Experimental Investigation of Heat Exchanger for Waste Heat Recovery Through HVAC system

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Abstract- *In last few decades, the energy demand from the world is increased enormously. So, regeneration and conversion of one form of energy into another useful form of energy is becomes a necessity of today's life. This paper work explains recovery of waste heat released from HVAC system. This will achieved by replacing air cooled condenser (forced air cooled) of HVAC system by heat exchanger for water heating applications. Heat exchanger will recover degree of superheat which is wasted to atmosphere from condenser. As concerns with 1TR capacity HVAC system used for domestic purpose, it will heat the water by 15º to 20º Celsius from ambient temperature. This will receive special attention towards reducing high electricity cost and fuel consumption to heat water. This waste heat recovery through HVAC system will help in improving the environmental conditions by reducing thermal pollution and thus increasing energy efficiency.*

Keywords- Waste heat recovery, Heat exchanger, HVAC, etc.

I. INTRODUCTION

Air Conditioning System

The refrigeration system is an enclosed, air-tight system of individual units and interconnecting pipe works so constructed as to allow a controlled quantity of refrigerant to flow between the units under definite and predetermined pressures. This allows thermal energy to be absorbed in a region of low pressure by means of liquid evaporation (in the evaporator unit), and rejected in a region of high pressure by means of condensation (in the condenser unit). The system is designed so that the refrigerant undergoes a cyclic series of processes.

The most common types of refrigeration systems are as follows:

i) Vapor Compression Refrigeration (VCR) System
ii) Vapor Absorption Refrigeration (VAR) System

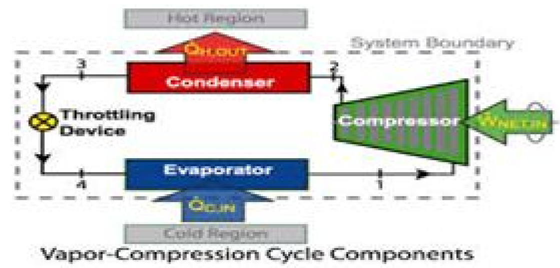

Figure 1 VCR system

Vapour Compression Air Conditioning (VCR) System

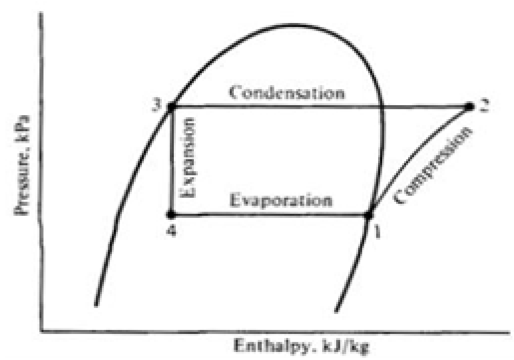

Figure 2 Standard Vapour Compression Cycle

The vapour compression cycle is the most widely used refrigeration cycle in practice. As shown in Figure, the processes constituting the standard ideal vapour compression cycle are:

- Process 1-2: Reversible and adiabatic compression from saturated vapour to the condenser pressure.
- Process 1-3: Reversible rejection of heat at constant pressure, causing superheating and condensation of the refrigerant.
- Process 3-4: Irreversible expansion at constant enthalpy from saturated liquid to evaporator pressure.
- Process4-1: Reversible addition of heat at constant pressure causing evaporation to saturated vapour.

In an actual vapour compression cycle, due to irreversibility and heat transfer to the compressor coolant, the compression process is neither reversible nor adiabatic. This process might approach either line 1-2a or line 1-2b in Figure, depending on whether frictional effect or heat-transfer effect dominates. In this figure, state 1 is shown slightly superheated and state 3 slightly sub-cooled. The superheating at state 1 is advisable to ensure complete vaporization at entrance to the compressor. The sub-cooling at state 3 is advisable, as it would result in increased refrigeration effect. The pressure differences between points 2 and 3 and between points 4 and 1 in Figures are simply to indicate that there usually are pressure drops in the condenser and evaporator coils, in compressor suction and exhaust valves and in pipelines.

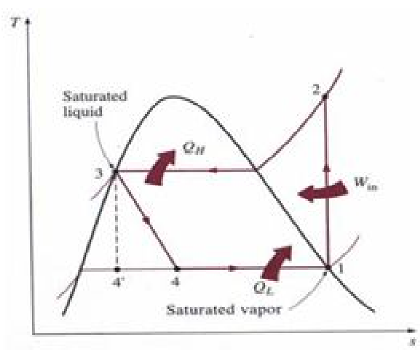

Figure 3 Ideal Vapour-Compression Refrigeration Cycle

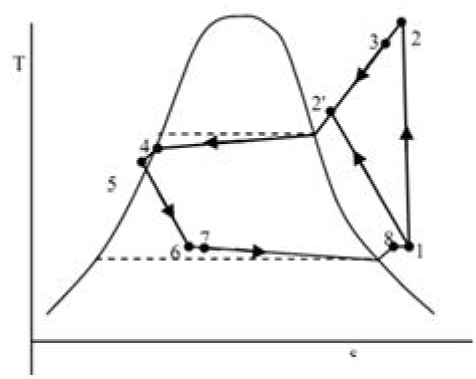

Figure 4 Actual Vapour-Compression Refrigeration Cycle.

II. RESEARCH ELABORATION

Existing Systems

During this cycle, the cold low pressure refrigerant vapour enters the compressor and is pumped into the high pressure side of the system. The hot high pressure gas passes through the condenser which is a coil placed outside the cooled space. A fan is used to cool the refrigerant and thus the refrigerant undergoes a change of state from gas to liquid. The refrigerant passes then through an expansion valve, where it undergoes a pressure decrease necessary to the evaporation process to occur in the evaporator. The heat required to the evaporation is removed from the indoor air resulting in decreasing its temperature. The principle of the recovery system suggested is to capture the heat rejected from the condenser of the HVAC system and use it to heat water.

The air flow produced by the condenser fan and heated by the heat released from the condenser is oriented to a concentric tube heat exchanger. When flowing in the heat exchanger, the hot air will heat the cold water supply. The heat exchanger considered in the present study is counter flow concentric tube heat exchanger with inner diameter *Di*, outer diameter *Do* and length *L*. In the thermal modelling presented below and for presentation clarity, water is considered flowing in the inner tube of the exchanger and condenser hot air flowing in the annulus of the exchanger. Later in the calculations, the configurations can be inversed and the governing equations inversed accordingly.

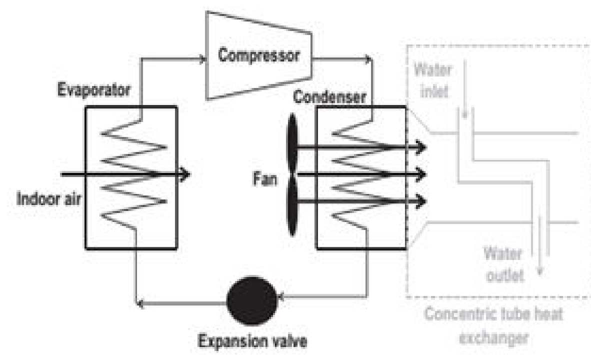

Figure 5 Schematic of heat recovery system

Heat recovery with Thermo syphon system

Figure shows household refrigerator with heat recovery unit. It consist of vertical copper tube of diameter 4.8cm through which water is flowing and refrigerant tube of 0.7cm is brazed helically on it for effective heat transfer. The Water tank is placed at the top of vertical tube on stand and with the help of flexible pipe it is again connected to bottom of vertical pipe to make close circuit. The heat recovery unit extracts heat from the hot refrigerant and heats the water which is inside the vertical pipe .Due to temperature difference hot water in pipe moves upward and cold water comes in from the bottom. As the circulation is by thermo syphon there is no need of pump. The heat recovery unit in figure is heating potable water for institutional uses such as food preparation, dishwashing, laundry, showers, etc. The amount of heat recovered is dependent upon discharge temperature of compressor, load in refrigerator, and water quantity in tank.

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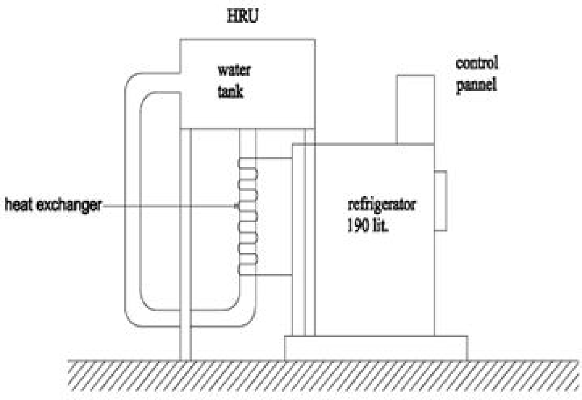

Figure 6 Thermo Syphon Systems

Efficient usage of waste heat recovery

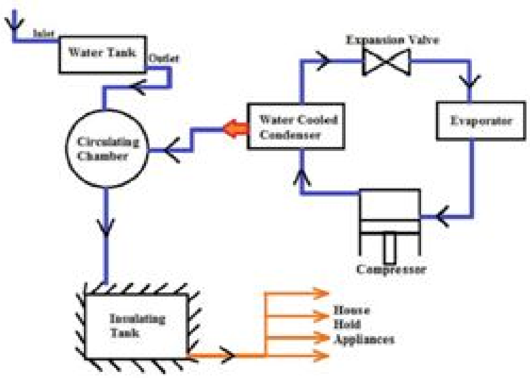

Figure 7 Flow chart for efficient use

The whole system deals by utilizing the waste heat energy discharged by the condenser. This system consists of several processes to achieve the desired output. An Air Conditioner mainly consists of four parts as Condenser, Expansion valve, Evaporator and Compressor. In normal Air Conditioning the process proceeds by compressing the working substance where the input energy is fed to the Air Conditioner and this working substance then enters the condenser where the heat energy releases at a certain rate. Then it is subjected to expansion valve where isentropic process takes place and the temperature and pressure of the working substance is drastically reduced. This will absorb the heat energy in the leeway and which takes place in the cooling coil and the air in the leeway is also ventilated and which is then compensated by letting the fresh air in a desired mass flow rate.

In the process stated above this paper mainly focuses on utilizing the waste heat discharged at the outlet. The waste heat is utilized by transferring the heat to the water and using it in many ways. In the first stage the calculated quantity of water is filled in the tank via inlet and the volume of the water remains fixed until it reaches the calculated temperature. The water from the tank is then circulated in a circulating chamber. Condenser coil is placed in the circulating chamber. Circulating water absorbs the heat rejected by the condenser and the heat is added by constant volume process. The temperature of the circulating water increases to the calculated temperature. When the desired temperature is reached in the circulating water it is then drained into the separate insulated storage tank. Suddenly fresh water will be filled into the tank as mentioned in the first stage and this process continues as whenever the Air Conditioner operates. Thus this large quantity of water is stored in the storage tank. Pipes can be connected from the tank to the household appliances. Thus the vegetables and raw materials for cooking can be washed cleanly in the hot water. This hot water is obtained by the waste heat rejected by the condenser. Thus is more economic process of obtaining the hot water. Water is the main course in each and every cooking. Hence utilizing hot water will save energy such as Liquefied Petroleum Gas, electrical energy in case of using an induction stove. This system can also applied in the hospitals for washing the patients clothes in hot water will save energy and also reduces the cost of washing. Furthermore if need for the temperature of the water is high then one should have a good refrigerant as a working substance otherwise the water to be drained in the insulated tank should be raised to a temperature of a desired level.

IV. FINDINGS

Calculation for HEAT EXCHANGER

Material selection for HE = Cu

At 0^0C Cu has 388W/m^{0}C thermal conductivity.

At 100^0C it is 378 W/m^{0}C

Condenser inlet temperature = 54^0C,

Condenser temperature = 45^0C,

Ambient temperature = 30^0C,

Heat needed to be removed = 563 W.

m_c = mass flow rate of cold fluid

m_h = mass flow rate of hot fluid

Q_{cold} = heat gain by cold fluid

Q_{hot} = heat loss by hot fluid

c_{pc} = specific heat of cold fluid

c_{ph} = specific heat of hot fluid

Tc_{out} = outlet temperature of cold fluid

Q_m = LMTD

$m_c = m_h$

$Q_{cold} = Q_{hot}$

$m_c*c_{pc}*\Delta T = m_h*c_{ph}*\Delta T$

$c_{pc}*\Delta T = c_{ph}*\Delta T$

$1*(Tc_{out} - 30) = 1.5*10$

$Tc_{out} = 45^0C$

$Q_m = (Q_1 - Q_2)/ \ln(Q_1/ Q_2)$

$Q_m = 11.74^0C$

U = overall heat transfer coefficient = 1000 W/m20C

$A = Q/Q_m * U$

$A= 0.047955\ m^2$

Diameter of tube = 0.01mm

Calculate length of tube of HE

No. tube, N = 4

$A = N*\pi*D*L_{tube}$

$0.047955=4*\pi*10*10^{-3}* L_{tube}$

L = 0.3816m

Two shell passes and four tube passes.

V.CONCLUSION

Heat recovery unit operate with air conditioning system to harvest excess heat which would be lost using that heat we would like to heating water up to certain temperature. Air conditioner by the system will to rescue four number of LPG gas cylinder per year. This not only save the cost but also ensure the environment by truncating the global warming because of LPG gas. We studied internal coil submerged in a hot water storage tank while the other had an external coil wound round the tank. It was found that there was very little difference in performance of the air conditioning system, with or without the heat reclaim system in terms of energy saving and cooling capacity. The internal coil system was found to be more efficient in heating the water in the tank.

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