Development and Analysis of Waste Heat Recovery System by Air Conditioning

Application

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Abstract

At domestic commercial and industrial level, lots of air conditioners units are being used nowadays. There is a need to decrease the wastage of heat energy using processes of waste heat energy recovery. Formerly this waste heat energy is able to be renewed to several supplementary convenient useful form of energy. In this research work the waste heat energy recovery of an air conditioning system has been compared and measured. In the present system, we have four major units in our air conditioners system i.e. compressor, evaporator, condenser & expansion valve. In these units we are recovering heat from condenser by which we have arranged cross flow system in condenser to recover maximum heat from that. In the condenser which we are introducing the hot air coming from the condenser units will flow to our arrangement of water fins which is based on the cross flow (water and air). The advantages of this system is that it will improve the efficiency of our condenser unit and minimize the global temperature which is also a major reason of increasing global warming and as we know global warming harms the ozone layer. This theoretical and experimental research has been completed on basis of previous papers. In this research three types of air conditioner are being used. The system which has been developed is observing more heat from the system than conventional air conditioner system.

Keywords: Air conditioning system, Waste heat energy, Waste Heat Recovery System (WHRS), Waste heat recovery devices, Waste Heat Recovery Model, Coefficient of Performance (COP).

1. Introduction

A refrigeration heat recovery water heating system harvests heat that would normally be rejected to atmosphere through refrigeration condenser system and utilizes this heat for water heating purpose. The primary limitation of refrigeration heat recovery water heating system is the fact that heat is available only when refrigeration system is in operation.

Fig: Heat Recovery Systems

1.1 Different Heat Recovery System

1.1.1 Recuperators

In a recuperator, heat exchange takes place between the flue gases and the air through metallic or ceramic walls. Duct or tubes carry the air for combustion to be pre-heated; the other side contains the waste heat stream.

1.1.2 Regenerator

The Regeneration which is preferable for large capacities has been very widely used in glass and steel melting furnaces. In a regenerator, the time between the reversals is an important aspect. Long periods would mean higher thermal storage and hence higher cost.

1.1.3 Heat Wheels

It is a sizable porous disk, fabricated with material having a fairly high heat capacity, which rotates between two side-by-side ducts: one a cold gas duct, the other a hot gas duct. The axis of the disk is located parallel to, and on the partition between, the two ducts.

1.1.4 Heat Pipe

Heat pipe is a thermal energy absorbing and transferring system and have no moving parts and hence require minimum maintenance.

1.2 Sensible heat recovery application

In air conditioning facilities with high outside air requirements such as cleanroom air conditioning systems, considerable energy savings is possible by heat recovery using heat pipe heat exchanger

(HPHX). Heat pipe heat exchanger (HPHX) is an excellent device used for heat recovery in air conditioning systems.

2. Literature Review

DhananjayParmar et al (2017) reviewed the design of working research model associated with maximum utilization of waste heat via installation of water chamber in between compressor and condenser. This paper proposes and attains optimum utilization of waste heat recovery from VCR system that has nominal constructional, renovation and operating cost, substantially useful for domestic intent [1].

FankaiMeng (2017) presents a waste heat recovery solution based on thermoelectric power generation technology. The general structure of an air-cooling heat recovery device is designed. The physical model is established and solved. The results show that the heat sink design is the most key factor affecting the performance of air-cooling thermoelectric power generation device [2].

G.G. Momin et al (2014) described the way to recover waste heat from condenser unit of a household refrigerator to improve the performance of the system. The heat recovery from the household refrigerator is by thermo siphon. From the experimentation it was found that after recovering heat from the condenser of the conventional refrigerator its performance get improved than conventional refrigerator [3].

Haitao Wang et al (2016) described the significance of A heat pipe air conditioning (AC) system which used heat pipe heat exchanger (HPHE) to realize secondary heat recovery was proposed. The analysis of experimental data revealed that the average heat recovery efficiency of the HPHE AC system in winter is 21.08%, while 39.2% in summer. The results show that the secondary heat recovery HPHE AC system has a certain energy-saving advantage [4].

JaragSachin et al (2015) described the theoretical analysis of production of hot water and reduction of LPG gas using air conditioner waste heat. An attempt has been taken to recover waste heat rejected by the 2 TR air conditioning systems. The result of the paper shows that the temperature of hot water, time required for attaining that temperature for the necessary volume of water and the reduction of LPG gas by using hot water is also confabulated [5].

Krunal R. Meshram et al (2016) reviews the various techniques for heat recovery from Air Conditioning systems. The types of heat recovery techniques under consideration are: Fixed Plate, Heat Pipe, Rotary Wheel and Run-Around. A comparison of the development of these technologies has been done. For performance rating the efficiency of technology is considered [6].

Nikhil S. Chougule et al (2016) focuses on the dehumidification enhancement and sensible heat recovery aspects of heat pipe heat exchanger for an air conditioning application. Based on this study, the

application of a heat pipe heat exchanger in the conventional air conditioning systems is recommended as an efficient means for energy savings and dehumidification enhancement to maintain acceptable room conditions [7].

P. Elumalai et al (2015) presents an investigation on heat recovery from the condenser of the Vapour Compression Refrigeration (VCR) system through hot oven and heater which is placed between the compressor and condenser components. The effectiveness of the cooler with varying working time has been studied [8].

Pankaj Sayare et al (2017) determined the energy savings associated with improved utilization of waste heat from a domestic refrigerator. This project explores the possibility of combining three units i.e. Refrigerator, Air-Conditioner and water heater into a single unit, such that the device saves energy and the lot of space. This project is about attempt to merge domestic Refrigerator and Air conditioner into a combined system [9].

R.B. Lokapure et al (2012) described the process of energy conservation by using technique of utilizing waste heat from Air-conditioning system and increasing COP. The target of improving COP was up to 20 %, but in this case they have achieved their goal by recovering energy and improving COP up to 13% [10].

Satish K. Maurya et al (2014) explained a hypothetical approach towards the utilization of waste heat of a vapour compression refrigeration system. The rejected heat could be used to operate any other low grade heat required refrigeration system such as simple ejector refrigeration system [11].

Selin Kim et al (2016) described a computational study to determine an optimum position of a super heater used in an automotive WHR (waste heat recovery) system integrated with a 3.3 L V6 gasoline direct injection engine, and the results were validated through an experimental study. Based on the result, the optimum layout of a dual loop Rankine system for an automotive waste heat recovery was developed, and the automotive waste heat recovery rate was assessed for many driving test modes widely adopted in various regions of the world [12].

Sohan Sarangi (2015) considered the waste heat recovery from an air conditioning system. Normally waste heat rejected from air conditioners are used to provide hot water for domestic purposes. But based on this research it can be shown that the waste heat rejected by ACs can supply enough heat energy to provide hot water to boilers for heating and washing purposes [13].

3. Problem Definition

The heat energy that the air conditioner absorbs from rooms is expelled into the atmosphere. This heat energy is completely wasted which can be otherwise used in more effective and efficient way. Recently, this waste heat rejected by ACs was used to provide hot water. But, this heat is of 'low grade variety' and so it cannot be used for industrial purposes. Hence the hot water is used only for domestic purposes. Hence, there is a need to implement such a heat recovery system where the waste heat obtained can be utilized not only for domestic purposes but for also various other industrial uses such as providing steam or hot water to boilers, used for the production of the bio-fuel by growing algae farms. In short, we must have a device by which we can convert the low grade waste heat into high temperature heat so that it can be utilized in various purposes.

4. Design of Heat Recovery System

The heat recovery system is designed for the available desuperheating heat in the window air conditioner. The available heat is calculated by using the rated conditions of the window air conditioner and after that the heat exchanger design is done for that heat recovery. The design process will be done based on following guidelines.

- The heat recovery system will serve as a retrofit for an existing air conditioning unit.
- It must include provisions for bypassing the heat recovery system. These bypasses must allow normal operations of the air conditioner without heat recovery.
- The heat recovery system must not require pumps rather it should utilize thermo-siphon effects or tap water.
- All components of the system should be instrumented with thermometer and manometer.
- The material must endure flow and temperature variations and be resistant to corrosion.
- The heat recovery system components, such as tubes and fittings, must be standardized to lower the cost.

4.1 Technical Specification of the Set Up 1

Air Conditioner: Videocon

Model No. : VS4T53.WV

Equipment Rating: Single Phase, 230 V, 50 Hz, 13 A. 3 ster

Power Rating: 2.5 Kw

Refrigerant: R-22 (Chclf₂)

Normal Capacity: 1.5 TR

At Compressor: Hermitically Sealed Rotary

Condenser: Forced Convection Air Cooled

Evaporator: Forced Convection Air Cooled

Thermostat: On Panel

Energy Meter: For Compressor Provided

Pressure Gauge: 1 for Suction Pressure and 1 for Discharge Pressure

Temperature Indicator: Thermometer Indicator

Air Flow Measurement: By volume of capacity of cube and fan base as given standard condition.

Temperature of Air

Temp. of air	DBT °C	WBT °C	Enthalpy kJ / Kg
Inlet	45	25	81 (H1)
Outlet	22	18	56 (H2)

Heat extracted from cooling space= 25 kJ/Kg of air flow

Air flow rate = 0.3568 Kg/sec

Refrigeration Effect= 8920 W

COP for normal air conditioning system= 3.568

COP for air conditioning system with exhaust heat collection using heat exchanger= 4.2084

% increase in COP= 17.94 %

4.2 Technical Specification of the Set Up 2

Model No. : VS3P2 WE1

Normal Capacity: 1TR

Rest is same as set-up 1.

Temperature of Air

Temp. of air	DBT °C	WBT °C	Enthalpy kJ / Kg
Inlet	45	25	81 (H1)
Outlet	24	19	63 (H2)

Heat extracted from cooling space= 18 kJ/Kg of air flow

Air flow rate = 0.258236Kg/sec

Refrigeration Effect= 4648W

COP for normal air conditioning system = 1.8592

COP for air conditioning system with exhaust heat collection using heat exchanger= 2.6228

% increase in COP= 29.11 %

4.3 Technical Specification of the Set Up 3

Model No. : VS6C3 WM1

Normal Capacity: 2TR

Rest is same as set-up 1.

Temperature of Air

Temp. of air	DBT ⁰ C	WBT ⁰ C	EnthalpykJ/Kg
Inlet	45	25	81 (H1)
Outlet	19	16	52(H2)

Heat extracted from cooling space=29 kJ/Kg of air flow

Air flow rate = 0.32546Kg/sec

Refrigeration Effect = 9438.34 W

COP for normal air conditioning system = 1.7832

COP for air conditioning system with exhaust heat collection using heat exchanger= 2.53458

% increase in COP= 29.64 %

5. Research Mechanism

5.1 Economizer

Economizer can be provided to utilize the flue gas heat for pre-heating the boiler feed water. On the other hand, in an air pre-heater, the waste heat is used to heat combustion air.

5.2 Plate heat exchanger

It consists of a series of separate parallel plates forming thin flow pass. Each plate is separated from the next by gaskets and the hot stream passes in parallel through alternative plates whilst the liquid to be heated passes in parallel between the hot plates.

5.3 Radiator

Radiators are heat exchangers used to transfer thermal energy from one medium to another for the purpose of cooling and heating. The radiator is always a source of heat to its environment, although this may be for either the purpose of heating this environment, or for cooling the fluid or coolant supplied to it, as for engine cooling.

5.4 Fan and Motor

A fan is a machine used to create flow within a fluid, typically a gas such as air. The fan consists of a rotating arrangement of vanes or blades which act on the fluid. The rotating assembly of blades and hub is known as an impeller, a rotor, or a runner.

An electric motor is an electrical machine that converts electrical energy into mechanical energy.

5.5 Electric Heater

An electric heater is an electrical device that converts electric current to heat. The heating element inside every electric heater is an electrical resistor.

5.6 Electrical Wire

It is commonly understood to be an electrical installation for operation by end users within a building. It includes the cabling and associated devices such as switches, distribution boards, sockets and light fittings but does not cover the transmission of electrical power to the installation.

5.7 Light Switch

It is a switch, most commonly used to operate electric lights, permanently connected equipment or electrical outlets.

6. Parts of Project

Fig: Heater coil and plate

Fig: Fan blade

Fig: Motor

Fig: Water Pump

Fig: Radiator assembly

Fig: Assembly of project parts

7. Results

7.1 Summary of experimentation on 3 different set-ups of air conditioning system

Object of research	Model No. VS4T53.WV	Model No. VS3P2 WE1	Model No. VS6C3 WM1
Refrigerating effect	180.58 kJ/kg	138 kJ/kg	104 kJ/kg
Mass flow rate (mR)	0.0296265kg/sec	0.0387717kg/sec	0.051447kg/sec
Heat available for desuperheating	1888.39 W	2752.797W	3759.81W
Overall heat transfer coefficient	125.535561 W/m ² K.	125.535561 W/m ² K.	185.21 W/m ² K.
To find out Area of Heat Exchanger	0.529M ²	0.923M ²	1.125M ²
Length of Tube	16.84 Meter	29.25 Meter	35.4 Meter
Heat absorbed by water in heat exchanger	1601 W	1909 W	1879 W
COP for normal air conditioning system	3.568	1.8592	1.7832
COP for air conditioning system with new system	4.2084	2.6228	2.53458
Comparison of COP in both above cases	17.94%	29.11%	29.65%

7.2 Comparison of COP for normal air conditioning system and new system

7.3 Model No. VS4T53.WV

7.4 Model No. VS3P2 WE1 **7.5 Model No. VS6C3 WM1** **8. Conclusions**

According to the experimental results, we used three different load requirement air condition (1ton, 1.5ton and 2ton). The result of the comparison between without coil mode and coil mode indicates that the higher cooling load is given from low to high, the compressor power, condenser room temperature and room temperature will rise slightly with coil mode. The water temperature in reclamation tank also increases with the increase of cooling load while the increase is slightly higher at 3000 W load because more heat is absorbed in room and more heat is rejected in the reclamation to atmosphere. The use of coil causes a slight increase in compressor power, where the COP increases higher than the increase of compressor power percentage, because the test unit gives capacity as cooling and heating simultaneously.

Generally, the application of Air conditioner combined with water heater using coil (trombone coil condenser) does not affect the cooling performance but it can improve energy performance considerably for cooling and heating. Finally following points can be concluded.

- 1) The C.O.P (coefficient of performance) of the system is increased by 13.66% using the heat exchanger with air conditioner.
- 2) Thermal pollution is reduced.
- 3) Waste heat is utilized for useful purpose.
- 4) By regulating water flow rate in heat exchanger, refrigerant can be cooled to required degree.

9. References

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