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Energy Conservation in Power Generation Boilers

S. Mahmood Ul Haq[1], and S. Shahab Anwar[1]

ABSTRACT

In this paper some energy conservation measures are suggested for power generation boiler plants on the basis of analysis of their energy consumption and heat transfer. Many left over areas such as heat recovery systems are important part of an energy conservation programme. Saving of energy could reduce the amount of purchased energy and the energy cost ultimately. Many recommendations are also made on the basis of the data collected from the plant.

INTRODUCTION

Energy conservation in a power plant based on the steam generation is a very important task in the background of all time energy shortfall in the country. Realizing the fact a study was conducted on power generation boilers to identify neglected areas of energy utilization (Couch et al., 1981) in order to save avoidable energy losses. During study of three power generation boilers in a chemical plant in Karachi, we were able to determine the magnitude of energy consumption (Table 1), conservation and combustion efficiency in these boilers. The plant has water tube package boiler unit of 36 tonnes per hour having superheater and economizer to increase thermal efficiency. It is apparent from Table 2 that the economizer in boiler no. 3 is wasting 2% heat resulting in an estimated loss of 22m^3 gas per hour. The other losses are dependent on fuel combustion and the boiler design (Dryden, 1975). Detailed study reveals that the combustion performance of burners is efficient which is confirmed by the excess air level in the boiler. The dry flue gas composition and negligible amount of unburnt gas indicate good performance of boilers.

INVESTIGATION AND FINDINGS

Combustion Air Fuel Ratio

The plant was found well balanced despite its long services for over 25 years. Energy management group has been saving energy through efficient method of energy utilization in major areas e.g. complete combustion in all three boilers. However, more saving could be achieved by further study of left over areas e.g. heat recovery in economizer and in steam traps. The combustion air measurement is vital for the derivation of air/fuel ratio and hence for the calculation of efficiency of combustion (Dryden, 1975).

Excess Air and Heat Loss Evaluation

In order to get complete combustion, it is required to maintain correct value of air to fuel ratio. Exhaustive analyses of flue gas of three boilers indicate that the process of combustion is complete (Table 3).

To determine the minimum excess air rate which permits entirely satisfactory operation, each boiler was studied with care, since the main error in fuel conservation occurs when the quantity of excess air is allowed to enormously exceed that quantity which would permit complete burning of fuel. Excess air serves as a coolant or heat sink in the furnace. If there is too much quantity of excess air the flue gas temperature falls down (Fuchs et al., 1977). In a programme of excess air reduction the boiler manufacturers always state that with a specified fuel at a particular excess air level boiler transfers the required quantity of heat at a specified thermal efficiency. The analysis of the plant under investigation narrates that the three boilers are maintaining from 8% to 16% of excess air (Table 3).

Flue Gas Analysis

Comparing three boilers the combustion pattern in boiler nos. 1 and 2 are similar while in the boiler no. 3, it is more efficient. Due to high flue gas temperature in the boiler no. 3 (which is quite higher than the other two boilers), its combustion efficiency resulted less than the other two boilers (Table 4). Considering the excess air level and the CO_2 and CO values of boiler no.3, it is concluded that high temperature of flue gas is due to poor waste heat recovery situation in boiler no.3 and this could be due to low heat transfer efficiency of economizer or some steam leakage from the steam tube.

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[1] Hydrocarbon Development Institute of Pakistan, Karachi.

Table 1. Energy consumption in boilers.

	Boiler 1	Boiler 2	Boiler 3
Flow rate of natural gas (m^3/hr)	900	1100	1100
Heat value (million Btu/hr)	30.9	37.8	37.8
Fuel temperature (°F)	90	90	90
Fuel pressure (Psi)	11.5	11.5	11.5

Table 2. Heat transfer through economizer.

Temperature	Boiler 1	Boiler 2	Boiler 3
Flue gas temperature before economizer (°C)	330	318	330
Flue gas temperature after economizer (°C)	176	181	240

Table 3. Flue gas analysis of boilers.

	Boiler 1	Boiler 2	Boiler 3
Oxygen (%)	2.6	2.9	1.6
CO_2 (%)	10.5	10.3	11.1
CO (ppm)	2	14	Nil
Unburnt HC (%)	0.1	0.1	Nil
Flue gas temperature (°C)	176	181	240
Amb. temperature (°C)	32	32	32
Efficiency by instrument (%)	84	84	81.5
Excess Air (%)	14	16	8

Table 4. Measurements for boiler efficiency.

	Boiler 1	Boiler 2	Boiler 3
Calorific value of fuel (Btu/ft^3)	975	975	975
Flue gas temperature (°C)	176	181	240
Combustion air temperature (°C)	32	32	32
Oxygen (%)	2.6	2.9	1.6
Excess Air (%)	14	16	8
Temperature difference betweem flue and combustion air(°C)	144	149	208
Dry flue gas loss (%)	5.1	5.2	6.2
Loss due to Hydrogen (%)	10.5	10.8	11
Radiation loss (%)	2	2	2
Unmeasured loss (%)	0.5	0.5	0.5
Total loss (%)	18.1	18.5	19.7
Combustion efficiency calculated based on above losses (%)	85	84	83
Boiler efficiency calculated by total losses (before steam distribution (%)	82	81	80

Energy Balance Through Flue Gas Weight

In order to prepare an energy balance sheet and to determine the economizer's efficiency (Cherrington and Michelson, 1974) through calculation based on flue gas weight, the velocity of the flue gas must be metered at the flue gas outlet duct and the duct area must also be known. These parameters are not being considered at the plant. A velometer for the measurement of velocity of flue gas escaping through duct is required to be installed in the plant.

Table 5. Heat balance.

	Gas (m^3/hr)	Heat Value (10^6 Btu/hr)	(%)
Heat input to system	3300	113.6	100
Heat Consumed by:			
Boiler	2682	92.3	81.3
Flue gases	535	18.4	16.2
Radiation & unaccounted	82	2.8	2.5

Radiation Through Furnace Wall

The radiative heat loss through the wall of the boiler is usually derived by measuring the wall temperature, the ambient air temperature and velocity, but due to the absence of such parameters measuring instruments it is estimated that the radiation loss is 2% of the total loss.

Blown-Down Heat Recovery

The blow-down from boiler is a large source of heat loss. (H.S.E. Guidance note, 1965). The heat from blow-down can be recovered by utilizing its low temperature usage. In these boilers temperature and pressure are not being recorded. Therefore, the calculation of heat loss through blow-down water could not be ascertained. Roughly we can say that 2% heat could be saved.

Economizer Efficiency

The purpose of heat transfer surface area within a boiler is to extract heat from hot combustion products and to transfer this heat to water. In modern water-tube boilers, economizer not only fulfils the important function of heat recovery surface, but it is, in general, an integral unit. The performance of the boiler's economizer is derived by the recorded values of flue gas before and after the economizer (Table 2). The values of these temperatures clearly show that the waste heat driven efficiency of the economizer in boiler no. 3 is low which leads to escape of 2% unrecovered heat resulting in the estimated loss of 22 m^3 per hour of natural gas from boiler no. 3.

Combustion Efficiency

The combustion efficiency of boiler furnaces nos. 1, 2 and 3 are calculated as 85%, 84% and 83% respectively (Table 4).

CONCLUSION

The detailed energy auditing of the plant indicates from its flue gas analyses that the process of combustion is complete. Mixing of fuel and air controls the rate of heat release by combustion in diffusion flame. The observations made on the analysis of O_2, CO and CO_2 values of three boilers show that in the boiler nos. 1 and 2 the mixing pattern is according to the boiler design. The high flue gas temperature of boiler no. 3 is due to the combustion process which is fast in relation to the rate of heat loss causing reduction in combustion efficiency. It can also be described as a poor waste heat recovery situation in boiler no. 3. This low rate of heat transfer may be either due to the low heat transfer efficiency of economizer or some steam leakage from the tube. The flue gas temperatures before and after the economizer vividly show that the waste heat driven efficiency of economizer in boiler no. 3 is very low. This leads to escape of 2% of heat which is un-recovered.

A regenerator may be retrofitted in addition to the existing system to recover heat loss. In order to prepare an energy balance on flue gas weight, the velosity of the flue gas must also be known. It is also recommended that the plant should make full use of latent heat in boiler blow-down water.

Finally, it is calculated from the data that the plant is running on 81% boiler efficiency before steam distribution and thus wasting 617 m^3/hr gas out of total supply of 3300 m^3/hr (Table 5) which could further be saved if rectrification is employed by considering above mentioned losses.

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