Heat Recovery Analysis of Window Air Conditioner

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Abstract - It is better to use maximum available energy for different purposes in a single device. That is a single device can be used for different applications without consuming additional work. An air conditioning system can be used multifunctional device. In air conditioning system high quality energy is degraded to surrounding at condenser. Heat recovery study of window air conditioner is carried out in this paper. The cooling capacity of unit is 1TR.working refrigerant is R22. By theoretical calculations the power input to the system is 1.0kW. Condenser heat rejection is estimated as 4.517kW. heat rejected by condenser is utilized to heat the water. Improved COP of the system will be the ratio of summation of refrigerating effect and heat recovery to the power input. Heat recovery is analyzed by two approaches. In first approach the temperature rise (dT) of water is kept constant. In the second method we investigate the same system for fixed heat recovery percentage (Q_{rc}). The water mass flow rate is varied from 20 to 200 LPH. It is observed that at low mass flow rates of water the high temperature rise up to 60^0C is achieved. Whereas as we increase the percentage of heat recovery the outlet temperature of water will increase expontionally. By increasing mass flow rate of water temperature rise of water (dT) decreases. The overall performance of thermodynamic system will get increase since COP will get increase. Combined effect of system proves the improved use of available energy. By using this system we get space cooling and water heating effects simultaneously with no additional power supply.

Keywords — availability, heat recovery, waste heat, work potentional

I. INTRODUCTION

Heat energy once degraded to lower temperature, it will not be of any use. Though atmosphere contain tremendous amount of energy but it will not be converted into high grade energy like electrical or mechanical work. Many of the devices working at higher temperature reject heat to surrounding. This heat rejection must takes place at atmospheric temperature in order to obtain maximum possible work from the device. Also heat is transferred from one body to another body when there is a finite temperature difference exists. If these two mediums are at same temperature then heat transfer will not be possible. So it is not possible to reject heat to surrounding at atmospheric temperature. Also according second law of thermodynamics system must exchange energy with at least two reservoirs otherwise such system practically does not possible. So any working device must that reject heat to surrounding at a temperature above the atmosphere. It is observed that almost all thermodynamic systems rejects heat energy to surrounding at very high temperature above the atmosphere. High temperature heat rejection will cause useful energy losses to surrounding. Otherwise this energy if supplied to heat engine will produce work. Therefore for any working thermodynamic system it is very important to do the waste heat recovery analysis to utilize the maximum potentional of system. By doing little modifications in existing system we will able to improve performance of the system. In this paper waste heat recovery analysis of air conditioning system is done. In air conditioning system heat is rejected to surrounding at condenser. It will cause wastage of energy, thermal pollution and increase global warming. This waste energy can be used to get sanitary hot water.

NOMENCLATURE

C_p	Specific heat of water (kJ/kg.K)
COP	Coefficient of performance
$\dot{m}$	Mass flow rate of water (kg/s)
Q_c	Heat rejected by condenser (kW)
Q_{rc}	Waste heat recovered from condenser (kW)
RE	Refrigerating effect (kW)
ΔT	Temperature rise of water (^{0}C)
W_{in}	Work input (kW)

II. LITERATURE REVIEW

Many researchers have studied the waste heat recovery technology of air conditioning system. Air conditioning system is one of the low temperature heat sources. Some of the important research work is discussed below Jie Jia W.L. Lee[1] studied the Storage-enhanced heat recovery room air-conditioner (SEHRAC). He focused on the optimal design of storage tank. . In this study, a typical residential estate in Hong Kong was chosen for supply and demand analysis. It was found that with the use of SEHRAC, the daily cumulative recoverable heat far exceeds the daily household water heating demand. For optimal design of the storage tank, an air-conditioner model (REFMOD) was_developed to enable ascertaining the operating parameters at the refrigerant side of SEHRAC.Other design requirements of the storage tank including the minimum required heat storage_capacity and heat transfer effectiveness were determined. The potential energy and energy cost savings, as well as CO2 emission reduction for wider application of SEHRAC were estimated as 9.3% of the overall contribution of the residential sector. Handing Wang, Qin Wang, Guangming[4] Chen have studied the experimental performance analysis of an improved multifunctional heat pump system. An improved multifunctional heat pump system integrates an air source evaporator and a water-water heat exchanger. Experimental results could show that MFHP system could simultaneously supply hot water & cold air for air conditioning. They have shown that coefficient of heating varies from 3.69 to 5.70. They also have shown that MFHP have satisfactory energy saving performance. Guangcai Gong, Wei Zeng, Liping Wang, Chih Wu[7] have researched a new heat recovery technique for air conditioning heat pump system this is so designed that it can shift flexibly between different working modes according to the building users requirement. They proved that system has better performance & COP is also increased upto 6.0. The problem they face is that hot water temperature is not too high in winter as required, so supplementary electric heating device should be used to heat water to a higher temperature. Guangcai Gong, Feihu Chen, Huan Su, Jianyong Zhou[3] have made working model of heat recovery on a single stage centrifugal chiller in a hotel having a capacity of 1750 kW. For various operating conditions they studied the performance of the system. It has been found that the performance of the system is increased; cost of producing hot water is minimized. C Aprea, A Greco[2], researched on a topic exergetic performance of R22 substitution by R407C. They analyzed the system for air cooled & water cooled condenser. They found that performance of R22 is extremely good than R407C. Also they studied what parameters decrease the performance of R 407C. Curtis Harrington, Mark Modera[5] study shows that rejecting A/C heat to swimming pool can save 25 – 30% of single family residential cooling electricity use and reduce cooling electricity demand during peak conditions by 30-35%, as compared to air cooled condenser system. Also they made a model for the same for various varying climate conditions of city. Ming Liu Jiang, Jing Yi Wu, Yu Xiong Xu, Ru Zhu Wang[6] do the investigation of Transient characteristics and performance analysis of a vapor compression air conditioning system with condensing heat recovery. They found that condensing heat recovery has a negative effect on the cooling capacity at the start of the heat recovery process, but average COP can be improved. The experimental comparison between the EEV and the thermostatic expansion valve (TEV) demonstrates that the EEV has better performance in both stability and efficiency in the condensing heat recovery system. The above studies shows that the heat recovery analysis only for the large capacity plants and not for the small units. So our study reveals the performance of small unit with and without heat recovery.

III. SYSTEM DESCRIPTION and METHODOLOGY

Following parameters are considered for analysis of waste heat recovery

- Refrigerant- R22
- Refrigerating capacity = 1TR
- Refrigerating effect = 3.517 kW
- Power supply = 1kW
- Condenser heat rejection = refrigerating effect + power supply
- Condenser heat rejection = 3.517+1 = 4.517kW
- COP of the system = 3.517

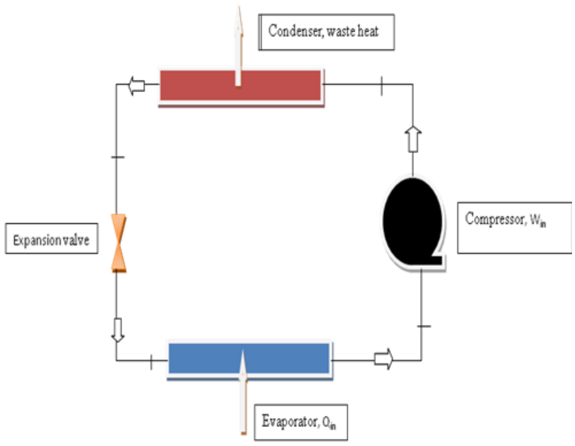

fig.1 schematic view of air conditioning system with waste heat recovery

Fig.1 shown above presents the schematic view of air conditioning system and waste heat. Fig.2 shows the P-h diagram for the vapor compression cycle with waste heat.

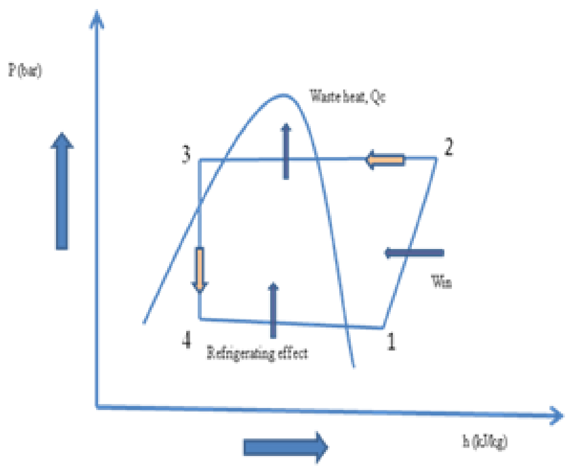

fig.2 P-h diagram of vapor compression cycle

3.1 Mathematical Calculations of Heat Recovery

The condenser waste heat will be utilized to heat water. Therefore, heat absorbed by water is given as,

Heat recovered,

$$Q_{rc} = \dot{m} \times Cp \times \Delta T \qquad (1)$$

Where,

Q_{rc} = the heat recovered by water

$\dot{m}$ = mass flow rate of water (kg/s)

C_p = specific heat of water = 4.187 kJ/kg.K

ΔT = temperature rise of water (K)

Heat recovered will be the additional benefit we get from the system. So the COP of the system will be redefined as

$$COP = \frac{\text{refrigerating effect} + \text{heat recovered}}{\text{workdone}}$$

$$COP = \frac{RE + Qrc}{Win} \quad (2)$$

Higher will be the temperature rise, more will be the heat recovery. So, important consideration of energy analysis is mass flow rate of water and percentage heat recovery.

The theoretical investigations are done to find the quality and quantity of heat recovery. For theoretical analysis we are considering two approaches one varying mass flow rate of water and water temperature rise (dT) is kept constant. Second approach analyzes system with constant percentage of heat recovery (10%, 20%, 30% etc.) and varying amount of mass flow rate of water. The results obtained are discussed below.

IV. RESULTS AND DISCUSSIONS

4.1 Constant Temperature Rise with Varying Mass Flow Rate of Water

As temperature of outgoing water is constant condenser heat and waste heat recovery will increase with mass flow rate of water. Important consideration in analysis is that power input to the system is considered as constant in any circumstances. Otherwise it will not possible to analyze system with varying availability of power. Fig.3 shows the variation of condenser heat and waste heat recovery with varying mass flow rate of water.

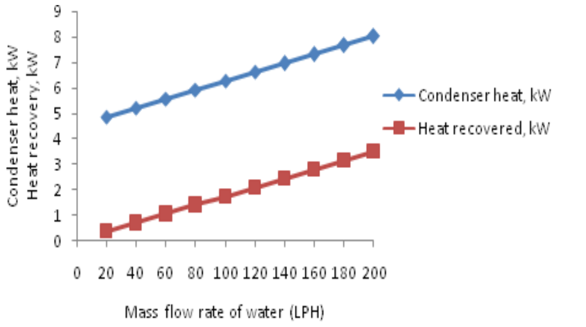

fig.3 Variation of condenser heat and heat recovery with mass flow rate of water

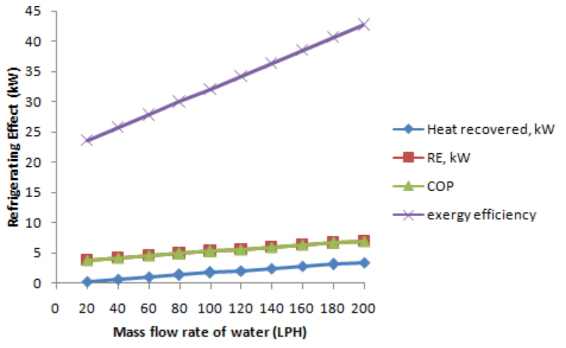

fig.4 variation of different parameters with mass flow rate of water

Fig.4 gives a cumulative result which shows that by increasing mass flow rate of water refrigerating effect is increasing whereas power supply remains same. Hence as an effect condenser heat rejection increases. Therefore waste heat recovery for constant temperature rise will get increase.

4.2. Analysis of Heat Recovery with Constant Heat Recovery and Power Supply with Varying Mass Flow Rate of Water

Following discussions represents the variation of COP, temperature rise and refrigerating effect for different percentage of waste heat recoveries. Author analyzed the system for 10%, 20%, 30% and 40% waste heat recovery from condenser. Also the theoretical investigations are done for same range of mass flow rates. The results obtain are represented below. For constant waste heat recovery of condenser the highest temperature rise obtained is at lower mass flow rate of water that is 20 LPH. Whereas Temperature decreases exponentially with mass flow rate of water. Fig.5 shows temperature variation of 10% heat recovery higher temperature raised by 20^0C.

Fig.6 shows the temperature graph for 20% heat recovery. Highest temperature rise achieved is 39^0C when water flow rate is 20 LPH.

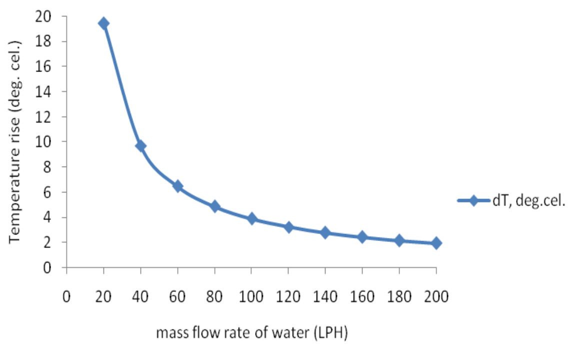

fig.5 Temperature rise of water for 10% heat recovery

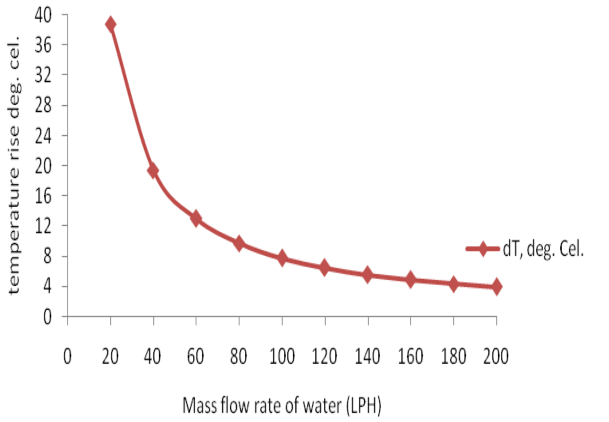

fig.6 Temperature rise of water for 20% heat recovery

30% heat recovery gives nearly 60^{0}C rise in temperature for 20 LPH water flow rate. As LPH increases temperature rise will get decrease. Temperature rise variation is shown in fig.7 for 30% waste heat recovery.

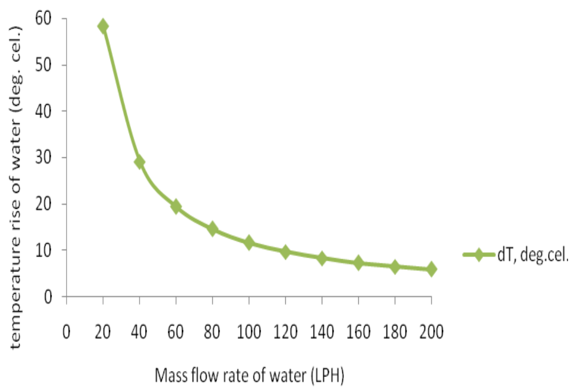

fig.7 Temperature rise of water for 30% heat recovery

Fig.8 shows comparison of all temperature profiles for different percentage of heat recoveries.

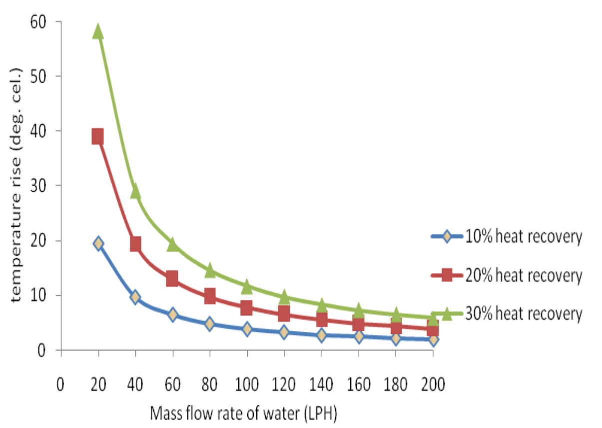

fig.8 Comparison of relative temperature rise of water for different percentage of heat recovery

CONCLUSION

The theoretical analysis of air conditioning system shows that large amount of energy is wasted at condenser. By doing heat recovery of the waste energy sanitary hot water can be obtained for different purposes. Theoretical analysis shows that for different mass flow rates of water for constant temperature rise COP of the system will increase with mass flow rates of water. Value of COP is 7 at 200 LPH and 4 at 20 LPH. Also for constant percentage of heat recoveries like 10%, 20%, 30% value of COP remains same. Temperature rise will be higher at lower mass flow rates of water and it decreases with increase in water mass flow rates. This system has very good impacts in energy saving technologies. Especially in tropical regions where air conditioners are widely used for space cooling can also be used for heating sanitary water. This technology has very good impact on global economy since millions of air conditioners having capacity few TR to thousands of TR being sold every year.

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