INVESTIGATION OF HEAT TRANSFER ANALYSIS IN A 4- PASS FIRE TUBE BOILER

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ABSTRACT

The efficiency of a boiler the ratio of heat utilized in producing steam and heat liberated in the furnace, but the heat liberated in the furnace is always greater than heat utilized in the boiler ,the differences that exist between these forms of heat is known as the heat losses in the boiler .This paper analyses the various heat losses as it affects the efficiency of the fire tube boiler located at the department of Mechanical Engineering, Kaduna Polytechnic. Emphasis was made on the reason for these losses and ways to minimize it.

SIGNIFICANCE OF THE PAPER: The performance parameters of boiler, like efficiency and evaporation ratio reduces with time due to poor combustion, heat transfer surface fouling and poor operation and maintenance. Even for a new boiler, reasons such as deteriorating fuel quality, water quality etc. can result in poor boiler performance. Boiler efficiency tests help us to find out the deviation of boiler efficiency from the best efficiency and target problem area for corrective action.

Keywords: Fire tube, Boiler, Heat losses, Fuel and efficiency.
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INTRODUCTION

A boiler is a closed vessel in which water under pressure is transformed into steam by the application of heat. In the boiler furnace, the chemical energy in the fuel is converted into heat, and it is the function of the boiler to transfer this heat to the contained water in the most efficient manner. The boiler should also be designed to generate high quality of steam for plant use (Abdulrahamn, 2001). A boiler must be designed to absorb maximum amount of heat released in the process of combustion. This heat is transferred to the boiler water through radiation, conduction and convection. The relative percentage of each is dependent upon the type of boiler, the designed heat transfer surface, and fuel (Abdulrahman, 2001). Two principal types of boilers are used for industrial applications: fire tube and water tubes boilers. In the fired tube boilers, products of combustion pass through the tubes, which are surrounded by water. In the water tube boilers, products of combustion pass around the tubes containing water. The tubes are interconnected to common channels or headers and eventually to a steam outlet for distribution to the plant system (Brockman, 1988).

Fire tube boilers consist of a series of straight tubes that are housed inside a water-filled outer shell. The tubes are arranged so that hot combustion gases flow through the tubes. As the hot gases flow through the tubes, they heat the water surrounding the tubes. The water is confined by the outer shell of boiler. To avoid the need for a thick outer shell fire tube boilers are used for lower pressure applications. Generally, the heat input capacities for fire tube boilers are limited to 50 mbtu per hour or less, but in recent years the size of fire tube boilers has increased.

Fire tube boilers are subdivided into three groups. Horizontal return tubular (HRT) boilers typically have horizontal, self-contained fire tubes with a separate combustion chamber. Scotch, Scotch marine, or shell boilers have the fire tubes and combustion chamber housed within the same shell. Firebox boilers have a water-jacketed firebox and employ at most three passes of combustion gases.

Most modern fire tube boilers have cylindrical outer shells with a small round combustion chamber located inside the bottom of the shell. Depending on the construction details, these boilers have tubes configured in either one, two, three, or four pass arrangements. Because the design of firetube boilers is simple, they are easy to construct in a shop and can be shipped fully assembled as a package unit.

These boilers contain long steel tubes through which the hot gases from the furnace pass and around which the hot gases from the furnace pass and around which the water circulates. Firetube boilers typically have a lower initial cost, are more fuel efficient and are easier to operate, but they are limited generally to capacities of 25 tonnes per hour and pressures of 17.5 kg per cm^2

Boilers mix air with fuel to provide oxygen in the combustion process. For safety reasons, a small amount of additional or "excess air" is always provided to assure that all fuel is burned inside the boiler [Stultz, S.C. and J.B. Kitto. (1992]. By operating a boiler with a minimum amount of excess air, stack heat losses can be decreased and the combustion efficiency can be increased. But, unnecessary amount of excess air can lead to [S. Krishnanunni (2012]:

Burner/control system imperfections:
Variations in boiler room temperature, pressure, and relative humidity
Need for burner maintenance

Changes in fuel composition

To achieve optimum combustion efficiency, heat losses must be minimized. Combustion losses are either fuel losses (that increase toward the fuel-rich end) or air losses where heat energy is wasted by heating excess air that is lost through the flue. Excess air results in the flue gases containing „free" oxygen. The percentage of oxygen in flue gas will increase with increasing excess air, and the proportion of carbon dioxide will correspondingly fall [Dukelow, S.G. 1991].

METHODOLOGY

This study was carried out on a fire tube boiler in the boiler unit of Mechanical Engineering Department ,Kaduna polytechnic.

The fuel is used in firing the boiler is Butane. The circulation of water is done manually by pouring through the inlet at the top of the boiler and saturated steam of 132 0C is produced. The specification of boiler is given below:-

- locally constructed Boiler
- Horizontal gas fired boiler
- Length :- 71cm
- Capacity :- 210kg/hr
- Working Pressure :- 10.1 Kg/cm2
- Chimney :- Diameter ;3.75cm

Height ;62.4cm

(1)**Percentage of heat loss in dry flue gas per kilogram of fuel**

The temperature of flue gas is above 150^{0}c,But excess of it will amount to heat loss.

$$\frac{m\ c[Tg - Tb]X\ 100}{\text{GCV of fuel}}$$

(2) **Percentage heat lost in moisture present in fuel**

$$\frac{m[hsup - h]X\ 100}{\text{GCV of fuel}}\ \text{but hsup} = \text{enthalpy of superheated steam}$$

(3)**Percentage heat lost to steam formed by combustion of hydrogen per kg of fuel.**

$$\frac{(9H_2 + M)[h + cp(tg - t) - h]X100}{\text{GCV of fuel}}$$

(4)**Percentage heat lost due to incomplete combustion of carbon to carbon monoxide**

This usually occur due to insufficient supply of oxygen

$$= \frac{mc\ X100}{\text{GCV of fuel}}, \text{where m}$$
$$= \text{mass of carbon monoxide in flue gas per kg of fuel and c}$$
$$= \text{calorific value of carbon monoxide}$$

(5) **Percentage of heat loss due to Blow down**

Water evaporates continuously leaving behind the salts in the boiler. This leads to continuous increase in the concentration of these salts in the boiler drum which requires regular blow down
and results in wastage of fuel.

$$= \frac{m\ X0.02\ X\ h\ X\ 100}{Mf\ X\ CV}$$

(6)Heat lost due to radiation is the differences between heat supplied per kilogram of fuel and heat utilized/heat lost, It occur due to the transfer of heat from the side walls of the boiler to outside. These are fixed losses and are assumed to be 1% or 2% as per BS 845,They also the unaccounted heat losses.

(7) **Mass of dry flue gas**

= mass of [C_3 +H_6 +O_2] +N_2 in air supplied for combustion.

Net efficiency of the boiler

= **100% − TOTAL LOSS%** [in percentage]

RESULTS AND DISCUSSION

This laboratory experiment was performed on weekly basis for a period of one semester, the months of October, November, January, February and March.

AVERAGE VALUE OF MASS OF FUEL CONSUMED AND MASS OF STEAM PRODUCED

TABLE 1:Mass of fuel Consumed and Mass of Steam Produced

MONTHS	MASS OF FUEL CONSUMED	MASS OF STEAM PRODUCED
OCTOBER	450 Kg	1200Kg
NOVEMBER	450Kg	1190Kg
JANUARY	500Kg	1223Kg
FEBRUARY	450Kg	1227Kg
MARCH	450Kg	1209Kg

From table 1,despite the constant amount of fuel supplied for students practical on monthly basis, variation in steam produced.

TABLE 2:Flue gas analysis

	OCT	NOV	JAN	FEB	MAR
FLUE TEMPERATURE	131^0	132^0	132^0	133^0	131^0
AMBIENT TEMPERATURE	31^0	31^0	32^0	32^0	32^0
HUMIDITY(kg/kg of dry air)	0.022	0.022	0.023	0.021	0.022
Co_2	8.2	8.8	8.1	8.7	8.2
O_2	7	9	9	8	9.1
CO	123	124	125	123	123

Percentage losses in various forms were calculated from the available figures in Table 1 and table 2 and the results is presented in table 3 below

TABLE 4:Observed heat losses from the boiler in a semester

OBSERVATION	MONTHS				
	OCT.	NOV.	JAN.	FEB.	MAR.
Percentage of heat loss in dry flue gas per kilogram of fuel	8.53	8.44	8.58	8.55	8.61
Percentage heat lost in moisture present in fuel	0.19	0.188	0.198	0.189	0.192
Percentage heat lost to steam formed by combustion of hydrogen per kg of fuel	7.3	7.1	7.33	7.34	7.61
Percentage heat lost due to incomplete combustion of carbon to carbon monoxide	0.93	0.91	0.94	0.97	0.92
Percentage of heat loss due to Blow down	0.86	0.9	0.86	0.89	0.87
Heat lost due to radiation	2	2	2	2	2
Mass of dry flue gas	16.8	16.0	16.7	16.9	16.5
TOTAL LOSS	36.61	35.53	3.638	35.95	3.77
EFFICIENCY	63.39	64.46	63.3	64.05	63.3

Table 3 shows that maximum amount of heat was lost along with flue gas. And next is heat loss due to evaporation of water due to the presence of hydrogen in fuel . unaccounted loss which occur due to the observation an error, convection and conduction loss which is assumed as 2% as per BS 845. Fourth loss was due to blow down .which can only be rectified by installing Automatic blow down controller. Its life span is short as its sensor requires high maintenance. So the durability and efficiency of the instruments can ensure by maintenance. Fifth loss was due to radiation occurs due to the transfer of heat from the boiler side- walls to outside. These are fixed losses and are assumed to be 1% as per BS 845. Sixth loss was due to unburned fuel. If heat loss in dry flue gas can be controlled, then heat loss due to unburned fuel can be automatically reduced to zero. Heat loss due to the presence of moisture in fuel is negligible. Among them, heat lost along with the flue gas and due to unburned fuel was considered as important reasons for the declining boiler efficiency.

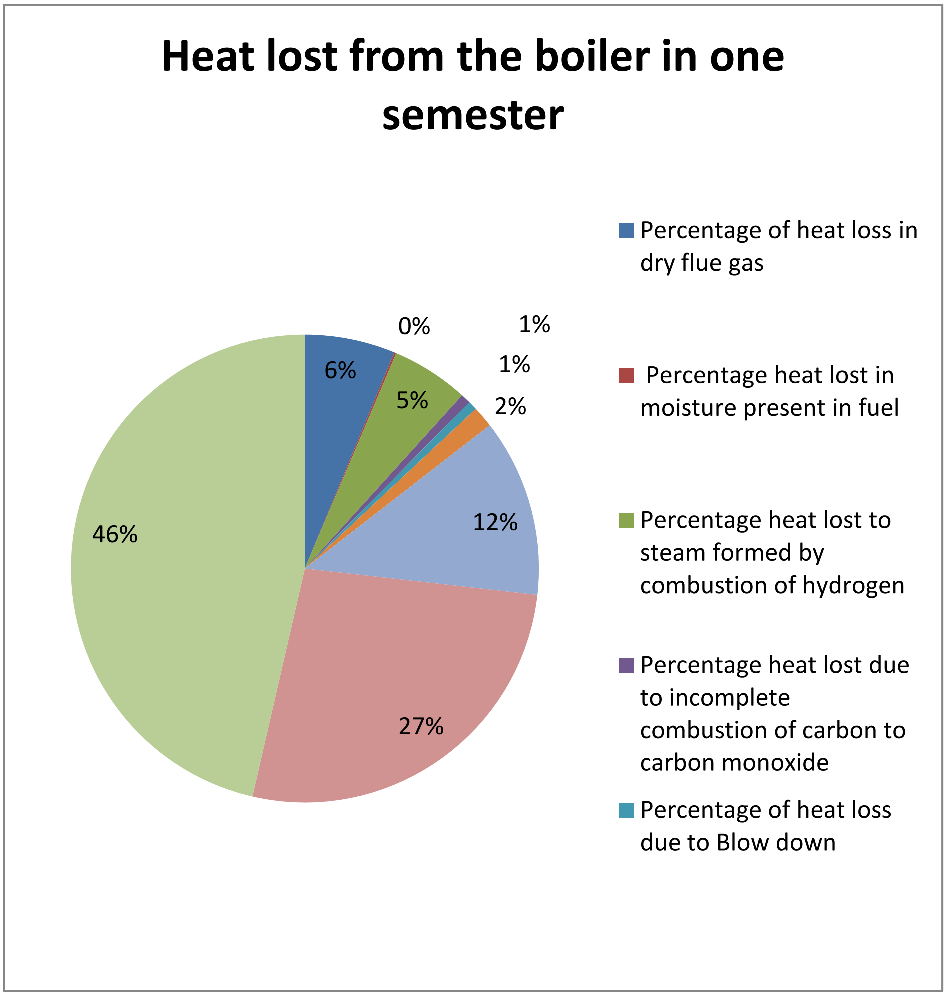

Fig 1 Percentage Heat lost

CONCLUSION

This analysis has shown that maximum heat lost is obtained from losses in flue gas and losses from unburnt fuel ,this cannot be unconnected with poor supply of oxygen. The heat exchange between the combustion gases and the boiler internal walls is therefore estimated according to a numerical scheme. The calculated results have been compared to the boiler operating data for different steady-state regimes, and good agreement is generally obtained. The operating pressure effect on the boiler heat transfer characteristics has been investigated. The calculation shows that, the prevailing mechanism of heat transfer in the 4-pass fire-tube boiler is convection, which accounts for over 70%.. The efficiency of the boiler at less than 70% shows a low efficiency, Therefore the introduction of zirconium oxygen sensor was suggested to the Department to reduce these losses and increase the boiler efficiency.

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