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Waste Heat Recovery from Vapour Compression Refrigeration System to Heat Water

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Abstract—Energy conservation is becoming a vital need of today's era. Conventional methods of energy extraction do not satisfy rate of consumption and they will deplete soon. So, it is necessary that the significant efforts should be made for conserving energy through waste heat recovery. In this project an attempt has been made to utilize waste heat from condenser of vapour compression refrigerator. This heat can be used for various household and industrial purposes. In this project we are going to keep our condenser in the flow of water instead of atmospheric air. Condenser will reject heat energy to flowing water so that temperature of water will increases up to certain notable amount and this hot water can be used for different domestic as well as industrial applications. For the purpose of flow of water, a compartment is used from which the condenser coils will passes. This compartment with an arrangement of condenser coils that will work as a heat exchanger for extraction of waste heat. These coils of condenser of refrigerator that will be modified and will put in the container can serve the purpose of geyser.

Index Terms—Condenser, Cooling, Energy, Heating, Performance, Recovery, Refrigeration

1 Introduction

WASTEheat is generally the energy associated with the waste streams of air, gases and liquids that leaves the boundary of the system and enter into environment. Waste heat which is rejected from a process at a temperature enough high above the ambient temperature permits the recovery of energy for some useful purposes in an economic manner. Waste heat recovery and utilization is the process of capturing and reusing waste heat for useful purposes. Not all waste heat is practically recoverable. The strategy of how to recover this heat depends on the temperature of the waste heat sources and the economics involves behind the technology incorporated.

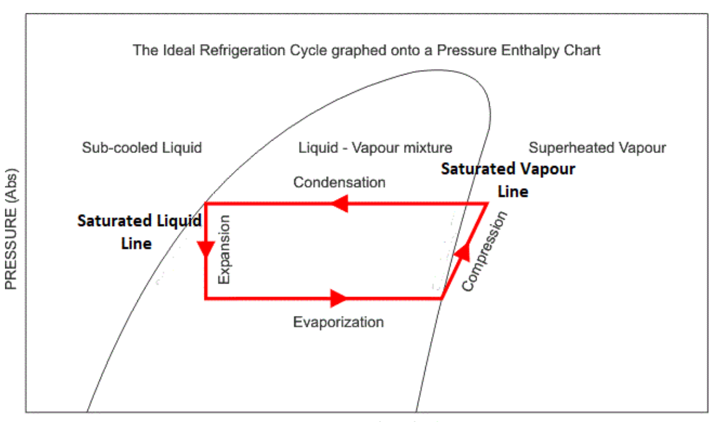

Figure 1: Simple VCR cycle

In most cases household refrigerators use air-cooled condensers. Generally, the heat from the condenser side is dissipated to the room air. If this heat is not utilized it simply becomes the waste heat. We have explained that the mostefficient way of heating water is with the help of heat pump. Because, if we use fossil fuels to heat the water then it will lead to global warming. If we use electricity, the cost for the energy consumption by the heater (geyser) will be greater than that of a heat pump. The household refrigerator can also be used as a heat pump by retrofitting a water-cooled heat exchanger to the conventional air-cooled condenser by making a bypass line, which can recover the heat from the condenser and utilized for the water heating purpose. The recovered heat is then used in several heating applications. The fabricated system can result in energy saving due to the non-usage of electrical energy for heating purposes and cost saving by combining both utilities (refrigeration and heating) in one system.

2 Problem Statement

From the literature survey we found that in VCR system for 1 Ton Refrigeration load, 4.3318 KW amount of heat rejecting from condenser to environment. This rejected heat affect the environment in larger extent. This will lead to various environmental problems like global warming and increasing surrounding temperature. To minimize this effect on environment waste heat should be recovered from the system. To recover this waste heat water cooled condenser will be used.

3 Methodology

3.1 Waste Heat Recovery System

The heat recovery technique provides a combined air cooling and water cooling in application of refrigeration system. The use of heat recovery system gives the significant improvement in COP and also the reduction in power consumption. The waste heat was recovered from the condenser of a refrigerator.

The design, construction, and testing of an integrated heat recovery system which has been designed both to enhance the performance of a residential refrigerator and simultaneously to provide water heater.

3.2 Modification Required in VCR Cycle

The basic layout of the modified heat recovery system is shown in fig. The major components of the system are indicated and includes

1. Compressor
2. Condenser
3. Evaporator
4. Expansion Device (capillary tube)
5. Water Tank
6. Shut off Valve.
7. Pump

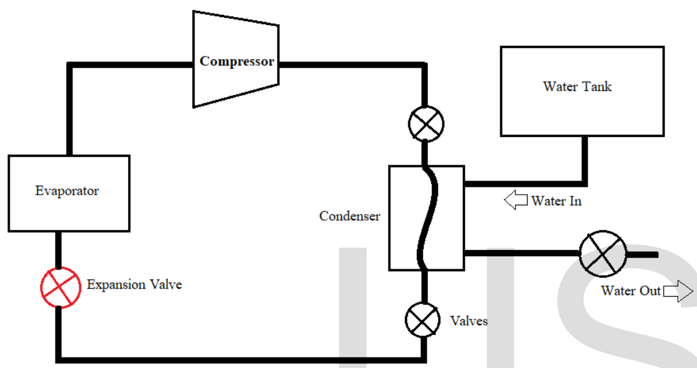

Figure 2: Modification Required in VCR Cycle

In the refrigeration system, cold is produced in the refrigerated space. It means refrigerant catches/absorbs heat in the evaporator and further energy in the form of work is added to the refrigerant by the compressor during compression process.

The condenser rejects the heat from the refrigerant which it receives in refrigerated space and the through compressor. Condenser (HE) placed immediately after compressor in the cycle so the refrigerant is at the highest temperatures. The heat energy from both sources is stored in the insulated water tank. The heated water stored in the insulated tank.

Energy consumption and environmental pollution can be reduced by designing and employing energy saving equipment. Hot water is a necessary in today's lifestyle. Residential and commercial water consume a substantial portion of the average utility bill. Generally, heat is rejected from and an air conditioner to the outside air. A water heating system can be designed to recover the rejected heat by adding a heat exchanger as shown in fig. The heated water can be stored in a tank for later use. The water heating heat exchanger is referred to a water heater henceforth.

4 Experimental Validation

Case – 1

Thermocouple Readings –

$$T_1 = 32.2\ °C$$
$$T_2 = 85.4\ °C$$
$$T_3 = 35.3\ °C$$
$$T_4 = -9.9\ °C$$

Pressure Gauge Readings –

$$P_1 = 1.99\ bar$$
$$P_2 = 10.19\ bar$$
$$P_3 = 10.27\ bar$$
$$P_4 = 2.01\ bar$$

p-h diagram plot –

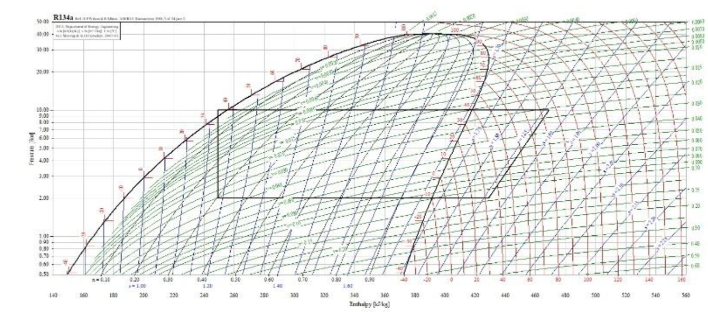

Figure 3: Case 1 p-h plot

Enthalpy values –

$$h_1 = 428.704\ kJ/s$$
$$h_2 = 469.001\ kJ/s$$
$$h_3 = 249.189\ kJ/s$$
$$h_4 = 249.189\ kJ/s$$

Mass flow rate of refrigerant (Rotameter Reading) -

$$\dot{m} = 290.25\ LPM = 0.02056\ kg/s$$

Compressor Work –

$$W = \dot{m} \times (h_2 - h_1) = 0.02056\ \times (469.001 - 428.704)$$
$$W = 0.8285\ kW$$

Refrigeration Effect –

$$RE = \dot{m} \times (h_1 - h_4) = 0.02056 \times (428.704 - 249.189)$$
$$RE = 3.6908\ kW$$

COP –

$$COP = \frac{RE}{W} = \frac{3.6908}{0.8285} = 4.4548$$

Mass flow rate of water (Rotameter Reading) –

$$\dot{m}_w = 2.96\ LPM = 0.04933\ kg/s$$

Thermocouple Readings (Water) –

$$T_{in} = 25.1°C$$
$$T_{out} = 43.7°C$$

Case – 2

Thermocouple Readings –

$$T_1 = 32.2\ ℃$$
$$T_2 = 85.4\ ℃$$
$$T_3 = 34.6\ ℃$$
$$T_4 = -9.9\ ℃$$

Pressure Gauge Readings –

$$P_1 = 1.20\ bar$$
$$P_2 = 10.19\ bar$$
$$P_3 = 10.27\ bar$$
$$P_4 = 2.02\ bar$$

p-h diagram plot –

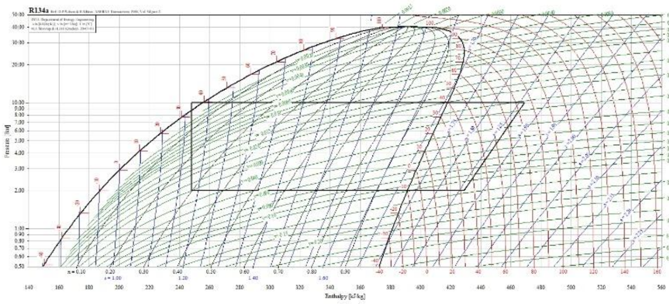

Figure 4: Case 2 p-h plot

Enthalpy values –

$$h_1 = 428.704\ kJ/s$$
$$h_2 = 469.001\ kJ/s$$
$$h_3 = 248.161\ kJ/s$$
$$h_4 = 248.161\ kJ/s$$

Mass flow rate of refrigerant (Rotameter Reading) -

$$\dot{m} = 290.25\ LPM = 0.02056\ kg/s$$

Compressor Work –

$$W = \dot{m} \times (h_2 - h_1) = 0.02056\ \times (469.001 - 428.704)$$
$$W = 0.8285\ kW$$

Refrigeration Effect –

$$RE = \dot{m} \times (h_1 - h_4) = 0.02056 \times (428.704 - 248.161)$$
$$RE = 3.7119\ kW$$

COP –

$$COP = \frac{RE}{W} = \frac{3.7119}{0.8285} = 4.4803$$

Mass flow rate of water (Rotameter Reading) –

$$\dot{m_w} = 2.88\ LPM = 0.04801\ kg/s$$

Thermocouple Readings (Water) –

$$T_{in} = 25.2℃$$
$$T_{out} = 44.4℃$$

Case – 3

Thermocouple Readings –

$$T_1 = 32.2\ ℃$$
$$T_2 = 85.4\ ℃$$
$$T_3 = 33.5\ ℃$$
$$T_4 = -9.9\ ℃$$

Pressure Gauge Readings –

$$P_1 = 1.21\ bar$$
$$P_2 = 10.18\ bar$$
$$P_3 = 10.27\ bar$$
$$P_4 = 2.01\ bar$$

p-h diagram plot –

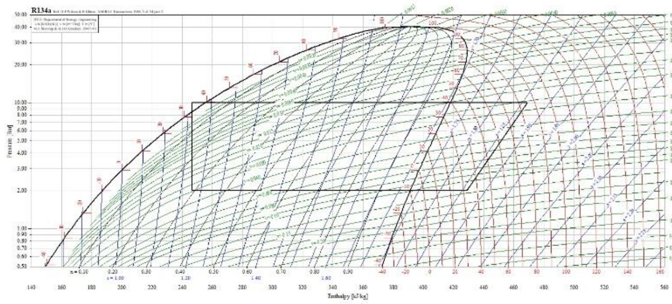

Figure 5: Case 3 p-h plot

Enthalpy values –

$$h_1 = 428.704\ kJ/s$$
$$h_2 = 469.001\ kJ/s$$
$$h_3 = 246.550\ kJ/s$$
$$h_4 = 246.550\ kJ/s$$

Mass flow rate of refrigerant (Rotameter Reading) -

$$\dot{m} = 290.25\ LPM = 0.02056\ kg/s$$

Compressor Work –

$$W = \dot{m} \times (h_2 - h_1) = 0.02056\ \times (469.001 - 428.704)$$
$$W = 0.8285\ kW$$

Refrigeration Effect –

$$RE = \dot{m} \times (h_1 - h_4) = 0.02056 \times (428.704 - 246.550)$$
$$RE = 3.7451\ kW$$

COP –

$$COP = \frac{RE}{W} = \frac{3.7451}{0.8285} = 4.5203$$

Mass flow rate of water (Rotameter Reading) –

$$\dot{m_w} = 2.78\ LPM = 0.04642\ kg/s$$

Thermocouple Readings (Water) –

$$T_{in} = 25.1℃$$
$$T_{out} = 45.1℃$$

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5RESULTS

Calculations shows that as we decrease mass flow rate of water fromcondenser outlettemperature of water also increases and COP of system also increases.

Temperature of water flowing from water cooled condenser increase up to 45 degree Celsius.

TABLE 1
RESULTS

Value	Case 1	Case 2	Case 3
Compressor Work	0.8285 kW	0.8285 kW	0.8285 kW
RE	3.6908kW	3.7119kW	3.7451kW
COP	4.4548	4.4803	4.5203
T_{out}	43.7°C	44.4°C	45.1°C

6 CONCLUSION

It is evident from above investigation that the machine called as "Refrigerator with water Heater" has performed the best result and heated water up to 45 degree in water heater.

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 fulfill the purpose. After the attachment of water heater, the energy consumption 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.

COP of system also increased.

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