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Heat utilization from refrigerator condenser using water heater and hot box

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Abstract
This project describes the development and use of new type of "multipurpose refrigerator- a refrigerator with hot box and water heater".
Normal refrigerator works on VCC, extract heat from substance to be cooled and exert that heat to the atmosphere through the device called condenser. That refrigerator which is been previously made to exert a lot of heat through condenser is modified to overcome this wastage of heat. For recovery of that waste heat we decide to develop a machine which utilizes that waste heat for heating hot case and heating water with the use of water heater. The main important thing in our model is, it does not require any kind of additional power supply for its working operation. As the energy saving plays vital role in development, our model has lot of importance from that particular point of view. Another interesting thing in this project is that it performs operation without disturbing original refrigerator working.

Keywords: Waste heat recovery, 165 liter Domestic refrigerator, Air cooled condenser, water heater, hotbox, Experimental analysis, COP of refrigerator

Introduction

Refrigeration

Refrigeration is the achievement of temperatures below that of the local environment. The main purpose of refrigeration is thermal conditioning (e.g. for good preservation OR air conditioning), and the basic apparatus is refrigerator, a thermal machine producing cold. Other names for special types of refrigerators are freezers, chillers, coolers, as well as the informal word fridge**.**

Introduction to simple refrigeration cycle

A vapour compression refrigeration system is an improved type of air refrigeration system in which a suitable working substance, termed as refrigerant, is used. It condenses and evaporates at temperatures and pressures closed to atmospherically condition. The refrigerants, used for this purpose are ammonia (NH_3), carbon dioxide (CO_2) and sulphur dioxide (SO_2). The refrigerant used, does not leave the system, but is circulated throughout the system alternately condensing and evaporating. In evaporating, the refrigerant absorbs its latent heat from the brine (salt water) which is used for circulating it around the cold chamber.
While condensing, it gives out its latent heat to the circulating water of the cooler. The vapour compression refrigeration system is therefore latent heat pump, as it pumps its latent heat from brine and delivers it to the cooler. The vapour 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.

Construction of Refrigerator

The vapour compression refrigeration system uses a circulating liquid refrigerant as the medium which absorb and removes heat from the space to be cooled and subsequently rejects that heat elsewhere. All such system have four components,
a compressor, a condenser, an expansion valve (also called throttle valve), and an evaporator. The compressor of the refrigerator is connected to two units, i.e., to evaporator and to condenser. Compressor is placed at back-lower side of the refrigerator. Gas charging to refrigerator is done at compressor.

Working of refrigerator

Circulating refrigerant enters the compressor in the thermodynamic state known as a saturated vapour and is compressed to a higher pressure, resulting in a higher temperature. The hot, compressed vapour is then in the thermodynamic state as a known superheated vapour and it is at a temperature and pressure at which it can be condensed with typically available cooling water or cooling air. That hot vapour is routed through a condenser where it is cooled and condensed into a liquid by flowing through a coil or tubes with cool water or cool air flowing across the coil or tubes. This is where the circulating refrigerant rejects heat from the system and the rejected heat is carried away by the air.

The condensed liquid refrigerant, in the thermodynamic state known as a saturated liquid, is next routed through an expansion valve where it undergoes an abrupt reduction in pressure. That pressure reduction results in the adiabatic flash evaporation of a part of the liquid refrigerant.

The auto-refrigeration effect of the adiabatic flash evaporation lower the temperature

of the liquid and vapour refrigerant mixture to where it is colder than the temperature of the enclosed space to be refrigerated.

The cold mixture is then routed through the coil or tubes in the evaporator. A fan circulates the warm air in the enclosed space across the coil or tubes carrying the cold refrigerant liquid and vapour mixture. That warm air evaporates the liquid part of the cold refrigerant mixture. At the same time, the circulating air is cooled and thus lowers the temperature of the enclosed space to the desired temperature. The evaporator is where the circulating refrigerant absorbs and remove heat which is subsequently rejected in the condenser and transferred elsewhere by the water or air used in the condenser.

To complete the refrigeration cycle, the refrigerant vapor from the evaporator is again a saturation vapour and is routed back into the compressor. And cycle is continued.

Introduction to modifications

Refrigerator with hot box & water heater tank

The refrigerator with hot box & water heater is based on same principle of vapour compression cycle but there is a small change in cycle. The discharge line of compressor is by passed before it go to regular condenser, it passed through system (water tank and in insulated box known as hot box). This system is controlled by valve mechanism. After passing through system liquid line is connected to evaporator then the compressor. And the cycle is continues.

The wasted heat is condenser is nearly above 50^0-60^0C. This wasted heat is utilized various applications such as the water heating and collected in box known as Hot Box.

System Description and Design

We manufacture the water heater tank of desired capacity accordingly we pass the compressors discharge line then pass through capillary and then evaporator and was connected to compressor and thus continued the cycle then we decided to install one more system called hot box. At that time we realize that when the refrigerant is passed through 2 systems simultaneously then efficiency of system is reduced. Then we fixed thevalve. Each system was given one inlet valve and one outlet valve. Then we prepared a circuit considering that one system will run at time, ensuring no leakage will occur and to increase the efficiency.

In the proposed system, the basic requirement is to utilize more and more energy (waste heat). For that purpose some calculations are made regarding size and length of condenser and then refrigerator with water heater and hot box is designed. But after different discussions and calculations for heat transfer rates we approached to the final design of insulated cabin (hot box) with compact construction and with reasonable cost by using old microwave. So as to extract more and more heat, we have wound copper tubing on old microwave after removing all unnecessary parts and then covered by hot line sheet (insulation) to avoid heat leakage to the surrounding.

This whole assembly is placed on the top of the refrigerator. The main advantage of this design is that we can get maximum heat with minimum losses.

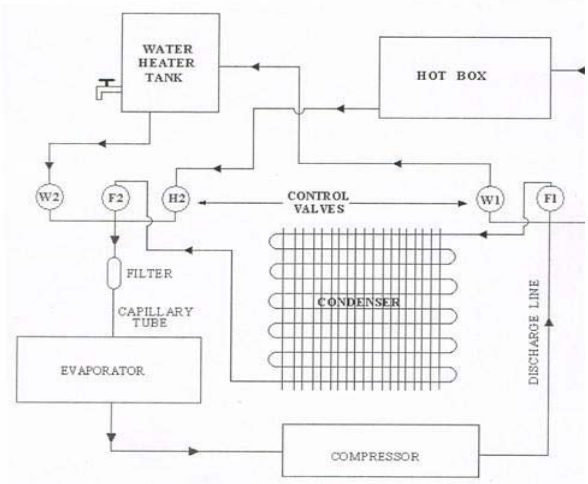

Fig 1.3.1 Refrigerator with hot box and water heater

Refrigerator with hot box & water heater tank

The refrigerator with hot box & water heater (FIG.1) is based on same principle of vapour compression cycle but there is a small change in cycle. The discharge line of compressor is by passed before it go to regular condenser, it passed through system (water tank and in insulated box known as hot box). This system is controlled by valve mechanism. After passing through system liquid line is connected to evaporator then the compressor. And the cycle is continues.

The wasted heat is condenser is nearly above 50^0-60^0C. This wasted heat is utilized various applications such as the water heating and reheating the food collected in box known as Hot Box.

A new valve mechanism is introduced in this prototype. This is a six valve mechanism. This valve mechanism enables the user to switch to different units, i.e., to water heater or to hot box or to regular condenser.

Literature Review

The survey of the literature regarding the waste heat recovery and using of various compressor oils in the household refrigerator and air-conditioners are listed.S.S. Hu, B.J. Huang et al conducted an experimental investigation on a split air conditioner having water cooled condenser. They developed a simple water-cooled air conditioner utilizing a cooling tower with cellulose pad filling material to cool the water for condensing operation. Abu-Mulaweh designed and developed a thermosyphon heat recovery system which can recover heat from a window air conditioner. They designed two types of heat exchangers, concentric type heat exchanger and coiled

heat exchanger and then it is retrofitted in to the air conditioning system. They analysed the performance of the system with these two types of heat exchangers. The circulation of water through the heat exchanger is done with the themosyphon effect which completely eliminates the need of a pump.For having that, the heat exchangers are connected to a water storage tank and when the water in the heat exchanger get heated up by the superheated refrigerant the hot water flow upward through the connecting pipe into the top of the storage tank and at the same time the cold water from the bottom of the tank will flow into the heat exchanger.

Sreejit k published journal papers on

"Experimental Investigation of A Domestic Refrigerator Having Water-Cooled Condenser

Using Various Compressor Oils" stating that condenser coils can be used for floor heater. Household refrigerator is common appliance that consists of thermally insulated compartment and which transfers heat from inside compartment to its external environment so that the condenser coil gets heated and can be used as a floor heater by simply forming a floor by adjusting the coil to the floor.So the floor heater can be used for heating water and many other purposes. This idea was brought by Sreejith k. jyoti engg college,kerla in feburary 2013.The refrigerating unit rejects considerable amount of heat to the atmosphere through its condensing coil unit. So, by suitably retrofitting the WHRS in the unit, waste heat is recovered. This heat is used to keep snacks and food warm, to heat the water which can be further used in health care centers, schools and industrial processes, to wash the cans in dairy by hot condensate, to dry clothes, grains etc. thereby saving significant amount of energy.

From these ideas we merged some of them and brought out a modified set up with the help of valve mechanism. The valve mechanism will help us to work with any of the components, i.e., water heater and hot box at a time as per the requirements of customer.

Working of System

The working of the system can be considered in three different ways. These are:

1. Regular refrigeration cycle
2. Refrigerator with water heater tank
3. Refrigerator with hot box

Regular refrigeration cycle

The construction and working of regular refrigeration cycle is as:

Construction

The vapour compression refrigeration system uses a circulating liquid refrigerant as the medium which absorb and removes heat from the space to be cooled and subsequently rejects that heat

elsewhere. All such system have four components, a compressor, a condenser, an expansion valve (also called throttle valve), and an evaporator.

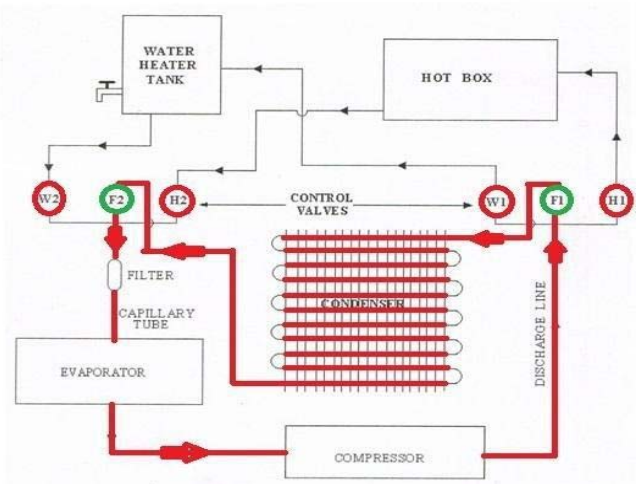

Fig 4.2.1 Regular condenser control system

Working

Circulating refrigerant enters the compressor in the thermodynamic state known as a saturated vapour and is compressed to a higher pressure, resulting in a higher temperature as well. The hot, compressed vapour is then in the thermodynamic state as a known superheated vapour and it is at a temperature and pressure at which it can be condensed with typically available cooling water or cooling air. That hot vapour is routed through a condenser where it is cooled and condensed into a liquid by flowing through a coil or tubes with cool water or cool air flowing across the coil or tubes. This is where the circulating refrigerant rejects heat from the system and the rejected heat is carried away by the air.

The condensed liquid refrigerant, in the thermodynamic state known as a saturated liquid, is next routed through an expansion valve where it undergoes an abrupt reduction in pressure. That pressure reduction results in the adiabatic flash evaporation of a part of the liquid refrigerant. The auto-refrigeration effect of the adiabatic flash evaporation lower the temperature of the liquid and vapour refrigerant mixture to where it is colder than the temperature of the enclosed space to be refrigerated.

The cold mixture is then routed through the coil or tubes in the evaporator. A fan circulates the warm air in the enclosed space across the coil or tubes carrying the cold refrigerant liquid and vapour mixture. That warm air evaporates the liquid part of the cold refrigerant mixture. At the same time, the circulating air is cooled and thus lowers the temperature of the enclosed space to the desired temperature. The evaporator is where the circulating refrigerant absorbs and remove heat which is subsequently rejected in the condenser and transferred elsewhere by the water or air used in the condenser.To complete the refrigeration cycle, the refrigerant vapor from the evaporator is again a saturation vapour and is routed back into the compressor. And cycle is continued.

Refrigerator with Water Heater Tank

The Refrigerator with water heater tank is a system which heats the water by using waste heat exerted by the condenser. It done by the circulating the hot refrigerant through the pipe line through the water tank. The construction and working of refrigerator with water heater tank is as:

Construction

This system contains Refrigerator (evaporator), valve system, water heater tank and pipe line circuit, The discharge line of compressor is connected to the water heater tank through a valve(W1) with help of copper pipe line having diameter 4mm. The pipeline circulated in the water tank and then is connected to the filter through valve(W2). Now the filter is connected to Refrigerator(Evaporator) by capillary. Then Refrigerator(Evaporator) outlet is connected to compressor and cycle is completed.

Working

Circulating refrigerant enters the compressor in the thermodynamic state known as saturated vapour and is compressed to a higher pressure, resulting in the higher temperature as well. The hot compressed vapour is then in the thermodynamics state known as super heated vapour and it is at the temperature and pressure is come to water heater tank then valve (W1) is open and other valve (F1 &H1) is closed. That what vapour is routed through a water heater tank where it is cooled by exerting heat and condensation takes place. This is where the circulating refrigerant rejects heat from the system and the rejected heat is carried out in the water heater tank.

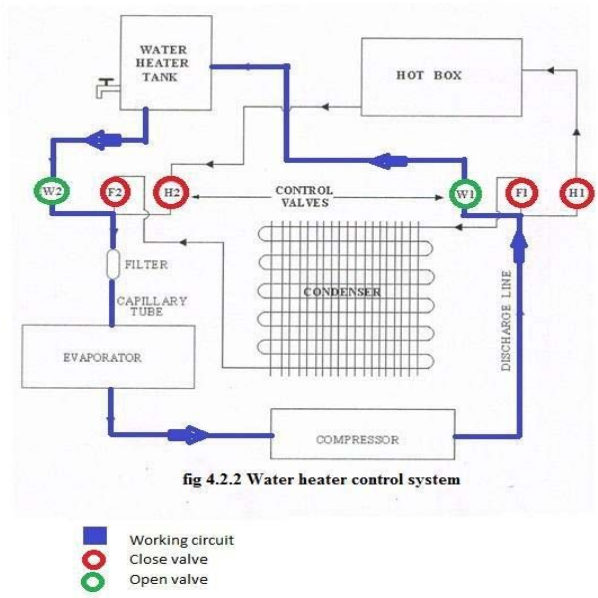

fig 4.2.2 Water heater control system

Now condensed liquid refrigerant is connected to a filter through valve (W2), when valve(W2) is open and other valve (F2&H2) are closed.The condensed liquid refrigerant in the thermodynamic state known as a saturated liquid, is passed through filter where refrigerant is filter and remove the moisture content from the refrigerant. Then the saturated liquid refrigerant routed through a capillary tube where expansion of refrigerant takes place and an a abrupt reduction iin pressure. That pressure reduction result in the adiabatic flash evaporation of a part of the liquid refrigerant. The autorefrigeration effect of the adiabatic flash evaporation lowers the temperature of the liquid and vapour refrigerant mixture to where it is colder than the temperature of the enclosed space to be refrigerated. Now section of saturated vapour takes place from evaporated and it goes to compressor. To complete the refrigeration cycle the refrigerant vapour from the evaporator is again a saturated vapour and it routed back in to the compressor. And cycle is continued

Refrigerator with hot box

The Refrigerator with hot box is a system which heat the space inside the box known as Hot Box by using waste heat exerted by condenser, It is done by circulating the hot refrigerant through the pipe line wound inside the box. The construction and working of refrigerator with hot box is:

Construction

This system contains Refrigerator (Evaporator), compressor, valve system, hot box and pipe line circuit. The discharge line of compressor is connected to the hot box through a vale (H1) with the help of copper pipe line having diameter 4mm. The pipe line circulated inside the hot box and the is connected to filter through valve (H2).

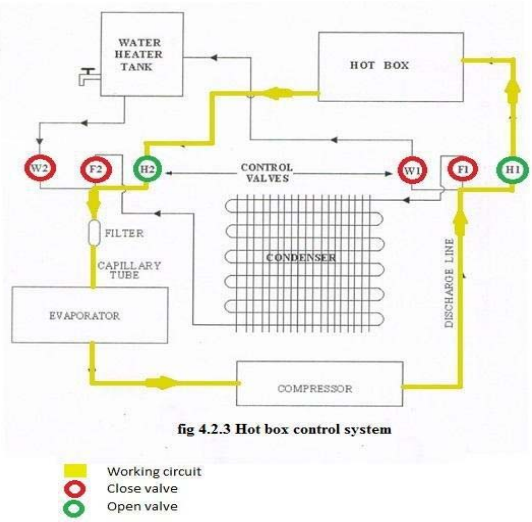

fig 4.2.3 Hot box control system

Working

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This is where the circulating refrigerant rejects heat from the system and the rejected heat is carried out in the hot box. Circulating refrigerant enters the compressor in the thermodynamic state known as saturated Now condensed liquid refrigerant is connected to a filter through valve (H2), when valve(H2) is open and other valve (F2&W2) are closed.

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evaporation lowers the temperature of the liquid and vapour refrigerant mixture to where it is colder than the temperature of the enclosed space to be refrigerated. Now section of saturated vapour takes place from evaporated and it goes to compressor. To complete the refrigeration cycle the refrigerant vapour from the evaporator is again a saturated vapour and it routed back in to the compressor. And cycle is continued.

Controls of valve mechanism

The refrigerator with hot box & water heater is based on same principle of vapour compression cycle but there is a small change in cycle. The discharge line of compressor is by passed before it go to regular condenser, it passed through system (water tank and in insulated box known as hot box). This system is controlled by valve mechanism.

This cycle can work with all the three system but for greater efficiency valves are provided in the cycle. The valves runes the single system at a time and can be runs all the system at a time. So valve system is necessary for greater efficiency.

Fabrication of parts

1) Water heater tank
2) Hot box
3) Pipe line circuit

Water heater tank

First we buy the steel pot of approximately 1.5 liter. This pot is use as water tank. Now this one cock is fitted to that tank drilling tank. And this is covered with hot line sheet for insulation.

Hot box

The hot box is made from evaporator of old refrigerator. Because of the evaporator is having material aluminum and the box inside wounded with tube in which aluminum coil in it. It has very good thermal conductivity hence efficiency of box is increases.

Pipe line circuit

The pipe line circuit is made from copper pipe having diameter 4mm. In which refrigerant is flows from various systems. We used this pipeline to join different components of the refrigerator. Brazing operation was performed at all copper joints and junctions to create the junctions and joints. We selected copper pipe as it is easy to shape in desired way.

Performance Analysis

Calculation

Measured temperature:

1. Suction temp of compressor (T1) = -4ºC
   =269K

2. Discharge temp of compressor (T2) =48ºC
   =321K

Measured mass flow rate of refrigerant (mR) =0.05kg/sec =3kg/min

Now, we know that,

COP of Refrigerator=Refrigerating Effect/Workdone of compressor

Refrigerating Effect=h1-h4

Now find h1=

So for that First find the dryness fraction (x) at pt 1,

We know that entropy at pt 1,

S1 = sf1 + x hfg1/T1 and

S2 = sf2 + sfg2 /T2

But S1 = S2

So, sf1 + x hfg1/T1= sf2+hfg2/T2

0.1777+x*200.15/269 = 0.4243+153.33/321

X=0.97

R.E. = h1-hf3

=238.89 – 118.35

=**120.54 KJ/kg**

Capacity of refrigerator =

(mR * R.E) / 210

=(3*120.54) / 210

= **1.722 TOR**

Enthalpy at pt 1,

h 1 = hf1 + x.hfg1

=44.76 + 0.97*200.15

h 1= 238.89 KJ/kg

h2 = hf2 + hfg2

=118.35+153.33

h 2=271.68 KJ/kg

From property table, hf3 = 118.35 KJ/kg

COP = h1 – hf3/h2-h1

=238.89-118.35/271.68-238.83

COP=3.67

Power required to drive the compressor = mR (h2-h1)/60

=3(271.68-118.35)

= 460 KJ/min

=3(271.68-118.35)

=460 KJ/min

Experimental result

From above calculational details we can see that the system is working very efficiently as the coefficient of performance of the system is 3.67. The capacity of the system is 1.72 TOR & the power required to drive the compressor is 1.64 kW. The system work as the regular refrigeration cycle with addition of two units, And gives better performance.

Observation

I) Temp. Observation for water tank

(Only water heater tank open)

Sr. No	Time (Min)	Temp(ºc)
1	0	32
2	5	36
3	15	42
4	25	47
5	35	50

II) Temp. Observation for hot box

(Only hot case valve open)

Sr. No.	Time(Min)	Temp(ºc)
1	0	32
2	5	36
3	15	39
4	25	43
5	35	45

Conclusion

It is evident from above investigation that the machine called as "Refrigerator with Hot Box And water Heater" performs the best result and heat water up to 55-60 degree in water heater and maintain temperature up to 45-50degree in Hot Box.

The refrigerator that we use in our daily routine release lot of heat which goes waste but as per the

accessories that attached we have used i.e. Hot Box and Hot water tank used above heat and fulfill the purpose. After the attachment of Hot Box and water heater the efficiency of refrigerator is not affected.

The machine fabricated has good utilization in hotels, dairy, industry and also useful for domestic purpose.

The serving cooling and heating both the purpose.

References

1. Khurmi R.S. J K Gupta" A Textbook of Refrigeration and Air Conditioning", „S Chand & Co Ltd publication"2006,pp. 306-313,727-730
2. R.B. Slama "Refrigeartor Coupling to a Water-Heater and Heating Floor to Save Energy and to Reduce Carbon Emmissions"January 2013, http://www.scirp.org/journal/cweee
3. Sreejith k. "Experimental Investigation of a Domestic Refrigerator Having Water-Cooled Condenser Using Various Compressor Oils" ,International Journal of Engineering and Science,Issn:2278-4721,vol.2,Issue 5,February 2013,pp. 27-31,www. Researchinventy.com
4. Lon E. Bell "Cooling,Heating,Generating Power, and Recovering Waste Heat with Thermoelectric Systems" www.sciencemag.org science vol. 321 no. 5895 pp. 1457-1461
5. Wikipedia "Refrigerator" http://en.wikipedia.org/wiki/Refrigerator
6. S. R. Ben, "Water Heating by Recovery of Heat Released by the Refrigerator",23rd IIR International Congress of Refrigeration,Praha,21-26, August 2011
7. G. Grazzini and R. Rinaldi, "Thermodynamic Optimal Design of Heat Exchangers for an Irreversible Refrigerator", International Journal of Thermal Sciences,Vol.40,No.2,2001,pp.173-180.
8. M.M.Rahman,Chin Wai Meng,Adrain Ng, "Air Conditioning and Water Heating-An Environmental Friendly and Cost Effective Way of Waste Heat Recovery",AEESEAP, Journal of Engineering Education 2007,Vol.31,No. 2
9. B. J. Huang, J. H Fast Response Heat Pump Water Heater Using Thermo- stat Made from Shape Memory Alloy," Applied Thermal Engineering, Vol. 29, No. 1, 2009, pp. 56-63.
10. K. Hidouri, S. R. Ben and S. Gabsi, "Hybrid Solar Still by Heat Pump Compression," Desalination, Vol. 250, 2010, pp. 444-449
11. S. R. Ben, K. Hidouri and S. Gabsi, "Distillateur Solaire Hybride à Pompe à Chaleur à Compression," 1er Colloque Maghrebin sur le Traitement et le Dessalement des Eaux CMTDE, Hammamet, 7-10 Décembre 2007.
12. S. R. Ben and S. Gabsi, "Design and Experimentation of a Solar Sea Water Distiller/Heat Pump," TIWATMED, Djerba, 24-26 Mai 2007