Heat Recovery from Refrigerator Using Water Heater and Hot Box

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ABSTRACT

Heat is energy, so energy saving is one of the key matters from view point of fuel consumption and for the protection of global environment. So it is necessary that a significant and concrete effort should be made for conserving energy through waste heat recovery too. The main objective of this paper is to study "Waste Heat recovery system for domestic refrigerator". An attempt has been made to utilize waste heat from condenser of refrigerator. This heat can be used for number of domestic and industrial purposes. The study has shown that such a system is technically feasible and economically viable.

Refrigerator which is been previously made exert a lot of amount heat through condenser to overcome this wastage of heat. We decide to develop this machine this heat is utilized for heating water and collecting in box we have also taken review of previous which help us to decide the work plan for this machine. In this project wastage is for useful work without disturbing refrigeration cycle

Keywords-Waste heat recovery, 165 liter Domestic refrigerator, Air cooled condenser, waterheater ,hotbox, Experimental analysis, COP of refrigerator.

1. Introduction

Introduction to regular refrigerator and working

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.

2. 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 the valve. 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.

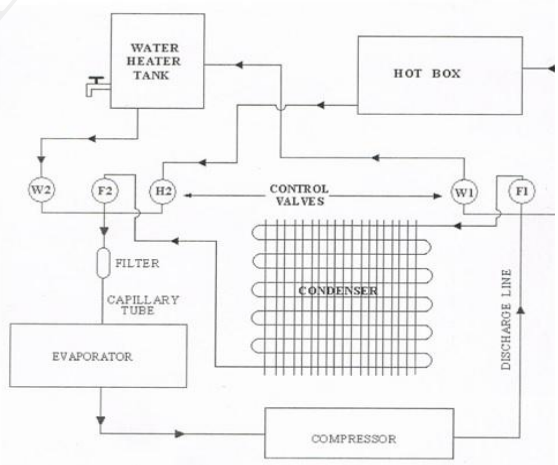


Fig 1.3.1 Refrigerator with hot box and water heater

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

1. 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.

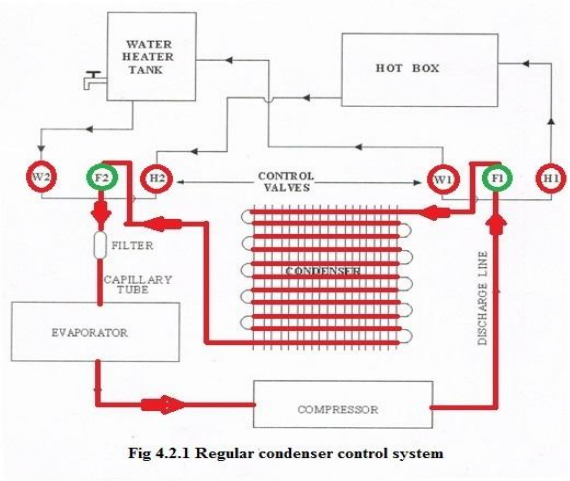


Fig 4.2.1 Regular condenser control system

Working circuit
Close valve
Open valve

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.

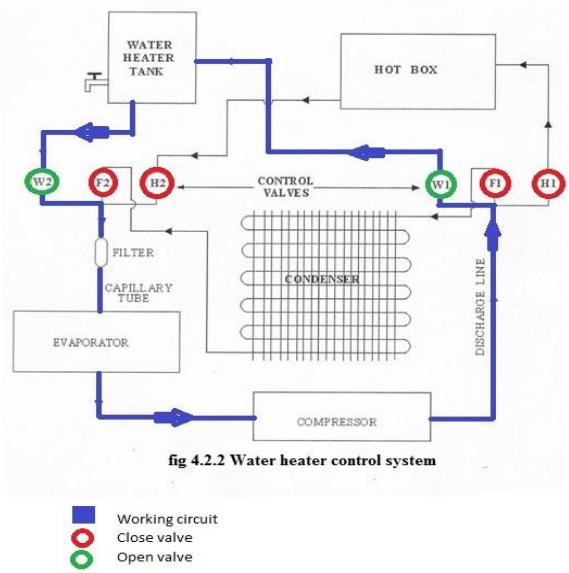


fig 4.2.2 Water heater control system

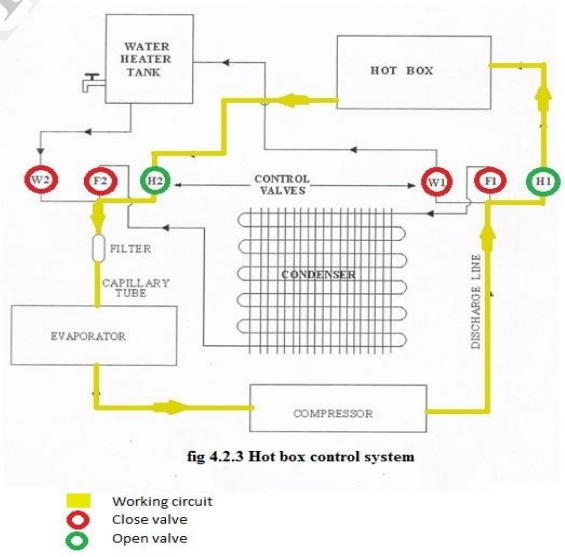
Now condensed liquid refrigerant is connected to a filter through valve (W2), when valve(W2) is open and other valve (F2&H2) are closed.The condensed liquid refrigerant in the thermodynamic state known as a saturated liquid, is passed through filter where refrigerant is filter and remove the moisture 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).



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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

Water heater tank

First we bought a steel pot of approximately 10 Ltr size. This pot is used as water heater tank. And this tank is covered with hotline sheet for insulation to avoid heat lekage to surrounding. The copper coil of calculated length is placed intentionally at bottom of the pot in order to have maximum heat exchange between water and copper coil carrying hot refrigerant.

Hot box

We bought a microwave ovan. Removed unnecessary circuit and unnecessary parts. We took a thread of equal length as that of copper tube and wounded around the micro to get proper markings to equal distribution of copper coil loops at equal intervals. More length of copper coil was put on lower side than upper side intentionally to get maximum heating effect. With the help of drill machine and tags we wounded the coil around the micro.

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.

Cop Calculations

Cop calculation include calculation of cop for all three cases

1.When regular condenser is in operation
2.When water heater is in operation
3.When hot box is in operation

Observation Tables
(a)Observation Table for regular condenser

Surrounding temperature = 35.1^{o}C

Standing suction pressure= 65 psi

Standing discharge pressure= 65 psi

Time (min)	Suction Pressure (psi)	Discharge Pressure (psi)
0	65	65
5	16	225
10	14	215
15	11	208
20	10	200
25	9	195
30	8	190

Table 2. Pressure vs Time

Time (min)	Temp at inlet of compressor(^{o}C)	Temp at discharge of compressor(^{o}C)	Temp after condensation(^{o}C)
0	35.7	35.7	35.7
5	38.8	51.2	51.8
10	38.7	51.7	50.8
15	38.5	52.3	49.6
20	38	53.1	48.6
25	37.9	55.1	47.7
30	37.5	55.3	47.2

Table 3. Tempearature vs Time

(b) Observation Table for water heater

Surrounding temperature = 35.1^{o}C

Standing suction pressure= 65 psi

Standing discharge pressure= 65 psi

Time (min)	Suction Pressure (psi)	Discharge Pressure (psi)
0	65	65
5	10	155
10	10	175
15	9	185
20	9	193
25	8	195
30	8	205

Table 4. Pressure vs Time

Time (min)	Temp at inlet of compressor (^{o}C)	Temp at discharge of compressor (^{o}C)	Temp after condensation (^{o}C)
0	35.1	35.1	35.1
5	33.9	45.9	38.7
10	34.7	48.3	42.6
15	35.8	49.7	45.5
20	36.6	49.6	47.5
25	37.2	50.8	48.6
30	37.9	51.5	49.7

Table 5. Tempearature vs Time

(c) Observation Table for hot box

Surrounding temperature = 35.1^{o}C

Standing suction pressure= 65 psi

Standing discharge pressure= 65 psi

Time (min)	Suction Pressure (psi)	Discharge Pressure (psi)
0	65	65
5	13	240
10	14	260
15	15	270
20	15	270
25	15	275
30	15	275

Table 6. Pressure vs Time

Time (min)	Temp at inlet of compressor (^{o}C)	Temp at discharge of compressor (^{o}C)	Temp after condensation(^{o}C)
0	34.9	34.9	34.9
5	38.6	52.2	53.2
10	40.6	54.3	54.9
15	41.8	55.7	56.7
20	42.4	56.8	57.6
25	42.4	56.6	57.2
30	42.5	57.3	57.3

Table 7. Tempearature vs Time

Cop calculation when regular condenser is in operation

From the P-h Chart for R-134a we find value of enthalpies h1,h2,h3 & h4

h1 = 435 KJ/Kg

h2 = 520KJ/Kg

h3 = 265KJ/Kg

h4 =265KJ/Kg

COP=Refrigeration effect/Work of compressor

= (h1-h4)/(h2-h1)

=2

Cop calculation when water heater is in operation

From the P-h Chart for R-134a we find value of enthalpies h1,h2,h3 & h4

h1 = 438KJ/Kg

h2 = 522KJ/Kg

h3 = 271KJ/Kg

h4 = 271KJ/Kg

COP=Refrigeration effect/Work of compressor

= (h1-h4)/(h2-h1)

=1.988

Cop calculation when hot box is in operation

From the P-h Chart for R-134a we find value of enthalpies h1,h2,h3 & h4

h1 = 441 KJ/Kg

h2 = 521KJ/Kg

h3 = 282KJ/Kg

h4 = 282KJ/Kg

COP=Refrigeration effect/Work of compressor

= (h1-h4)/(h2-h1)

=1.9875

Results

Temperature result for water heater tank

(only water heater valves open)

TIME(MIN)	TEMP(DEG-CEL)
0	36
5	40
15	47
25	52
35	57

Table 8. Table for Water Heater

We observed that after 35 minutes temperature of water in water heater tank reaches to 57^0C.

5.1.2 Temperature result for hot box

(only when hot box valves open)

TIME(MIN)	TEMP(DEG-CEL)
0	36
5	39
15	42
25	45
35	48

Table 9. Table for Hot Box

We observed that after 35 minutes temperature of hot box reaches to 48^0C.

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. Machine is multipurpose.

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