Water Purification using Controlled Waste Heat Recovery from Refrigerator

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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 of heat through condenser. To overcome this wastage of heat we decided to develop this machine. This heat is utilized for heating water and purifying it. In this project wastage is for useful work without disturbing refrigeration cycle.

Key words: Waste Heat Recovery, 165 Litre Domestic Refrigerator, Air Cooled Condenser, Water Heater, Experimental Analysis, COP of Refrigerator

I. INTRODUCTION

A. Refrigerator with Water Heater

The refrigerator with 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 goes to regular condenser, it is passed through system (water heater). 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 50^0C. This wasted heat is utilized for purifying impure water.

B. System Description & Design

We selected a water heater 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. At that time, we realized that when the refrigerant is passed through system then efficiency of system is reduced. Then we fixed the valve. The system was given one inlet valve and one outlet valve.

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 is designed. The main advantage of this design is that we can get maximum heat with minimum losses.

II. WORKING OF SYSTEM

The working of the system can be considered in 2 different ways. These are:
2.1) Regular Refrigeration Cycle
2.2) Refrigerator with Water Heater

A. Regular Refrigeration Cycle

The construction and working of regular refrigeration cycle is as:

1) 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.

2) 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 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.

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.

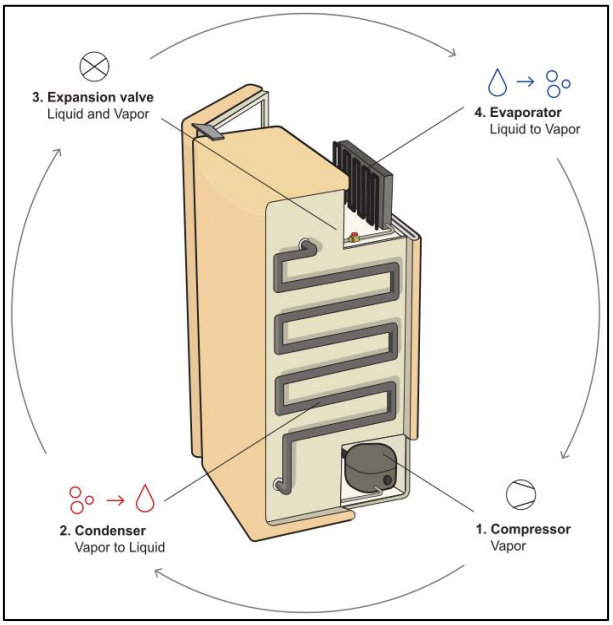

Fig. 1: Working of Refrigerator

B. Refrigerator with Water Heater

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

1) Construction

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

2) 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 high temperature and pressure is come to water heater tank then valve (W1) is open and other valve (F1 &H1) is closed. The 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.

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 filtered 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 abrupt reduction in pressure. That pressure reduction result in the adiabatic flash evaporation of a part of the liquid refrigerant. The auto refrigeration 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. 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.

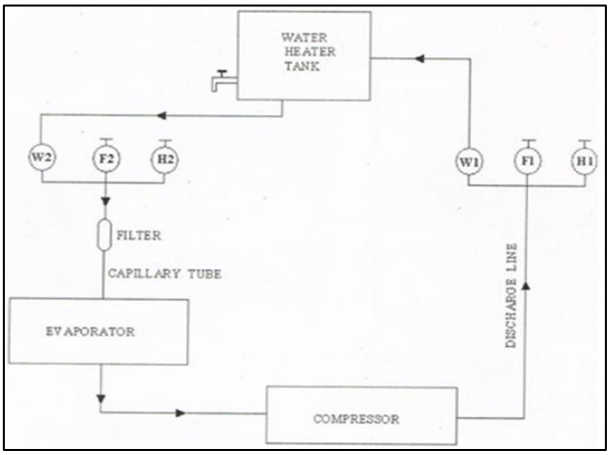

Fig 2: Refrigerator with water heater

C. Controls of Valve Mechanism

The refrigerator with 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 goes to regular condenser, it is passed through system (water tank). This system is controlled by valve mechanism.

This cycle can work with both the systems but for greater efficiency valves are provided in the cycle. The valves run the single system at a time and can run both the system at a time. So, valve system is necessary for greater efficiency.

III. FABRICATION OF PARTS

A. Water Heater Tank

First, we bought a steel pot of approximately 10 Litre size. This pot is used as water heater tank. And this tank is covered with hotline sheet for insulation to avoid heat leakage 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. We also placed a steel pot fitted with candle filter above water heater tank so that filtered water enters the heater tank.

B. Pipe Line Circuit

The pipe line circuit is made from copper pipe having diameter 4mm in which refrigerant 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.

IV. OBSERVATION TABLES

A. Observation Table for Regular Condenser

Surrounding temperature =	35.7 ºC
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 1: Pressure vs Time

Time (min)	Temp at inlet of compressor(°C)	Temp at discharge of compressor(°C)	Temp after condensation(°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 2: Temperature vs Time

B. Observation Table for Water Heater

Surrounding temperature = 35.1°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 3: Pressure vs Time

Time (min)	Temp at inlet of compressor(°C)	Temp at discharge of compressor(°C)	Temp after condensation(°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 4: Temperature vs Time

V. 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

A. 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

B. 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

VI. RESULTS

A. Temperature Result for Water Heater Tank

(Only Water Heater Valves Open)

TIME(MIN)	TEMPERATURE (°C)
0	29
20	33.1
40	38.3
60	42
80	44.3
100	46
120	47.7
140	49.2
150	50

Table 5: Table for Water Heater

We observed that after 150 minutes temperature of water in water heater tank reaches to 50^0C.

VII. CONCLUSION

It is evident from above investigation that the machine called as "Refrigerator with water heater" performs the best result and heat water up to 50 °C.

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 water tank used above heat and fulfil the purpose. After the attachment of 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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