Design for Improvement of COP from Waste Heat Utilization through Airconditioning System

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Abstract— Now day's demand of energy increases due to various applications of energy, but available source of energy lacks in supply. Hence move towards the alternative sources of energy and conservation of energy from the waste heat of air-conditioning system. the main focus of this paper to utilization of waste heat from domestic air conditioner system and improve the COP. To achieve this by experimental setup in which indirect type of heat recovery device is used in system in which a refrigerant to water heat exchanger is installed between the host refrigeration system compressor and condenser. Water is circulated through one side of heat exchanger and hot refrigerant gas from the compressor is routed through the other side. Heat is transferred from the hot refrigerant gas to the water. According to this improve the COP of system up to 16%.

Keywords — Waste heat recovery, COP, Heat exchanger, cooling effect, De-superheat, air-conditioning system

1 INTRODUCTION

Energy is a basic need for the development of human life. Main commercial sources of energy are fossil fuels (oil, coal and natural gas), hydroelectric and nuclear power plants sources of energy generated according to need of country. Due to releases of radioactivity in form of waste from nuclear power which is higher harmful for atmosphere. View of these problem move towards the conventional energy sources and also focus to conservation and effective utilization of energy.

Now day's main objective is efficient utilization & conservation of energy. The annual energy consumption of electricity increases day by day because of high demand of window Air-Conditioner.so the new energy efficiency standard for window type air conditioners will take effect in future. Therefore, to meet this standard development of energy efficient system is compulsory. So for energy efficient system we have to focus on to increase performance of system.. The purpose of this experimental apparatus is to develop a multi utility air conditioning system to produce air conditioning effect (cooling of space) and generation of hot water (by using extracted heat from cooling space) simultaneously. This project presents an experimental set up which uses waste heat from a window type air conditioner to heat water for residential and commercial use. It is found that on increasing each degree Celsius in condenser temperature, coefficient of performance (C.O.P) of an air conditioner decreases about 2 to 4 %. So in hot weather condition C.O.P of air conditioner could drop down as much as 40%.So due to reduction of C.O.P. of Air-Conditioner power consumption of electricity increases.

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1.1 What is waste heat?

Waste heat is heat, which is generated by fuel combustion, chemical reaction or by any mechanical system then "exhausted" into the environment but it could still be reused for some useful and economic purpose. The important part of waste heat is its quality rather than amount. The recovery of heat depends on quality (temperature) of the waste heat gases and the economics involved. Large amount of hot flue gases is generated from Boilers, mechanical systems and from Furnaces. From this recovery we can save considerable amount of primary fuels. Through waste heat recovery system we recover some amount of energy.

1.2 Waste heat Recovery System

Desuperheater is a type of heat recovery system which is used for superheated heat (waste heat) recovery in window air conditioner system. Desuperheater is basically a condenser type waste heat recovery system. Desuperheater may be used as a direct or indirect but in this projects heat recovery system used by indirect system.

1.3 Heat exchangers

Heat exchangers are widely used in industry both for cooling and heating large scale industrial processes. In many industrial processes there is waste of energy or a heat stream that is being exhausted, heat exchangers can be used to recover this heat and put it to use by heating a different stream in the process. This practice saves a lot of money in industry, as the heat supplied to other streams from the heat exchangers would otherwise come from an external source that is more expensive and more harmful to the environment.

Fig.1. Heat exchanger coil

Heat exchangers are used in many industries, including:

1. Waste water treatment
2. Refrigeration
3. Wine and beer making
4. Petroleum refining
5. Nuclear power

2. DESIGN OF HEAT RECOVERY SYSTEM

To design of Waste Heat recovery system by using available desuperheating in window air conditioner. The available waste heat calculated by using the rated condition of window air conditioner and heat recovery done by the design of heat exchanger

2.1 Design of Heat Exchanger Unit

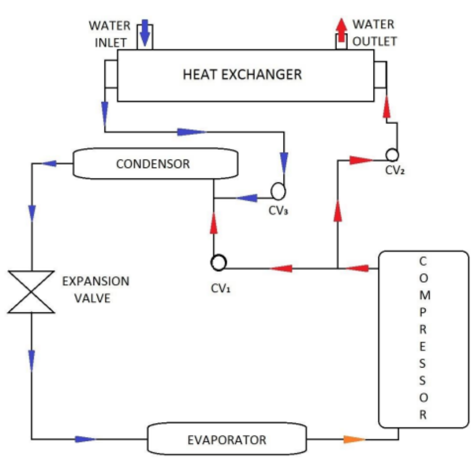

Fig.2. Schematic diagram of waste heat recovery form air conditioner

2.2 Technical Specification

Air conditioner

Model number	AH5522E
Equipment rating	Single phase, 220V, 50Hz, 8.5A
Power rating:	1.870kW
Refrigerant:	R-22 (CHClF2)
Normal capacity:	1.5 TR
Compressor:	Hermitically Shield Displacement type
Condenser:	Force convection air cooled
Evaporator:	Force convection air cooled
Pressure gauge:	One for suction pressure & one for discharge pressure
Temperature Indicator:	Digital Thermometer
Control valve:	1.In between compressor discharges and condenser (CV1). **2.** In between heat exchanger suction and compressor (CV2). **3.** In between heat exchanger outlet and condenser inlet (CV3).

2.3 Methodology

1) Calculation of energy supplied for refrigeration effect
2) Design of heat exchanger unit
3) Measurement of heat collected in heat exchanger unit.
4) Calculation of COP for normal air conditioning system
5) Calculation of COP for air conditioning system with exhaust heat collection using heat exchanger.
6) Comparison of COP in both above cases.
7) Conclusion

3. DESIGN PROCESS

3.1 Calculation of energy supplied for refrigeration effect

Input power of Air conditioner unit = 1.870kW =

= 1870W =1870 J/sec.

3.2 Design of Heat Exchanger Unit

To find the heat removed from refrigerant during desuperheated conditions:

At 35^{0}C Ambient temperature

Compressor inlet/suction pressure; Pi =60 psi

Pi =60 X 6895 {1 psi = 6895 Pa}

Pi =4.137 bar

Discharge pressure; Po =250 psi

Po =250 X 6895

Po=17.2375 bar

Condenser Temperature = 45^{o}C = 318K

Condenser pressure = 17.2375 bar

Compressor inlet = 4.137 bar

Compressor Outlet = 17.2375 bar

Cooling capacity = 1.5 TR =1.5 X 3.5 = 5.250 kW

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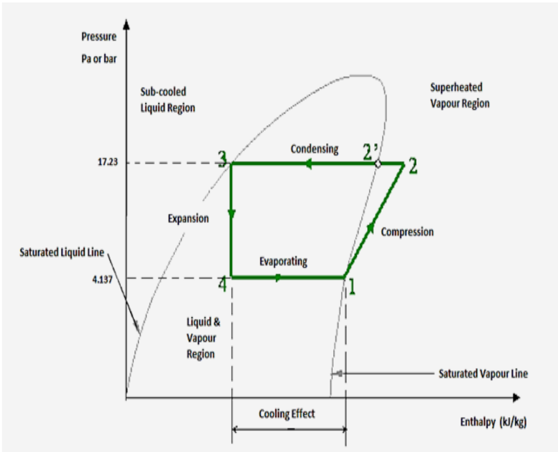

Fig. 3. Pressure enthalpy plot

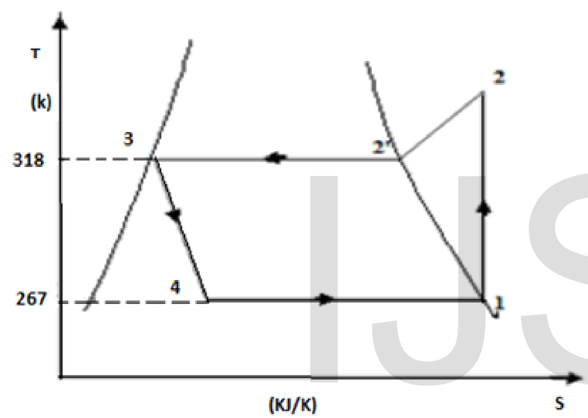

Fig. 4. T-S diagram for refrigeration cycle

By interpolation

T1 = -6 + (4.13 - 4.09172)/ (4.3797 – 4.09172) X 2 + 273

T1 = 267.266 K

T3 = T2′ = 45°C = 318 K

From R-22 Table: h 3 = hf3 = 105.58 kJ/kG = h2

h 1 = hg1 = (250.30+249.46)/2 = 249.88 kJ/kg

Refrigerating Effect = h1 – h3

= (249.88 – 105.58) kJ/kg

R.E. = 144.3 kJ/kg

Mass Flow Rate of Refrigerant

mr˙ = (5.25 kJ/sec) / (144.3 kJ/kg)

mr˙ = 0.0364 kg/sec

For Superheated temperature (T2)

i.e S1 = S2

At P=4.13 bar; S1 = Sg1 = 0.94105 kJ/kg

At P=17.34bar; S2 = 0.8755 kJ/kg

S2 = S2′ + Cp ln (T2/T2′)

S2 = 0.94105 = 0.8755 + 1.0256 ln (T2′/318)

T2 = 338.9882 K {(Cp) R-22 = 1.0256 KJ/Kg}

T2′ = 65.988°C ≈ 66°C

Enthalpy of Superheated Refrigerant

h 2 = h2′ + Cp (T2 – T2′)

h 2 = 263.67 kJ/kg at P2 =17.34bar

h 2 = 263.67 + 1.0256 (338.9882 – 3.18)

h 2 = 285.2076 kJ/kg

Heat available for Desuperheater (Qsup.)

Qsup. = mr· (h2 – h2′) = 0.0364 (285.2076 – 263.67)

Qsup. = 0.78397 kW = 783.9686 W

Heat Exchanger Unit

Given Data:

Material selected = copper

Thermal conductivity (k) = 380 W/mk

Inner diameter of tube (Di) = 6.4 mm

Outer diameter of tube (Do) = 8.0 mm

Fouling factor for refrigerant (F_r)= 0.000095

Fouling factor for water (Fw) = 0.000095

Thickness of tube (t) = 1.6/2 = 0.8mm

Heat transfer co-efficient for refrigerant side; hi = 898 W/m²K

Heat transfer co-efficient for water side; h_w = 151.85 W/m²K

Overall heat transfer co-efficient

1/U = 1/hi + 1/ h_w + dx/Kcu + Fr + Fw

= 1/898 + 1/151.58 + 0.8/380 + 0.000095 + 0.000095

U = 99.94 W/m²K

To find out Area of Heat Exchanger

Now find outlet temperature of water

Initial temperature; T_{w1} = 25°C

Qsup. = m_w· *Cpw *ΔT

783.9686 = (0.5/60) X 4.2 X 103 (Tw_2 – 25)

Tw_2 = 47.3991°C ≈ 47°C

By using Log mean temperature difference (LMTD) method

(ΔTm):

ΔT1 = (66 – 47)°C = 19°C

ΔT2 = (45 – 25)°C = 20°C

LMTD = (ΔT1 - ΔT2)/ln(ΔT1/ΔT2) = (19 – 20)/ln(19/20)

LMTD = 19.496°C

Now, Area of Heat Exchanger

Qsup. = U* A*LMTD(ΔTm)

783.9686 = 99.94*A*19.496

A = 0.4024 m2

To find length of pipe

$A = \pi * D_o * L$

$0.4024 = \pi * 8 * L * 10^{-3}$

L = 16.0095 m (i.e Fig.1)

3. Heat absorbed by water in heat exchanger

Flow rate of water LPM	Inlet temp. of water ^{O}C	Outlet temp. of water ^{O}C
0.5	25.3	52

Table -1 Temperature of Water

Heat absorb by water in heat exchanger

$Q_w = m_w^{\cdot} * c_{pw} * \Delta T$

= 0.5*4.2*103*(52 – 28.2)/60

Q_w = 829.5 W

4. Calculation of COP for normal air conditioning System

$(COP)_{th}$ = Refrigeration Capacity/power input

Cooling effect / power input = 5.25 / 1.870

$(COP)_{th}$ = 2.8075

Fig.5 Experimental set – up

5. Calculation of COP for air conditioning system with exhaust heat collection using heat exchanger:

COP = (Refrigeration Capacity + heat absorb by water in heat exchanger)/input power to air conditioning unit

= (5.25 X 103 W + 829.5 W)/(1.870 X 103 W)

$(COP)_{th}$ = 3.2511

6. Percentage increase in COP theoretically:

= (3.2511 – 2.8075) X 100/2.8075

=15.7945 % ≈ 16 %

4. Validation and Discussion of Results

In this paper, we have design the Heat Exchanger which uses the waste heat of air-conditioner for useful purpose (heating of water). The use of desuperheater tends to control the fluctuation in temperature of superheating reason.

The utilization of waste heat from AC via heat exchanger to heat the water which extracted superheated heat from it that increases the Coefficient of Performance (COP) of the Air-conditioner.We increases COP of AC by using desuperheater upto 16%.

5. Conclusions and Recommendations for Future Work

The following conclusions can be made based on the models and analyses presented in the previous chapters on the Waste Heat Recovery from Air-Conditioner as:

The C.O.P (coefficient of performance) of the system is increased by 16% using the heat exchanger with air conditioner.

a) Thermal pollution is reduced.
b) Waste heat is utilized for useful purpose (heating of water).
c) By regulating water flow rate in heat exchanger, refrigerant can be cooled to required degree.

Future aspect of our project

a) As we have a limited conventional energy resources, so we have to utilize the energy we have. So, by this system use can utilize the waste heat for usable purpose and also we can increase the effectiveness of AC.
b) Usable in Nursing Homes, Industrial purpose, Hotels, Mess, other place where hot water is required.
c) Electricity generation upto 200-500 Watt by designing suitable thermocouple by selecting the material having lower excitation temperature.

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