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Utilization of Waste Heat from an Air Conditioning System

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ABSTRACT

The energy demand of the world is increasing significantly.High grade energy can be completely converted into other form while the same cannot be done for the low-grade energy. One type of low grade energy is Heat energy. Thus,attempts should be taken to utilize this heat energy through waste heat retrieval systems. This paper concentrates on use of waste heat from Air Conditioning Unit, to heat water thus reducing the consumption of any form of heat and electrical energy. The water is heated in a storage tank comprising of a copper tube network in it. The waste heat utilized is the heat rejected by the condenser. When this heated water reaches the calculated temperature, it is then used for the required purpose. The result of the paper shows the amount of electricity saved while heating water for industrial purposes.

Keywords: Air Conditioning Unit, Copper Tube Network, Heat Energy, Saves Electricity, Waste Heat Recovery.

I INTRODUCTION

Energy is the preliminary requirement in day to day life. Energy is categorized as Renewable Energy and Non-Renewable Energy. Renewable energy is energy that is acquired from renewable resources, which are replenished in a natural manner whilenon-renewable energy does not renew itself at an adequaterate. Thus, non-renewable energy are finite resources which will deplete with time.

Energy conservation is the exercise of lessening the amount of energy used, this can be done either by using energy efficaciously or deducting the quantity of amenities used or using waste energy. One such type of waste energy is heat energy. Waste heat is the energy generated by many refrigeration operation and this energy is dissipated to the surrounding even when it can still be utilized for some advantageous and lucrative purposes. If efficient steps are taken to utilize this waste heat energy, the amount of actual heat energy required for various purposes will automatically reduce.

Refrigeration cycle which generates waste heat is as air-conditioning unit. The yearlyconsumption of energy by Air Conditioners hasenlarged as those have convertedinto a steadfast resource for providing zone space cooling for residential and commercial buildings. Therefore, more energy efficient systems are required to be developed to meet the standards.

This paper mainly dealswith heating of water for several applications by the use of heat dissipated by condenser of an Air conditioning unit. Waste heat which is rejected by the condenser in condensation process is at higher temperature than that of atmospheric temperature which is further transferred through a copper tube winding and used for heating purpose.This solution uses the heat efficaciouslyfor some other beneficial work.

The concept of hot water production system using an air conditioning unit is evaluated, divided and organized into seven sub-sections. The first subsection deals with existing theories and models discussed by other researchers related to the system. This sub-section is followed by the second section which explains the construction of the hot water production system with a relevant diagram. The third section throws light on the working of this system followed by the detailed mathematical and thermodynamic calculations which forms the fourth section. The fifth section mentions the results and graphs regarding the calculations done in the previous section. The sixth section deals with the future scope and advantages of the system. The last section is the conclusion which illuminates the practicality of the system and the amount of electricity saved.

II EXISTING SYSTEMS

Wasteheat recovery from air conditioners by use of heat absorption pump by SohanSarangi*[1]*.

The paper states that the waste heat exhausted by Air-Conditioners can supplysatisfactory heat energy to provide warm water to boilers for heating and other purposes. If the system uses absorption heat pump, the low-qualityleft-over heatcan be transformed into high temperature heat which can be utilized for industrial purposes.

Efficient usage of waste heat from air conditioner by M. Joseph Stalin, S. Mathana Krishnan, G. Vinoth Kumar*[2]*

This paper explains the conceptual analysis of creation of hot water and minimizing usage of LPG gas by means of air conditioner waste heat. For this water-cooled condenser is used and the water is circulated by the pump until the desired temperature is acquired. The heated water is accumulated in an insulated tank for further use.

Waste Heat Recovery through Air Conditioning System by R. B. Lokapure, J. D. Joshi*[3]*.

In this paper, the main criteria areenergy conservation by using technique of gaining waste heat from Air-conditioning system and increasing Coefficient of Performance (COP). The target of improving COP was up to 20%, but in this case, only13%was achieved.

Heat Recovery from Vapor Compression Air Conditioning by Michael Guglielmone, Fred Scheideman, Yogesh Magar*[4]*.

This paper is proposed to introduce the idea of heat retrieval from vapor compression air conditioning systems. Other adjustments on this theme are possible, such as transferring the heat to a process fluid like ethylene glycol and using the heat in industrialprocesses instead of potable water heating.

III DESCRIPTION

As the global heat goes on increasing, more and more people can relate to luxury of an air conditioning system.Vapor Compression Refrigeration System is most extensively used by an Air Conditioning unit. As the name indicates, these systems are grouped as a traditional class of vapor cycles in which the working fluid undergoes a phase change*[5]*.In a vapor compression cycle, the cooling is gained as the refrigerant evaporates at low temperatures. While evaporation, it gains heat from the cold body and this heat is used as its latent heat for transforming it from the liquid to vapor form. In condensing, this heat is dissipated to an external body, thus generating a cooling effect in the working fluid*[6]*.

This refrigeration arrangement thus worksas a latent heat pump.The system pumps its latent heat from the cold body and transmits it to the exterior hot body. These kinds of systemsrequire mechanical energy to run the compressor. Thus, these systems are termed as mechanical refrigeration systems*[5]*. Vapor compression refrigeration systems are available for relief as well as many processes with the refrigeration sizes reaching upto few megawatts.

The main setback of this system is that a large amount of waste heat is dumped into the surrounding. This heat causes rise in global average temperature, thus leading to many environmental problems*[7]*.

This heat can be extensively used for many purposes. Some industries like food and beverage, textile, chemical and pharmaceutical require hot water for carrying their regular process. Even hospitals are in a need of efficient hot water system.

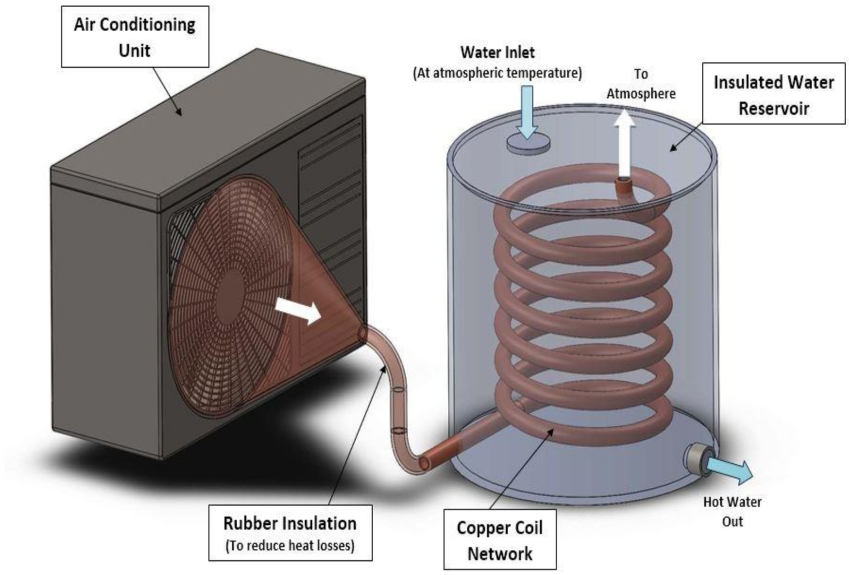

Fig 1: Waste Heat Recovery Setup

Thus, an idea has surfaced that can solve both the problems as well as save energy. By implementation of this waste heat recovery system (Fig 1) can scale back the typical electricity consumption.

The heat require for this system is acquired from the condenser of an air conditioning unit. The system uses 1TR air conditioning unit and the heat is rejected from the condenser unit in the form of hot air.

The arrangementcontainsa copper coil inside an insulated water reservoir. The material copper was selected for the coil because it has many advantageous properties, on being high thermal conductivity which is approximately 399W/m-K. This is higher than all other metals excluding silver which is very expensive as it is a valuable metal. The copper also exhibits maximum Tensile Strength, Yield Strength, Creep Rupture Strength, andhigh melting point. The copper also has ease of joining which makes it easy to work with.

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The coil and the condenser are connected by a copper pipe with rubber insulation. The rubber insulation is used to avoid the loss of heat energy from the copper pipe to the surrounding.The diameter of pipe carrying this hot air is ½ inch according to the standardsavailable.

A sensor is attached at the mid length of the copper coil to indicate that the pipe is half filled with air. This copper tube is placed inside an insulated water tank. This insulated water tank has a rubber insulation on its outer periphery to avoid heat loss.A thermostat is attached on the inner wall of the tank for recording the temperature of water. The tank has one inlet and one outlet for water flow. Inlet valve and outlet valve are at inlet and outlet position respectively. The inlet valve is controlled i.e. it will be opened by the sensor placed in the copper tube while the outlet valve will be controlled by the thermostat placed on the inner wall of the tank.

These components together form a waste heat recovery system which uses the waste heat from an air conditioning unit and reduces the consumption of energy which is required for production of hot water.

IV WORKING

The system works on the principle of using waste heat energy from condenser of an air conditioning unit. An air conditioner mainly consists of four parts, compressor, condenser, expansion valve and evaporator coil and works on the principle of vapor compression cycle *[6]*. The low pressure low temperature air enters into the compressors and gets transformed into high pressure high temperature air. Further this high pressure high temperature air goes to the condenser coils where it condenses and transforms to high pressure high temperature liquid. This liquid when enters the expansion valve, it undergoes throttling process. In throttling process, there is an abrupt reduction of temperature and pressure of liquid due to which it gets converted into liquid and flash gas *[8]*. This mixture then enters into the evaporator coil which helps cooling the air that is to be transmitted in the room and the cycle repeats.

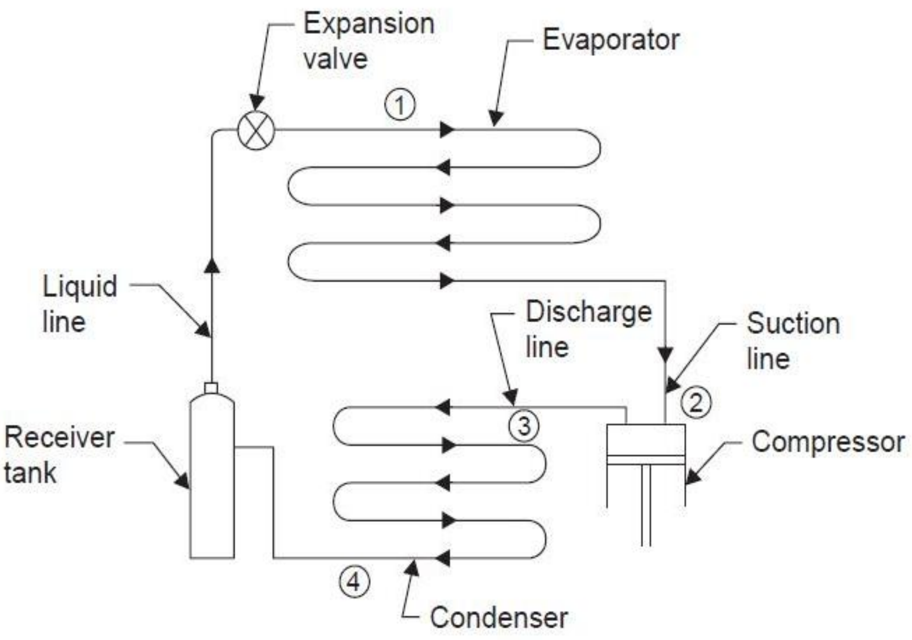

Figure 2: IdealVapor Compression Cycle *[5]*.

The actual vapor compression cycle which is used in air conditioning system is different from the theoretical cycle in various ways. Usually the liquid refrigerant enters the expansion valve after sub-cooling, and generally superheated gas leaves the evaporator a few degrees before it enters the compressor *[8]*.

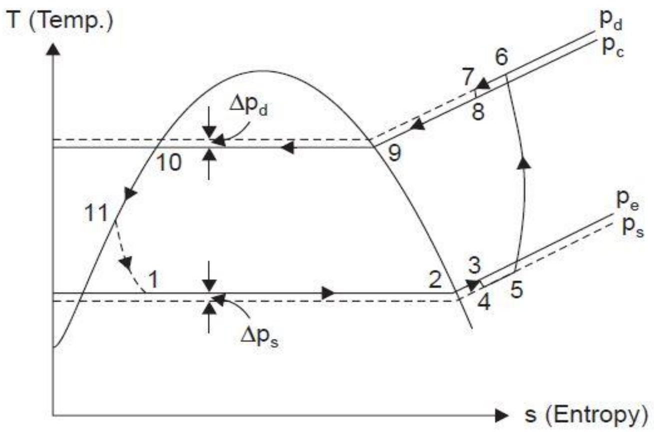

Fig 3: Actual vaporcompression cycle (T-s diagram) *[5].*

The actual vapor compression cycle on T-s diagram is as shown above. The various processes are discussed as follows:

Process 1-2-3: The progress of refrigerant through the evaporator is shown by this process, with 1-2 indicating gain of latent heat of vaporization, and 2-3, the gain of superheat before entrance to compressor. Both of these processes approach very similar to the constant pressure conditions *[5]*.

Process 3-4-5-6-7-8: This path represents the passage of the vapor refrigerant from entrance to the discharge of the compressor. Path 3-4 represents the throttling action that occurs during passage through the suction valves, and path 7-8 represents the throttling during passage through exhaust valves. Both of these actions are accompanied by an entropy increase and a slight drop in temperature. Compression of the refrigerant happens along route 5-6, which is truly neither isentropic nor polytropic. The heat transfers indicated by path 4-5 and 6-7 occur essentially at constant pressure *[5]*.

Process 8-9-10-11: This process denotes the way of refrigerant through the condenser with 8-9 representing removal of superheat, 9-10 the subtraction of latent heat, and 10-11 removal of warmth of liquid or sub-cooling*[5]*.

Process 11-1: This processdenotes the passage of the refrigerant through the expansion valve *[5]*.

The air conditioning unit described aboveuses an air-cooled condenser. The AC condenser provides with the supply of heated air. The heated air fromthiscondensergoes into a copper cone which is connected to the copper pipe.

The copper cone has larger area on its one end thus it will collect the maximum amount of waste air released from the condenser and direct the flow into the copper pipe. Also, the cone will increase the velocity of the air slightly due to reduction in cross section area thus aiding the flow of air. The copper cone and pipe have a rubber insulation so that there is no loss of heat energy.

This network of copper tubes further attached to the copper coil which is placed inside an insulated water tank.

The sensor which is attached inside the copper coil indicates that the coil is half filled with hot air.

The water tank consists of an inlet to which a valve is attached through which the water enters at room temperature. This inlet valve will open only when it receives a signal from the sensor placed in the pipe. This process is done to ensure that the whole coil is filled with hot air and the water in the tank is heated throughout.

When the heated air is passing through the coil, heat transfer takes place. This leads to increase in temperature of water. The water tank being insulated from outside reduces heat transfer to the surrounding by a greater amount. A thermostat is mounted on the surface of the water tank which measures the temperature of water and the water is heated until the maximum stable temperature is attained.

When the water attains the calculated temperature, the outlet valve has to open. This outlet valve is being controlled by the thermostat which is measuring the temperature of the water. When a signal is received, the outlet valve will open to allow the flow of water.

Many industries require hot water in the range of 30-80ºC. Also, hospitals require hot water for processes like cleaning, sterilizing, bathing, etc. In a hospital 9-10% of total water requirement is of hot water which is produced by electrical energy or solar energy. Also, the hospitals use air conditioning units on a large scale. Therefore, this system can be extensively used in hospitals. Thus, this system helps in saving a large amount of electricity required to heat water.

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V CALCULATIONS

Case 1)

When Air Conditioning unit operates at 30ºC i.e.at extreme temperature, the waste heat recovery arrangement can heat the water near 50ºC.

Heating of water is a classic thermodynamics problem and has the following formula:

$Q = m \times C_p \times dT$

Where,

Q = amount of heat (kJ)

Cp = specific heat (kJ/kgK)

m = mass (kg)

dT = temperature difference between hot and cold side (K)

For heating 25 liters of water from 25°C to 50°C

$Q_1 = m\, C_p\, dT$

$= 25 \times 4.187 \times (50-25)$

$= 2616.875$ kJ

For heating 25 liters of water from 25ºC to 90ºC

$Q_2 = m\ C_p\ dT$

= 25x4.187x(90-25)

= 6803.875 kJ

Thus, saving in the energy for heating water from 25ºC to 90ºC is given by,

$Q = Q_2 - Q_1$

= 6803.875-2616.875

= 4187 kJ

Calculation for electricity unit is given by *[9]*:

$$\text{Units} = \frac{\text{Volume of Water x Temperature Difference x 4}}{3412}$$

Consider the water requirement to be 25lts of hot water per day and preferred temperature of water is 90ºC. Let the inlet water temperature be 25ºC.

Then the best electricity units for water heating requirement is:

(25 x (90-25) x4)/3412 = 1.95 units per 25 liters.

By implementation of waste heat recovery system, we are able to accomplish temperature upto50ºC.Now if the industry requires the water at 90ºC so they wouldhave to start heating the water that is already reached at 50ºC. Hence input temperature becomes 50ºC and required temperature is 80ºC. Then units for water heating requirement is calculated as:

25 x (90-50) x 4/3412 = 1.2 units per 25 liters.

Hence saving in units =1.95-1.2

=0.75 Units

Cost per unit electricity=Rs 5.75

Hence,

Total saving of cost for heating 25 liter of water, up to 90ºC =0.75 x 5.75

= Rs. 4.3125.

Therefore, in a month (assuming 30 days) total saving of cost = 4.3125x30

= Rs. 129.375

And in 1-year total saving of cost for 25 liters of water = 129.375x12

= Rs.1552.5.

Case 2)

When Air Conditioning unit operates at 22ºC-23ºC i.e.at intermediate temperature, the waste heat recovery system can heat the water up to 55ºC

For heating 25 liters of water from 25ºC to 55ºC

$Q_1 = m\ C_p\ dT$

= 25x4.187x(55-25)

= 3140.25 kJ

For heating 25 liters of water from 25ºC to 90ºC

$Q_2 = m\ C_p\ dT$

= 25x4.187x(90-25)

= 6803.875 kJ

Thus, saving in the energy for heating water from 25ºC to 90ºC is given by,

$Q = Q_2 - Q_1$

= 6803.875-3140.25

= 3663.625 kJ

Calculation for electricity unit is given by *[9]*:

Units= $\frac{\text{Volume of Water x Temperature Difference x 4}}{3412}$

Consider the water requirement to be 25lts of hot water per day and preferred temperature of water is 80ºC. Let the inlet water temperature be 25ºC.

Then the best electricity units for water heating requirement is:

(25 x (90-25) x 4)/3412 = 1.95 units per 25 liters.

By implementation of waste heat recovery system, we are able to accomplish temperature upto55ºC.Now if the industry requires the water at 80ºC so they wouldhave to start heating the water that is already reached at 55ºC. Hence input temperature becomes 55ºC and required temperature is 90ºC. Then units for water heating requirement is calculated as:

(25 x (90-55) x 4)/3412 = 1.05 units per 25 liters.

Hence saving in units=1.95-1.05

=0.9Units

Cost per unit electricity=Rs 5.75

Hence,

Total saving of cost for heating 25 liter of water, up to 90ºC= 0.9 x 5.75

= Rs. 5.175.

Therefore, in a month (assuming 30 days) total saving of cost = 5.175 x 30

= Rs. 155.25

And in 1-year total saving of cost for 25 liters of water = 155.25 x 12

= Rs.1863.

Case 3)

When Air Conditioning unit operates at 16ºC -17ºC i.e.at minimum temperature, the waste heat recovery system can heat the water up to 60ºC.

For heating 25 liters of water from 25ºC to 60ºC

$Q_1 = m C_p dT$

= 25x4.187x(60-25)

= 3663.625 kJ

For heating 25 liters of water from 25ºC to 90ºC

$Q_2 = m C_p dT$

= 25x4.187x(90-25)

= 6803.875 kJ

Thus, saving in the energy for heating water from 25ºC to 90ºC is given by,

$Q = Q_2 - Q_1$

= 6803.875-3663.625

= 3140.25 kJ

Calculation for electricity unit is given by *[9]*:

Units= $\frac{\text{Volume of Water x Temperature Difference x 4}}{3412}$

Consider the water requirement to be 25lts of hot water per day and preferred temperature of water is 80°C. Let the inlet water temperature be 25°C.

Then the best electricity units for water heating requirement is:

(25 x (90-25) x 4)/3412 = 1.95 units per 25 liters.

By implementation of waste heat recovery system, we are able to accomplish temperature up to60°C.Now if the industry requires the water at 80ºC so they wouldhave to start heating the water that is already reached at 60°C. Hence input temperature becomes 60°C and required temperature is 80°C. Then units for water heating requirement is calculated as:

(25 x (90-60) x 4)/3412 = 0.9 units per 25 liters.

Hence saving in units = 1.95-0.9

=1.05 Units

Cost per unit electricity=Rs 5.75

Hence,

Total saving of cost for heating 25 liter of water, up to 90°C = 1.05 x 5.75

= Rs. 6.0375.

Therefore, in a month (assuming 30 days) total saving of cost = 6.0375 x 30

= Rs. 181.125

And in 1-year total saving of cost for 25 liters of water = 181.125 x 12

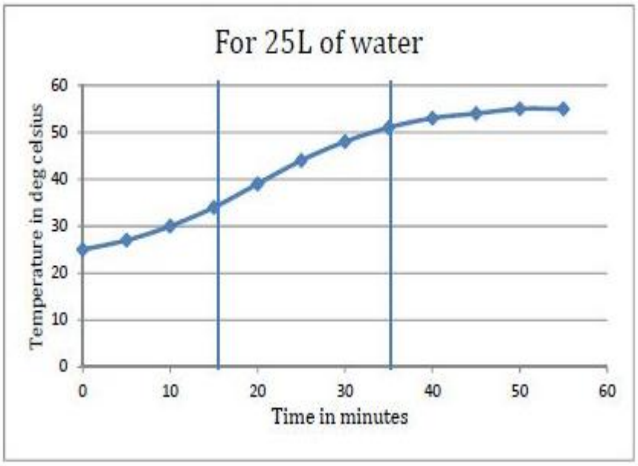
= Rs.2173.5.

Hence from above three cases it can be concluded that when Air Conditioning unit operates at 16-17ºC i.e. at lowest temperature waste heat retrieval system is extraadvantageous.

VI RESULTS

A 1TR air conditioning unit is used to run the systemwhich works for 8 hours per day maintaining 18ºC room temperature. Results of our system are explained with the help of a graph which is a temperature versus time graph. Now the water entering the system is 25 liters and will be approximately at 25ºCi.e. at atmospheric temperature.

According to the graph the temperature increases slowly in the beginning as the water is at 25ºC temperature. Further the temperature increases at a higher rate. As the temperature of goes on increasing the air will lose heat energy and the heat transfer rate will reduce thus making the graph a straight horizontal line.



Graph 1: Temperature vs Time

This system provides water at 55ºC but if the industry requires water at 90ºC then the temperature is to be increased by only 35ºC. Thus, this system will save electricity because the initial 55ºCis attained using waste heat form the air conditioning unit.

It is seen that 1.95 units is required to heat25 liters of water from 25ºC to 90ºC. But due to this system a temperature of 55ºC is already attained thus only 1.05 units of electricity is required to heat the water. Hence the electricity saved for every 25 liters of water is 0.9 units.

VII FUTURE SCOPE

As our global temperature is increasing day by day it is not advisable to dump the heat generated from air conditioning units into the surrounding. Also, the water heating units consume a large amount of energy that can be saved by using the waste hear recovery system. Thus, this system targets two problems in one go.

The system is quite efficient for heating the water up to the temperature of 55ºC. But in future the size of the copper tube can be changed to increasing the heat transfer rates. Also, fins can be added on the copper coils which will increase the heat transfer rates because the surface area in contact with water increases.

VIII CONCLUSION

From the above experimental analysis, it is seen that if this hot water system uses the heat energy from a condenser of an air conditioning unit maintaining room temperature between 16ºC-18ºC, it will save approximately 0.9 units of electricity for heating 25 liters of water up to 90ºC. This system not only saves cost for heating water but also avoids the unwanted heat from being dumped into the surroundings. If the system is incorporated in various industries, it will save a large amount of electricity.

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