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Efficiency Assessment and Improvement of Boiler at Super Thermal Power Station

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Abstract: *-Performance as boiler efficiency and evaporation ratio decreases with time due to poor operation poor combustion, heat transfer fouling and poor combustion and maintenance. A deteriorating fuel quality and water quality also leads to poor performance of the boiler. Efficiency tests help us to know what the efficiency of the boiler is far from the best efficiency.. Evaluation of the efficiency of boiler is a vital concept in any thermal power plant. Boiler is the heart of the power plant and for benefit of the plant there is a need to increase the efficiency of the boiler. The boiler efficiency can be evaluated by the direct and indirect method. In the direct method the energy gain by working fluid compared to the energy content of the fuel, while indirect method where various losses compared to the energy input. Current research deals with the Efficiency Assessment of Boiler at* ***super thermal power station (S.T.P.S),****. Coal is used as fuel at S.T.P.S,*

Keywords—*Thermal industries, Coal, Boiler, Boiler Efficiency.*

1. INTRODUCTION

Energy is essential to the progress of mankind instrument. High level of standard life today has been possible only through the judicious use of various energy resources to order. Realizing the fact that energy is the tendon of economic growth and energy conservation are paramount. This, together with improved energy efficiency are the only profitable and viable means to minimizing operating costs and increased corporate profitability. Boiler is one of the important components. Boiler is a closed pressure vessel in which water can be fed and by applying heat continuously, steam generated. The function of the boiler is to generate steam at the desired efficiency and with low operating costs. Low pressure steam is used in the process of an application while the high pressure superheated steam is used to generate energy through steam turbines. Boilers consist of a number of tubes for maximum heat transfer. These tubes goes between the steam distribution drum on top of the boiler drum and water collecting in the bottom of the boiler. Steam goes from the steam drum to the super heater before entering the steam distribution system.

2. METHODOLOGY TO CALCULATE THE BOILER EFFICIENCY

The thermal industry is known as a major source of conventional energy in India. In a thermal industry, there are lots of components are included. But beyond that, boiler is important than any other. To maximize the power plant production, it is necessary to maintain the boiler design efficiency. Thus, the performance test of the boiler is necessary to know the variation of boiler efficiency related to its design values. Therefore, it is necessary to know the current level of efficiency for performance evaluation, which is mandatory for the actions of conservation of energy in industry.

2.1 Boiler Efficiency Boiler efficiency is a ratio between the energy supplied to the boiler capacity and the energy received from the boiler. It is expressed in percentage.

$$=\frac{Heat\ exported\ by\ the\ Ssteam)}{heat\ provided\ by\ the\ fluid}*100$$

2.2 Reference Standards for efficiency

2.2.1 British Standards, BS845:1987:-

The British Standard BS 845:1987 describes the methods and conditions under which a boiler must be tested to determine their efficiency. For the test to be performed, the boiler must be operated under constant load (full load) for a period of one hour readings are taken within one hour of continuous operation to allow efficiency to calculate. Boiler efficiency is quoted as % available useful heat, as a percentage of total energy potentially available by the burning fuel. This is expressed in the basis of gross calorific value (GCV). This refers to the balance of complete heat and has two parts:

Part I. It deals with standard boilers, where the indirect method specified.

Part II. It deals with complex installations where there are many channels of heat flow. In this case, the direct and indirect methods are applicable in whole or in part.

2.2.2 Standard ASME PTC-4-1

This consists:-

Part I. Direct method (also known as input -output method

Part II. Indirect method (also called as a method of heat loss)

2.2.3 IS 8753: Indian Standard for Testing Efficiency of Boilers:- Most of the rules for calculating the efficiency of boiler, taking BS845 and IS 8753 are designed for in measurement of boiler efficiency. These standards do not include blow down as a loss in the determination process efficiency.

2.3 Method for testing boiler efficiency

1) Direct method: When the energy gain of the working fluid (water vapor) is compared to energy content of the

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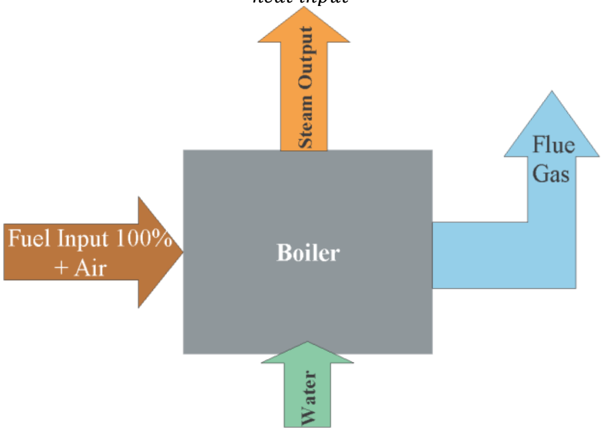
boiler fuel.

2) **Indirect method**: When efficiency is the difference between losses and energy input.

2.3.1 Direct Method

This is also known as "input-output method 'due to the fact that it needs only the useful output (steam) and the heat input (i.e., fuel) to assess efficiency. This efficiency can be evaluated using the formula:

$$\text{Boiler efficiency} = \frac{heat\ output}{heat\ input}$$



$$\text{Efficiency} = \frac{\text{Heat addition to Steam} \times 100}{\text{Gross Heat in Fuel}}$$

$$\eta_{boiler} = \frac{\text{steam flow rate(steam enthalpy} - \text{feed wate enthalpy)}}{\text{fuel firing rate} * \text{gross calorific value}} * 100$$

2.3.1.1 Measurements for direct method testing.

2.3.1.1.1 Heat input.

Measuring the heat input required data of the heating value of the fuel and its flow rate in terms of mass or volume as fuel nature. Correct flow measurement coal or other solid fuels is very difficult. The measurement must be based on mass, which means that a bulky apparatus must be set in the boiler house ground. Samples must be collected and bagged all proof, sealed and sent to a laboratory for investigation and determination of the calorific value bags. In some newer houses the boiler, the problem has been alleviated by mounting hoppers boilers over calibrated load cell.

2.3.1.1.2 Heat output

There are several methods that can be used to measure the heat output. With steam boilers, meter installed steam can be used to measure the flow rate, but this must be corrected for temperature and pressure. In previous years, this method is not favored by the change in precision orifice or venturi flow meter. The alternative is to measure the small boiler feed water, this can be done by previously calibrated feed tank and noting the level of water in the beginning and end of the test. Care should be taken not to pump water during this time. Addition of heat to converting feed water to the steam inlet temperature is considered for the heat output. In the case of boilers with intermittent venting, purging should be avoided during the trial period. For continuous purge boilers, heat loss due to bleeding must be calculated and added to the steam heat.

3. BOILER EFFICIENCY (DIRECT METHOD): CALCULATION AND EXAMPLE

3.1 Test Data and Calculation.

Water consumption and coal consumption were measured in a coal boiler in hourly intervals. Where fed weighted quantities of coal to the boiler during the trial period. Concurrently Water level difference was observed to calculate the generation of steam during the trial period. Blow was avoided during the test. The measured data are given below.

Formula for boiler efficiency calculation:-

Boiler efficiency=

$$\frac{\text{S.H steam flow} * \text{S.H steam enthalpy} + \text{R.H steam flow} * \text{R.H enthalpy} - \text{F.W flow} * \text{F.W enthalpy}}{\text{fuel flow} * \text{gross calorific value}} * 100$$

Type of boiler: Coal fired boiler

Table 1: Design data

S. No.	Boiler Parameter for Rated Load (250 MW)	Unit	Design
1	Fuel Flow	Kg/hr	160400
2	GCV	Kcal/Kg	3500
3	Heat Input to Boiler	kcal/Hr	561400000
4	FW Flow (Eco Inlet)	Kg/hr	720500
5	FW Pr.	Kg/cm^2	170.7
6	FW Pr.	bar	167.40
7	Fw Temp. (Eco Inlet)	^oC	246
8	FW Enthalpy	KJ/Kg	1068
9	FW Enthalpy	Kcal/Kg	255
10	SH Steam Flow	Kg/hr	740800
11	SH Steam Pr.	Kg/cm^2	154
12	SH Steam Pr.	bar	151.12
13	SH Temp	^oC	540
14	SH Enthalpy	KJ/Kg	3420
15	SH Enthalpy	Kcal/Kg	816.862
16	RH Steam Flow	Kg/hr	665500
17	RH Steam Pr. (Inlet)	Kg/cm^2	37.6
18	RH Steam Pr. (Inlet)	bar	36.9
19	RH Steam Temp (Inlet)	^oC	342.00
20	RH Enthalpy	KJ/Kg	3082

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	(Inlet)		
21	RH Enthalpy (Inlet)	Kcal/Kg	736.183
22	RH Steam Pr. (Outlet)	Kg/cm^2	35.6
23	RH Steam Pr. (Outlet)	bar	34.9
24	RH Steam Temp (Outlet)	^{o}C	540.00
25	RH Enthalpy (Outlet)	KJ/Kg	3541
26	RH Enthalpy (Outlet)	Kcal/Kg	845.689
27	Heat Gain in RH	Kcal/Kg	109.506
28	Boiler Efficiency	%	88.05
29	Heat Credits	%	-0.427
30	Actual Boiler Efficiency	%	87.62

Table 2: Actual data

S. No.	Boiler Parameter for Rated Load (250 MW)	Unit	Actual
1	Fuel Flow	Kg/hr	170100
2	GCV	Kcal/Kg	3427
3	Heat Input to Boiler	kcal/Hr	582932700
4	FW Flow (Eco Inlet)	Kg/hr	809000
5	FW Pr.	Kg/cm^2	183
6	FW Pr.	Bar	179.46
7	Fw Temp. (Eco Inlet)	^{o}C	250
8	FW Enthalpy	KJ/Kg	1087
9	FW Enthalpy	Kcal/Kg	259
10	SH Steam Flow	Kg/hr	785000
11	SH Steam Pr.	Kg/cm^2	147
12	SH Steam Pr.	bar	143.86
13	SH Temp	^{o}C	532
14	SH Enthalpy	KJ/Kg	3407
15	SH Enthalpy	Kcal/Kg	813.637
16	RH Steam Flow	Kg/hr	681345
17	RH Steam Pr. (Inlet)	Kg/cm^2	40.7
18	RH Steam Pr. (Inlet)	bar	39.9
19	RH Steam Temp (Inlet)	^{o}C	348.00
20	RH Enthalpy (Inlet)	KJ/Kg	3090
21	RH Enthalpy (Inlet)	Kcal/Kg	738.070
22	RH Steam Pr. (Outlet)	Kg/cm^2	37.7
23	RH Steam Pr. (Outlet)	bar	37.0
24	RH Steam Temp (Outlet)	^{o}C	534.00
25	RH Enthalpy (Outlet)	KJ/Kg	3525
26	RH Enthalpy (Outlet)	Kcal/Kg	841.939
27	Heat Gain in RH	Kcal/Kg	103.869
28	Boiler Efficiency	%	85.70
29	Heat Credits	%	-0.427
30	Actual Boiler Efficiency	%	85.27

Table 3: Corrected Data

S. No.	Boiler Parameter for Rated Load (250 MW)	Unit	Corrected data
1	Fuel Flow	Kg/hr	155000
2	GCV	Kcal/Kg	3660
3	Heat Input to Boiler	kcal/Hr	567300000
4	FW Flow (Eco Inlet)	Kg/hr	767000
5	FW Pr.	Kg/cm^2	172
6	FW Pr.	bar	168.67
7	Fw Temp. (Eco Inlet)	^{o}C	250
8	FW Enthalpy	KJ/Kg	1091
9	FW Enthalpy	Kcal/Kg	261
10	SH Steam	Kg/hr	757000

	Flow		
11	SH Steam Pr.	Kg/cm^2	153
12	SH Steam Pr.	bar	150.04
13	SH Temp	^oC	542
14	SH Enthalpy	KJ/Kg	3442
15	SH Enthalpy	Kcal/Kg	822.044
16	RH Steam Flow	Kg/hr	682647
17	RH Steam Pr. (Inlet)	Kg/cm^2	37.3
18	RH Steam Pr. (Inlet)	bar	36.6
19	RH Steam Temp (Inlet)	^oC	346.00
20	RH Enthalpy (Inlet)	KJ/Kg	3097
21	RH Enthalpy	Kcal/Kg	739.742
	(Inlet)		
22	RH Steam Pr. (Outlet)	Kg/cm^2	36.5
23	RH Steam Pr. (Outlet)	bar	35.8
24	RH Steam Temp (Outlet)	^oC	537.00
25	RH Enthalpy (Outlet)	KJ/Kg	3554
26	RH Enthalpy (Outlet)	Kcal/Kg	848.842
27	Heat Gain in RH	Kcal/Kg	109.100
28	Boiler Efficiency	%	87.59
29	Heat Credits	%	-0.427
30	Actual Boiler Efficiency	%	87.16

4. MERITS AND DEMERITS OF DIRECT METHOD

4.1 Merit

1. People of the plant can quickly assess the efficiency of boilers
2. Requires few parameters for the calculation.
3. Needs few instruments for monitoring

4.2 Demerits

1. No operator gives clues about why the system efficiency is lower
2. No calculates various losses responsible for the different levels of efficiency
3. Relationship and efficiency of evaporation can be misleading, if the steam is wet due to the drag of water.

5. BOILER TERMINOLOGY

5.1 MCR: Boilers steam output are also usually defined as MCR (Maximum continuous Rating). This is the maximum evaporation rate that can be sustained for 24 hours and may be less than a maximum duration shorter rating boiler Rating Conventional boilers are specified by their ability to keep generating water and steam rate. Often, the ability to generate steam is specified in terms of the equivalent evaporation (kg steam / hr: In the boiler industry there are four common definitions of efficiency:

5.1.1 Combustion efficiency:-Combustion efficiency is the efficiency of the burner and only refers to its ability to completely burn fuel. The boiler has little to do with the efficiency of combustion. A well designed burner work with as little as 15 to 20% excess air, while the conversion of all fuel in the fuel into useful energy.

5.1.2 Thermal efficiency:-The thermal efficiency is the efficiency of heat transfer in a boiler. It does not account losses by radiation and convection boiler - e.g. pipe column body boiler water etc.

5.1.3 Boiler efficiency:-The term boiler efficiency is often substituted for the combustion or thermal efficiency. True boiler Efficiency is a measure of fuel efficiency steam.

5.1.4 Fuel to steam efficiency:-Fuel to steam efficiency is calculated using either of the two methods as prescribed by the ASME (American Society for Mechanical Engineers) power test code, PTC 4.1.

1. The first method is input output method.
2. The second method is heat loss method.

5.2 Boiler turndown Boiler turndown ratio between full boiler output and boiler output when operating at low power. Typical boiler turndown is 4:1. The power of the boiler turndown decrease on and off cycles. Most Modulating burners are usually designed to operate down to 25% of rated capacity. In a material that is 20% of cargo capacity, the boiler will kill and cycle regularly. A boiler operating at low load conditions can cycle as frequently as 12 times per hour or 288 times per day. With each cycle, pre and post eliminating airflow removes heat from the boiler and send it out the stack. Keeping the boiler on a low firing rates can eliminate the energy loss. Always boiler cycles off, it must go through a set-up list for the safety promise. It requires about one or two minutes to put the boiler back on line. And if there is a sudden gear need not start up list will be added. Keeping the boiler on line to ensure the quickest response to load changes. M cycles also accelerates wear and boiler components. Maintenance increase and more importantly, the number of component failure increases. Boiler (s) required access is pretty much different type of load variations in the system. On boiler sizing occurs when future expansion and safety factors are added to ensure that the boiler is large enough for the application. If the boiler is oversized and the power of the boiler handle variable loads without reducing cycles. Therefore capacity and turndown should be considered compatible with the boiler selection to meet the overall system load requirements.

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5.3 Primary air: This part of the air supply to the combustion system and the first oil encountered.

5.4 Secondary air: The second stage of the air to the combustion system, usually to complete primary combustion initiated air. It can be injected into the furnace of the boiler under relatively high pressure during firing m upgrading to create turbulence above the burning fuel to ensure good mixing of gases produced in the combustion process and, is complete combustion.

5.6 Tertiary air: A third stage of the air to the combustion system, the characteristics of which have largely been completed and secondary air. Large wind is rarely needed.

5.7 Stoichiometric: A combustion technology, stoichiometric air is that much of the air, and no more, which was written and needed to completely burn unit a lot of oil. 'Sub-stoichiometric' refers to surgical burns fuel in a lack of wind.

5.8 Balanced draught: The conditions found when the pressure of the gas in a furnace is the same as or slightly below the ambient, in the yard or building houses.

5.9 Gross calorific (PCS): The amount of heat released by the complete combustion, under specified conditions for a unit volume of a gas or of a unit mass of a solid or liquid fuel, in determining the water produced by the combustion of the fuel is assumed to be completely condensed and its latent and sensible heat available.

5.10 Net calorific value (NCV): The amount of heat generated by the complete combustion, low specified conditions, for a unit volume of a gas or a unit mass of a solid or liquid fuel, in the determination that assumes that the water produced by the combustion of the fuel to remain in vapor form. The absolute pressure is the sum of gauge and atmospheric pressure. For example, if the meter of steam in the boiler shows 9 kg / cm^2 absolute water vapor pressure is 10 kg / cm^2.

6. CONCLUSION

1. As shown in design data (table no.01) and actual data (table no.02) efficiency is less in actual data. Efficiency can be attained nearby design value by controlling various parameters.
2. As shown in corrected data (table no.03) as coal came with high calorific value than design value then we can decrease coal flow lower than design value which will result in heat addition nearby design value so there will be less fluctuation in cost.
3. Due to the higher gross calorific value heat addition in furnace will be more and due to this pressure or temperature of steam will increase or both as result enthalpy of steam will be more. And as given in formula more enthalpy means more efficiency.
4. When steam is superheated than temperature is increasing while in reheating pressure is increasing which result in more enthalpy and more efficiency.
5. So we can increase efficiency of boiler by increasing pressure or temperature or both of steam by providing more coal flow rate or coal with grosser calorific value. But these two should be such that is balance cost with design cost.

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