

Performance Improvement of a Boiler through Waste Heat Recovery from an Air Conditioning Unit

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Abstract: In the present scenario energy crises is a severe problem across the globe. For the protection of global environment and maintain ecological balance, energy saving is one of the most vital issue from the view point of fuel consumption also. Therefore, it is essential that we should endeavour for waste heat recovery by making significant and concrete effort. Conservation of energy by waste heat recovery is the need of hour. In this paper main objective of the researcher is to study and analyses the feasibility of retrofitting the waste heat recovery system for hot water generation. An attempt has been made to recover the heat rejected by an air conditioning system used in a factory. The waste heat is used for producing hot water for Boiler Feed. The demand & supply and storage requirement is attempted. Such a system can be fabricated in the work shop of a factory and preliminary experiment can be carried out. This study will focus on the fact that such a system is technically feasible and economically viable. Waste heat is the heat which is produced in a process by combustion of fuel or exothermic chemical reaction and then rejected into the environment even though it can still be utilized for some useful and economic purpose. In most general case, waste heat is the energy associated with the waste streams of air, gases and liquid leaving the boundaries of a plant, section or building and lost to the environment. Waste heat which is rejected from a process at a temperature sufficiently higher than ambient air temperature permits the recovery of energy for some useful purpose in an economical manner. The essential quality of heat recovered is not the amount but it's "Value". The strategy of recovery of this heat not only depends on temperature of waste heat sources but also on the economics involved behind the technology used.

Keywords: Waste Heat, Air conditioning, recovery, Temperature

I. INTRODUCTION

Today's high costs of energy together with its environmental impact are reasons enough to warrant a reduction in energy consumption in current air conditioning systems or those at the design stage(Francisco Javier Rey Mart'inez et al, 2003). Any study of an air conditioning system in a building should focus mainly on indoor air quality (IAQ), thermal comfort, energy saving and environmental protection. Any approach aimed at improving IAQ [1] involves an increase in ventilation rates in buildings and therefore in the energy consumption linked to air-conditioning systems. Most air conditioning systems affect the environment in two ways:

1. Contributing to the greenhouse effect as energy consumers and producing CO₂, as well as through the use of organic substances in the cooling cycle.
2. Damaging the ozone layer as a result of the use of CFCs and HCFCs.

Taking all these factors into account, it is clear that the use of air energy air recovery equipment in air conditioning systems leads to-

1. An improvement in IAQ by allowing the introduction of greater ventilation air flows,
2. Reduced energy and thus primary energy consumption, with the resulting drop in CO₂ production and improvement in the environment,
3. Reduced energy requirements for air conditioning equipment and thus in the amounts of coolants used in them,
4. A reduction in operating costs.

In this thesis, the researcher has investigated a waste heat recovery system (WHRS) and experimented to recover condensation heat (heat rejected) from a commercial air conditioner unit of 22TR. The air conditioning unit rejects considerable amounts of heat to the atmosphere through its condensing coil unit. So, by suitably retrofitting the WHRS in the air condition ring unit, hot water is generated. The generated hot water is supplied for the purpose of Boiler Feed. Thereby saves significant amount of energy.

II. LITERATURE REVIEW

a. RECOVERY OF ENGINE WASTE HEAT

There are various works available on the Adsorption cooling with exhaust gas heat of engine. But, no significant work has been carried out by recovering and utilizing Engine heat in refrigeration system of a vehicle. According to Palm [1], Corberan et al.[2], Domanski and Yashar,[3]), most HFC refrigerants have a relatively high global warming potential (GWP) which is also being regulated by the Kyoto Protocol. They have cited that recent passage of legislation in the European Community requires the use of refrigerants with GWPs of less than 150 in all new-type vehicles starting in 2011 and in all new vehicles by 2017. Recently, Sami et al. [4] presented an improved dynamic model to study the single absorber and/or double absorber systems with heat recovery. The systems they studied employed an air cooled evaporator and an air cooled condenser. Hot oil, superheated steam or exhaust gas could be used as heating fluids for the absorbers. In these respects, they are similar to the automobile waste heat cooling system we propose. And it gave an insight into the thermodynamics for some of the system components. However, in their analysis, the cycle time was quite long and an equilibrium adsorption state was assumed. Colbourne [5] summarized a study analyzing over 50 published technical documents comparing the performance of fluorinated refrigerants and HCs. A significantly higher number of tests showed an increase in performance when using HCs as compared to using fluorinated refrigerants (Colbourne and Suen,)[6]. Similarly, Colbourne and Ritter[7] investigated the compatibility of non-metallic materials with HC refrigerant and lubricant mixtures. They performed experiments in compliance with European standards for the testing of elastomeric materials and ASHRAE material compatibility test standards. Maclaine-Cross and Leonardi[8] compared the refrigerant performance of HCs based on refrigerant properties and concluded that the COP improvements, commonly reported in literature, were consistent with better thermodynamic properties of HCs. R600a properties and their influences on system performance were discussed. Joudi et al. [9] studied the performance of MAC systems with alternative refrigerants. A computer model was developed to determine the most suitable alternative refrigerant to R12. The influence of evaporating temperature, condensing temperature and compressor speed in an ideal cycle was considered. Ghodbane [10] investigated the use of R152a and HCs in MACs.

b. PERFORMANCE IMPROVEMENT OF AIR CONDITIONING BY HEAT RECOVERY

Ambient temperature (average of 30°C) and humidity (70-80%) of Thailand are rather high, which affect the living and working efficiency (Poonpong Swatdepan et al 2006) [23]. Therefore, air conditioning in office is necessary. From previous researches, it revealed that amount of energy consumption of air conditioning in building is approximately 50-70% of the total energy consumption. Consequently, energy saving technique for air conditioning system should be examined. Liquid-suction heat exchangers are commonly installed in refrigeration systems in order to increase the performance of system. Domanski et al. [24] investigated the effect of LLSL-HX on system performance by taking liquid refrigerant from condenser to exchange heat with vapor refrigerant from evaporator. The authors reported that coefficient of performance was increased after installed LLSL-HX. Zhaolin et al. [25] used the PCMs (Phase change materials) to receive the sensible and latent heat from air conditioning system for washing and bathing processes. It was found that the energy consumption of compressor and heat transfer increased with increasing condenser temperature. It was revealed that the coefficient of performance increased from 2.96 to 3.45. The objective of this work is to comparatively study the performance of air conditioning systems. The criteria for investigating the performance are energy consumption, coefficient of performance, and energy efficiency ratio.

c. STRATEGY OF HEAT RECOVERY

The strategy of how to recover this heat depends not only on the temperature of the waste heat sources but also on the economics involved behind the technology incorporated (P. Sathiamurthi ET AL 2011)[27]. By experimenting with waste heat recovery system in Refrigeration unit, Kaushik and Singh [28] have found that, in general, 40% of condenser heat can be recovered through the Canopus heat exchanger for a typical set of operating conditions. Tugrul Ogulata [29] discussed the utilization of Design and Development of Waste Heat Recovery System for air Conditioning Unit 103 waste-heat recovery in textile drying process. Abu-Mulaweh [30] made a case study of a Thermo Siphon heat recovery system that recovers the heat which is rejected from an air conditioner. Soylemez [31, 32] studied on the thermo economical optimization of Heat Pipe Heat Exchanger (HPHE) for waste heat recovery system. Hung et al [33] discussed in a review of Organic Rankine Cycles (ORCs) for the recovery of low-grade waste heat in the energy-to-power conversion industry and suggested that for recovering low-grade waste heat in power generation industries is economically feasible using ORCs. In this paper, the authors have investigated a Waste Heat Recovery System (WHRS) and experimented to recover condensation heat (heat rejected) from a commercial air conditioner unit of 22 TR. The air-conditioning unit rejects considerable amount of heat to the atmosphere through its condensing coil unit. So, by suitably retrofitting the WHRS in the air conditioning unit, hot water is generated. The generated hot water is supplied to the student's hostel for bathing purpose. Thereby saves significant amount of energy.

III. EXPERIMENTAL SETUP

Air conditioning is the process of altering the properties of air (primarily temperature and humidity) to more favorable conditions. More generally, air conditioning can refer to any form of technological cooling, heating, ventilation, or disinfection that modifies the condition of air. An air conditioner (often referred to as AC) is a major or home appliance, system, or mechanism designed to change the air temperature and humidity within an area (used for cooling and sometimes heating depending on the air properties at a given time). The cooling is typically done using a simple refrigeration cycle, but sometimes evaporation is used, commonly for comfort cooling in buildings and motor vehicles. In construction, a complete system of heating, ventilation and air conditioning is referred to as "HVAC". The basic concept behind air conditioning is known to have been applied in ancient Egypt where reeds hung in windows had water trickling down. The evaporation of water cooled the air blowing through the window, though this process also made the air more humid. In Ancient Rome, water from aqueducts was circulated through the walls of certain houses to cool them down. Other techniques in medieval Persia involved the use of cisterns and wind towers to cool buildings during the hot season.

Modern air conditioning emerged from advances in chemistry during the 19th century, and the first large-scale electrical air conditioning was invented and used in 1911 by Willis Haviland Carrier. The introduction of residential air conditioning in the 1920s helped start the great migration to the Sunbelt. The first air conditioners and refrigerators employed toxic or flammable gases, such as ammonia, methyl chloride, or propane, that could result in fatal accidents when they leaked. Thomas Midgley, Jr created the first non-flammable, non-toxic chlorofluorocarbon gas, Freon, in 1928. "Freon" is a trademark name owned by DuPont for any Chlorofluorocarbon (CFC), Hydro chlorofluorocarbon (HCFC), or Hydro fluorocarbon (HFC) refrigerant, the name of each including a number indicating molecular composition (R-11, R-12, R-22, R-134A). The blend most used in direct-expansion home and building comfort cooling is an HCFC known as R-22. It was to be phased out for use in new equipment by 2010, and is to be completely discontinued by 2020.

In this research work, For the air conditioning of plant a 22 TR centralized air conditioner is being used. It has an air cooled condenser as shown in the figure. This air conditioning unit operate for an average of 18 hrs in a day. In order to utilize waste heat rejected by condenser to the atmosphere additional water cooled condenser can be installed which will heat boiler feed water. Also some necessary modifications are made to make the system feasible and economically viable. Construction and working of proposed model are shown below:

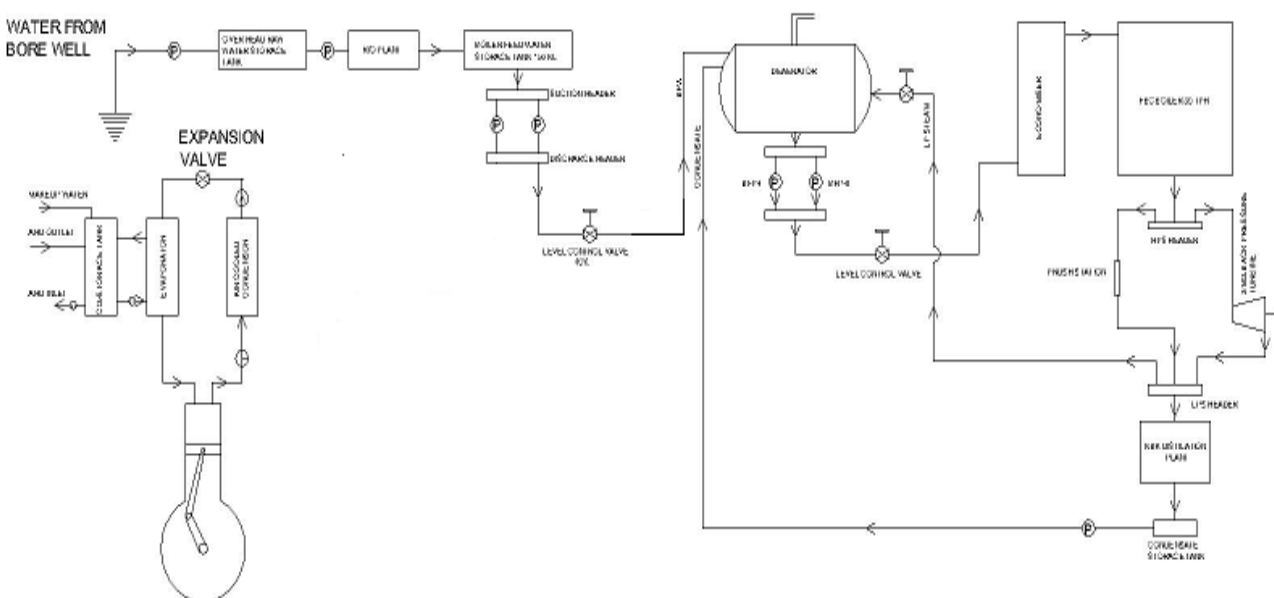


Figure: 3.1 Experimental Set-up before Modification

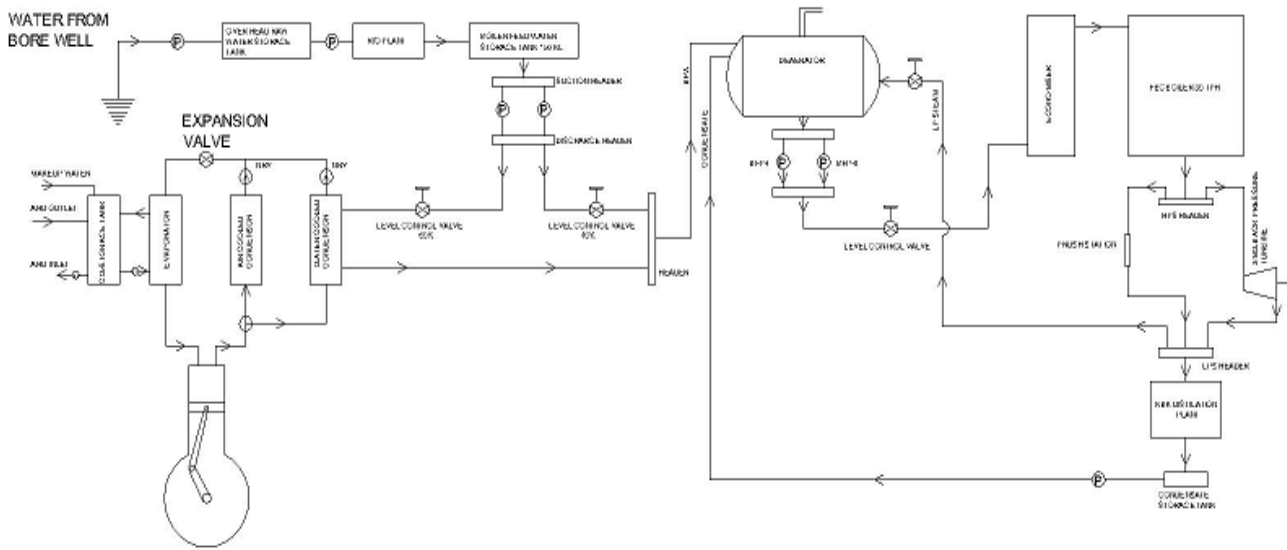


Figure: 3.2 Experimental Set-up after Modification

IV METHODOLOGY

The Air Conditioning Unit of “Gwalior Alcobrew Private Limited” Rairu was observed for few months working hours on the regular intervals. Time measurement for various losses was setup and adjustment; changes in process, Transportation, Inventory Management were suggested. It was observed by the researcher that waste heat of Air Conditioning Unit could be utilized for Heating Feed water of boiler. A hypothetical model as discussed above was suggested on the basis of research and Analytical interpretation and comparison of data.

V. CALCULATION

22 TR Air Conditioning Systems SPECIFICATIONS

1. Average COP = 5
2. Working Hrs. (Average) = 18
3. Water flow rate for air conditioner $m_{w1} = 16.8$ Ton per hour
4. Inlet temperature of water = $25^{\circ}C$
5. 1 TR = 13,938 KJ / Hr.

5.1 Fuel Saving

Heat rejected by air conditioner –

$$COP = \frac{Q_2}{Q_1 - Q_2}$$

$$5 = \frac{22 \times 13938}{Q_1 - 22 \times 13938}$$

$$Q_1 = 367936.2 \text{ KJ/hr}$$

Again

$$Q_1 = m_{w1} S \Delta T$$

$$T_{w2} = 30.23^{\circ}C$$

Heat Gained by Water = Mass of Coal X GCV of Coal

$$367936.2 = M_f \times 19228$$

$$M_f = 19.13 \text{ kg per hour}$$

So, Total coal saving in a day

$$M_{f/day} = 344.34 \text{ kg per day.}$$

So, Cost saving in rupees/month,

$$\text{Coal Cost Rs. 6 / kg}$$

$$C = \text{Rs. 61981 / month}$$

5.2 Pay back Calculation

(Details of Total Expenses are given in Table 5.1)

$$\text{Total Expenses} = \text{Rs. 545000.00}$$

$$\text{Cost saving per month} = \text{Rs. 67651.00}$$

So, Pay back is

$$= 545000.00 / 67651.00$$

$$= 8.06 \text{ month.}$$

5.2.1 Cost of fuel calculation per day

$$\text{Coal Saving} - 344.34 \text{ kg per day} \times \text{Rs. 6 / kg}$$

$$= \text{Rs. 2066 / day}$$

$$\text{Cost of fuel per day before implementation}$$

$$= \text{Rs. 80,4000}$$

$$\text{Cost of fuel per day after implementation}$$

$$= \text{Rs. 80,1934}$$

5.2.2 Boiler performance calculation

- Boiler performance calculation before implementation
- Mass of steam produce per day $M_s = 672$ Tons
- Enthalpy of produced steam $H_s = 790$ kcal / kg
- Enthalpy of feed water $H_f = 105$ Kcal / kg
- Mass of Coal consume per day $M_f = 134000$ kg
- Gross Calorific Value of Coal = 4500 Kcal / kg

Efficiency of Boiler before implementation

$$= \frac{M_s(\text{Enthalpy of Steam} - \text{Enthalpy of Feed water})}{M_f \times \text{GCV of coal}}$$

$$= \frac{672(790 - 105)}{134 \times 4500}$$

$$= 0.7633$$

$$= \mathbf{76.33\%}$$

Boiler performance calculation after implementation

- Mass of steam produce per day
M_s = 672 Tons
- Enthalpy of produced steam
H_s = 790 kcal / kg
- Enthalpy of feed water
H_f = 105 Kcal / kg
- Mass of Coal consume per day
M_f = 133655.66 kg
- Gross Calorific Value of Coal = 4500 Kcal / kg

Table I

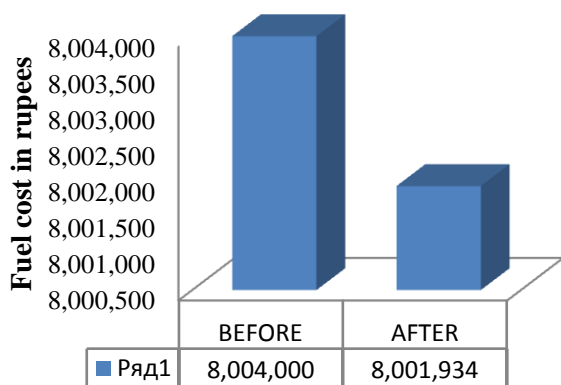
S. No.	Particulars	Quantity	Total Amount in Rs.
01	Water cooled condenser for 22 TR AC System	01	3,10,000.00
02	Control Valves, Three way Valve and NRV etc	One lot	1,35,000.00
03	Pipe line and fittings	One lot	35,000.00
04	Installation, erection and commissioning work	Job work	35,000.00
05	Insulation cost	Job work	30,000.00
Total Cost = 5,45,000.00			

VI. CONCLUSION

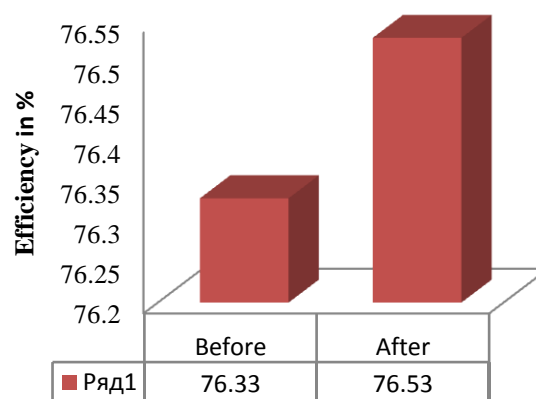
Results of present research are as follows-

1. Waste Heat of Air Conditioning Unit can be utilized for an useful purpose.
2. After Implementation of proposed model Fuel consumption reduces from 1,34,000 kg to 1,33,655 kg per day.
3. Fuel cost reduces from Rs. 8,04,000 to Rs. 8,01,934 per day.
4. Efficiency of Boiler will increase from 76.33% to 76.53%.

Fuel Cost Per Day



Comparison of Boiler Efficiency



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Biography



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