namely the evaporator and the condenser. The refrigerant enters into the compressor and is compressed to a higher pressure which results in higher temperature. This thermodynamic state of the refrigerant is known as saturated vapour. This vapour is sent through the condenser coils or tubes where it is cooled and converted into liquid. In the process, the heat in the refrigerant is rejected or carried away by the surrounded air. This liquid state of the refrigerant in the thermodynamic state is called as saturated liquid. This is next sent through an expansion valve where a sudden reduction in pressure. As a result of this a flash evaporation of a part of liquid happens. This phenomenon results in lowering the temperature of the vapour liquid refrigerant mixture than the enclosed space to be refrigerated. This cold mixture is circulated in the coils or tubes of the evaporator which in turn absorbs heat present in the enclosed chamber evaporating the remaining liquid in the mixture, thus lowering the temperature of the enclosed space. The heat absorbed in the process is later rejected in the condenser and wasted. This process is repeated as a cycle.

III. CONSTRUCTION OF MULTI USE REFREGERATION SYSTEM

The vapour compression refrigeration system is the one which uses a liquid refrigerant circulating as the medium which absorb and also removes heat from the enclosed space to be cooled and rejects that heat elsewhere.

Revised Manuscript Received on 30 July 2019.
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These systems have four components namely a condenser, a compressor, an evaporator and a throttle or expansion valve (Fig.1.1). The compressor is charged with a gas and is connected to two other units namely the evaporator and the condenser The refrigerant enters into the compressor and is compressed to a higher pressure which results in higher temperature.

The condenser system is splited into two units for the utilization of dissipated heat in terms of water heating and space heating .And further the evaporator system is splited into two units for cooling water and for space cooling (Fig. 1.2). The whole system works in a single vapor compression cycle. There by utilizing the maximum amount of waste heat this was rejected to the outer environment.

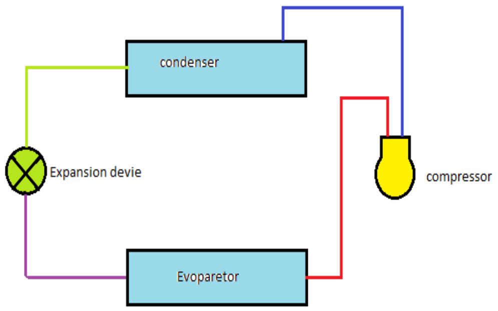

Fig. 1.1. Flow chart of Genral RFS

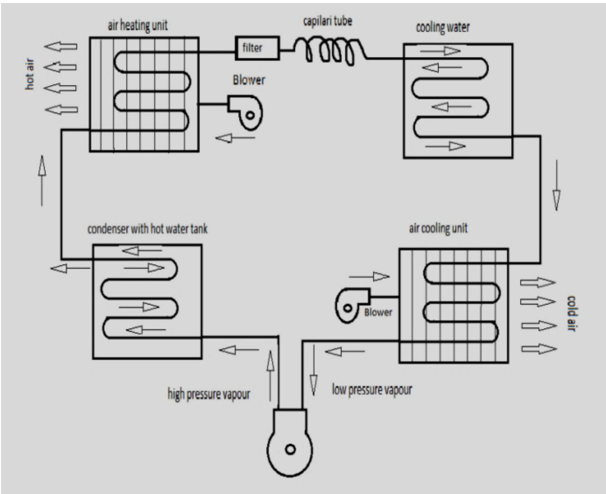

Fig. 1.2: Actual flow chart of MURFS

IV. WORKING

In this system the same old principle "the liquid when evaporates absorbs heat" is employed. The only specialty of this method is that same refrigerant is used again and again in a cycle. The refrigerant continues changing from liquid to vapour state, when absorbing heat and from vapour to liquid state, when giving out heat. The refrigerant picks up heat from the space to be cooled and takes it to a distant point and rejects it there. In other words in this care heat is transferred from a lower temperature to a higher temperature. According to second law of thermodynamics this can only be accomplished by the expenditure of energy from some external source. Vapour compression refrigeration system was refrigeration sealed in an airtight and leak proof mechanism. The refrigerant is circulated through the system and it undergoes a number of changes in its state while passing through various components of the system. Each such change in the state of vapour is called a process. The system repeats over and over again this process. The process of repetition of a similar order of operation is called cycle. The high pressure high temperature refrigerant coming out from the compressor is passed to the condenser. The condenser coil placed around inside periphery of the heating water tank filled with water. During condensation large amount of heat is lost, this lost heat utilize to the water. Now the low temperature high pressure liquid refrigerant is passed through the expansion device, which is a copper tube of diameter around "0.01m". After expansion, pressure decreases and temperature also decreases. The low pressure low temperature liquid refrigerant is passed to the evaporator. The boiling of refrigerant takes place at lower temperature by absorbing heat from the water surrounded by cooling tank.so the water in the tank getting cooled. The refrigerant coming out from the tank which is under cold condition is passed through an air-cooler. The air-cooler consists of radiator and a blower. The refrigerant is passed through the copper tube aligned in zigzag manner connected with fins. Refrigerant absorbs heat from the fin material, the temperature of fin getting lowered also air around the fins getting cold. This cold air is drawn though the radiator chamber by the help of a blower and it is then discharge to space to be cooled. During this process the liquid refrigerant is converted in to vapour state and again passed to the compressor. This cycle repeats. The function of the radiator is to reject coolant heat to the outside air. The name radiator is a misnomer because the heat transfer from coolant to the air is by conduction and forced convection instead of by radiation.

V. COEFFICIENT OF PERFORMANCE (COP)

COP of a heat pump, refrigerator or air conditioning system is ratio of useful heating or cooling provided to work required.

A. *COP of Normal Refrigeration*

Heat extracted (Q) = m $\times$ C_p $\times$ ΔT

Where, m = mass, kg

C_p = Specific heat, kJ/kg.K

ΔT = raise in temperature, K

Density of water = 1000kg/m^3

Volume of water = 6 liters

Mass of water = Volume $\times$ Density

= 6/1000$\times$1000

= 6 kg

Specific heat of water = 4.187kJ/kg.K

Raise in temperature = T_1-T_2

T_1 = Normal water temperature =32^{0}C = 305K

T_2 = Cold water temperature = 25^{0}C =298K

t =10 minutes

t = Time taken to raise the temperature from T_1 to T_2

Work done (W) = 0.76$\times$230

=174.8W

= 0.1748 kW

=

0.1748kJ/s $\times$10 $\times$ 60sec

W =104.88 kJ

Retrieval Number: A9251058119/19©BEIESP
DOI: 10.35940/ijrte.A9251.078219
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Heat extracted (Q) = 6 × 4.187 × (305-298)
= 175.85 kJ (water cooling effect)

COP = Heat extracted/ Work done
= 175.85/104.88
= **1.67**

B. COP of Multiuse Refrigeration System

Heat extracted = m × C_p × ΔT

Where, m = mass, kg
C_p = Specific heat, kJ/kg.K
ΔT= raise in temperature, K
Density of water = 1000kg/m^3
Volume of water = 6 liters

Mass of water = Volume × Density
= 6/1000×1000
= 6 kg

Air discharge,
At air cooling = Velocity of air × Area
= 4.3 × (0.1×0.13)
= 0.0559 m^3/s

At air heating = Velocity of air × Area
= 8 × (0.07× 0.13)
= 0.0728 m^3/s

Mass of air,
At air cooling = Density × Discharge × Time
=1.225×0.0559×10×60
= 41.08 kg

At air cooling = Density × Discharge × Time
=1.225×0.0728×10×60
= 53.5 kg

Specific heat of water, C_{pw} = 4.187 kJ/kg.K
Specific heat of air, C_{pa}=1.005 kJ/kg.K
Raise in temperature = ΔT
T_1- Normal water temperature =32^0C = 305K
T_2- Cold water temperature = 25^0C =298K
T_3- Hot water temperature = 40^0C =313K
T_4- Normal air temperature = 33^0C =306K
T_5 –Cold air temperature = 29^0C =302K
T_6- Hot air temperature = 36^0C =309K
t =10 minutes
t = Time taken to raise the temperature from T_1 to T_2

Work done (W) = 1.06×230
= 243.8W
= 0.2438kW
= 0.2438kJ/s ×10×60sec
=146.28kJ

Total heat extracted (Q) = Heat extracted in water cooling unit + Heat supplied in water heating unit + Heat extracted in air cooling unit + Heat supplied in air heating unit

$$Q =\{ m_w C_{pw}(T_1-T_2)\} +\{ m_w C_{pw}(T_3-T_1)\} +\{ m_a C_{pa}(T_4-T_5)\} + \{m_a C_{pa}(T_6-T_4)\}$$

= {6×4.187×(305-298)}+{6×4.187×(313-305)} +{41.08×1.005× (306-302)}+{ 53.5×1.005× (309-306)}

Q = 703.27 kJ

COP = Total heat extracted/ Work done
= 703.27/146.28
= **4.8**

VI. RESULT AND DISCUSSION

The energy input supplied to the normal system and to this system is nearly same, but output from this fabricated system is comparatively higher. When the single system is working the COP of the system is 1.67, whereas in the multi-use refrigeration system a COP of 4.8 is obtained which is higher from the single system. Normal system serves only a single purpose; whereas the fabricated system is multi-functional.

VII. CONCLUSION

In this ever changing world every day there is a new discovery in all fields of science and technology, benefiting the mankind. Multi use refrigeration system is a simple compact system with moderate efficiency and low power consumption. Waste heat recovery from the condenser is made possible with the desired effects of cooling water and air cooling. The four systems are considerably effective and economical. Even though single compressor is used, the desired effects are sensible. The addition of the three units does not need extra power supply which shows the effectiveness of the system.

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