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"Energetic Analysis of Steam generation unit like a Boiler with various types of fuel which is used in 25 MW capacity Captive Power Plant in Textile Process Plant"

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Abstract – *Energy means ability to exert effort in sector is one of the major demands now days for the development country. A steam generation unit like a Boiler is a important device or main component of the various industries as well as power generation plant company because the hot gas produce by the water like a steam is the main fluid for the working device power plant company or other processes. For that steam generation device like a Boiler is most costly and main useful equipment. Various types of fuels used in steam generation device to increases its capacity and found them which is more economical for produced energy and we can find out maximum heat to convert in suitable work. Here finding the efficiency of Boiler with different fuels by Direct and Indirect Method and analysis is done on basis of 1st and 2nd law. After completing the whole 1st law and 2nd law analysis of Boiler plant then compare which is best and economic fuel for use power generation. The Sankey diagrams are presented to depict the pictorial representation of Energy flow in the system and the losses in the various components during normal operating condition have been identified.*

The performance analysis shows that the 1st law efficiency of Boiler Plant with different fuels like Bituminous (Indian coal), Anthracite (imported coal), (60% Ant + 40% Bit) coal, **(20% Bagasse + 80 % Ant),** *and L.S.H.S oil are 77.30.54%, 83.03%, 80.60%, 76.44 % and 88.20% respectively.*

Keywords: - ***Steam generation unit, Energy analysis method, Efficiency calculation***

1. INTRODUCTION: - In this current doing work is for such a basic deep knowledge of thermodynamic performance of steam generation device like a Boiler in the Captive Power Plant of Textile Process Plant. This plant have 2 unit of 25 MW capacity of captive power plant of turbine generator set with two uncontrolled extraction points which supply heat energy to meet process demand. The steam is generated in 50 Kg/sec capacity achieved by various types of Coal and Oil fired boiler.

The objective of this paper is to study the captive steam power plant components using the first and second laws of thermodynamics. The concepts of energy destruction enable us to evaluate the efficiency with which the available energy is consumed.

2. OVERVIEW OF BOILER SYSTEM:-

A boiler is an enclosed vessel that provides a means for combustion heat to be transferred into water until it becomes heated water or steam. Water is a useful and cheap medium for transferring heat to a process. When water is boiled into steam its volume increases about 1,600 times, producing a force that is almost as explosive as gunpowder. This causes the boiler to be extremely dangerous equipment that must be treated with utmost care.

3 INTRODUCTION OF FUELS:-

Fuel represents a combustible substance which, once raised to ignition temperature, continues to burn without any external support provided a sufficient quantity of oxygen is available for combustion. A fuel may be also defined as a substance which on burning with oxygen in the atmospheric air produces a large amount of heat.

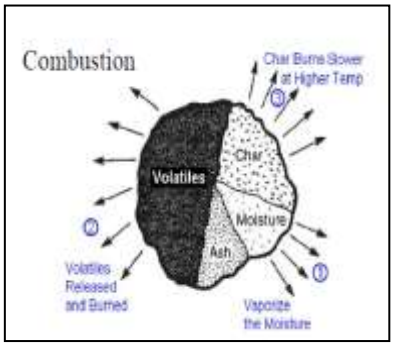
The various types of fuels like liquid, solid and gaseous fuels are available for firing in boilers, furnaces and other combustion equipments. The selection of right type of fuel depends on various factors such as availability, storage, handling, pollution and landed cost of fuel. The knowledge of the fuel properties helps in selecting the right fuel for the right purpose and efficient use of the fuel.

3.1 ANALYSIS OF COAL:- Mainly two methods: **Ultimate analysis** and **Proximate analysis**. The ultimate analysis determines all coal component elements, solid or gaseous & the proximate analysis find only the fixed carbon, volatile matter, moisture and ash percentages.

Conversion relation for Ultimate analysis to Proximate Analysis

RELATIONSHIP BETWEEN ULTIMATE TO			
	%C	=	0.97C+ 0.7(VM - 0.1A) – M(0.6–0.01M)
	%H	=	0.036C + 0.086 (VM–0.1xA) - 0.0035M^2 (1–0.02M)
	$\%N_2$	=	2.10 – 0.020 VM
Where	C	=	% of fixed carbon
	A	=	% of ash
	VM	=	% of volatile matter
	M	=	% of moisture

4 INTRODUCTIONS TO COMBUSTION:-



Combustion involves a chemical reaction during which the interatomic bonds of the molecules of fuel and oxygen are broken and there is rearrangement of atoms in new molecular combination. The new compounds have less energy, and the energy released during combustion equals the difference in the energy of reactants of that of products formed:

Fuel + Oxygen $CO_2 + H_2O + N_2$

---------- = ---------- + Heat

Simplified view of solid fuel

Products Reactants

Combustion is obviously an exothermic reaction; during combustion energy is released to the surroundings in the form of heat which can be used economically for industrial and domestic purposes.

Combustion refers to the rapid oxidation of fuel accompanied by the production of heat, or heat and light. Complete combustion of a fuel is possible only in the presence of an adequate supply of oxygen.

Nitrogen reduces combustion efficiency by absorbing heat from the combustion of fuels and diluting the flue gases. This reduces the heat available for transfer through the heat exchange surfaces.

4.1. 3 T's of Combustion

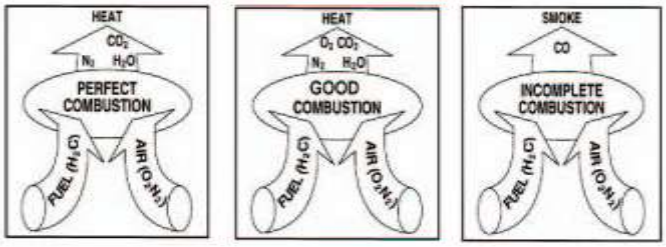
$C + O_2 \rightarrow CO_2$ + 8084 kCals/kg of Carbon
$2C + O_2 \rightarrow 2CO$ + 2430 kCals/kg of Carbon
$2H_2 + O_2 \rightarrow 2H_2O$ + 28,922 kCals/kg of Hydrogen
$S + O_2 \rightarrow SO_2$ + 2,224 kCals/kg of Sulphur

1. Temperature high enough to ignite & maintain ignition of the fuel,

2. Turbulence or intimate mixing of the fuel and oxygen, and

3. Time sufficient for complete combustion.

Commonly used fuels like natural gas and propane generally consist of carbon and hydrogen. Water vapor is a by-product of burning hydrogen. Amount of O_2 is needed for perfect combustion and some additional (excess) air is required for ensuring complete combustion. Not all of the heat in the fuel are converted to heat and absorbed by the steam generation equipment. So the main challenge in combustion efficiency is directed toward unburned carbon, which forms CO instead of CO_2.



5 ENERGY ANALYSES:-

Following assumptions are made for present analysis

1. Consider Combustion products are as an ideal gas.

2. Consider complete combustion process in the combustion chamber.

3. Consider Kinetic and potential components of energy are negligible.

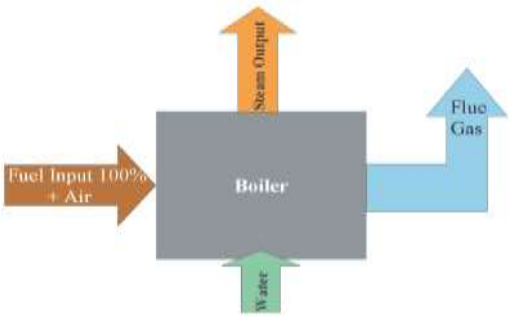
4. Consider Losses in various pumping devices are not considered.

5.1. ENERGY ANALYSIS:-

Basically Boiler efficiency can be tested by

Direct Method

The Direct method is old method and is considered as a standard.

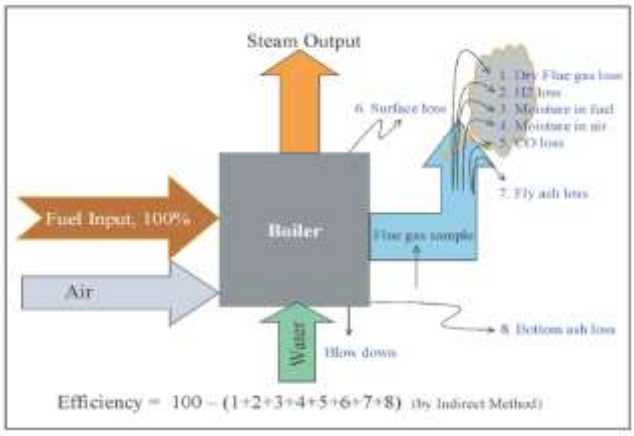


$$\text{Boiler Efficiency} = \frac{\text{Steam flow rate x (steam enthalpy} - \text{feed water enthalpy)}}{\text{Fuel firing rate x Gross calorific value}} \times 100$$

Indirect Method

Indirect method is also called as heat loss method. The efficiency can be arrived at, by subtracting the heat loss fractions from 100.

Boiler Efficiency = 100 - (L1 + L2 + L3 + L4 + L5 + L6 + L7 + L8)



6. CALCULATION DATA OF STEAM GENERTATION DEVICE:-

Now, from the Annexure the Proximate Analysis and Ultimate Analysis is given.

Steam generation rate	=	50 Kg / sec
Steam pressure	=	98 bar
Steam temperature	=	510 °C
Feed water temperature	=	186 °C
$\%CO_2$ in Flue gas	=	14
%CO in flue gas	=	0.45
Average flue gas temperature	=	151 C
Ambient temperature	=	31 C
Humidity in ambient air	=	0.0201 kg / kg dry air
Surface temperature of boiler	=	75 C
Wind velocity around the boiler	=	2.89 m/s
Total surface area of boiler	=	68 m^2
GCV of Bottom ash	=	2892.25 kJ/kg
GCV of fly ash	=	1849.61 kJ/kg
Ratio of bottom ash to fly ash	=	60:40
Fuel Analysis (in %)		
Ash content in fuel	=	43.37
Moisture in coal	=	12.97
Carbon content	=	39.28
Hydrogen content	=	2.175
Nitrogen content	=	1.683
Oxygen content	=	9.98
GCV of Coal	=	13959.74 kJ/kg

7. RESULT:-

The performance of steam generation unit like a Boiler is calculated then found that various types of losses, which take place in a Boiler. 1st law analysis shows the efficiency of the *Bituminous* (Indian coal) fired Boiler is 77.30%. This causes loss of 22.70%. Table in Annexure gives the energy distribution and losses of various thermodynamic states of Boiler with various fuels used.

Energetic Efficiency of Various fuel used in steam generation device like a Boiler

Fuel	L1	L2	L3	L4	L5	L6	L7	L8	Total	H
Bituminous **(Ind Coal)**	5.6	3.2	2.1	0.1	2.7	0.6	1.9	6.5	22.70	77.30
Anthracite **(Imp Coal)**	5.25	3.37	1.25	0.1	2.64	0.36	0.76	2.59	16.9	83.0
(60% Ant + 40% Bitu) coal	5.8	3.9	1.8	0.1	2.5	0.3	1.0	3.7	19.4	80.6
(20% Bagasse + 80 % Ant)	5.2	3.8	2.8	0.23	2.9	0.4	1.9	6.23	23.46	76.44
LSHS Oil	5.2	5.9	0.02	0.2	-	0.3	-	-	11.8	88.2

8. CONCLUSION:-

1. Here from the energy analysis of the steam generation device like Boiler Plant *Bituminous* (Indian coal as a fuel), it is seen that the energy analysis attributes all the inefficiencies to losses as 22.70%. The first law efficiency of the Boiler plant is 77.30%.

2. Here we can see there was a large difference between the 1st law and 2nd law efficiency of the Boiler plant. This is due to large amount of energy losses which increases the entropy and hence a decrease in the second law efficiency.

3. Here if we can mixing with Bagasse and Anthracite fuel with (ratio 40:60) mixer which can reduce environmental pollution as well as economical benefits for the steam generation plant.

4. From the analysis, the heat transfer and combustion process, the stack losses are comparatively very less. An energy analysis, heat transfer is also highly efficient, while stack gases carry away the majority of the lost energy.

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STANDARDS

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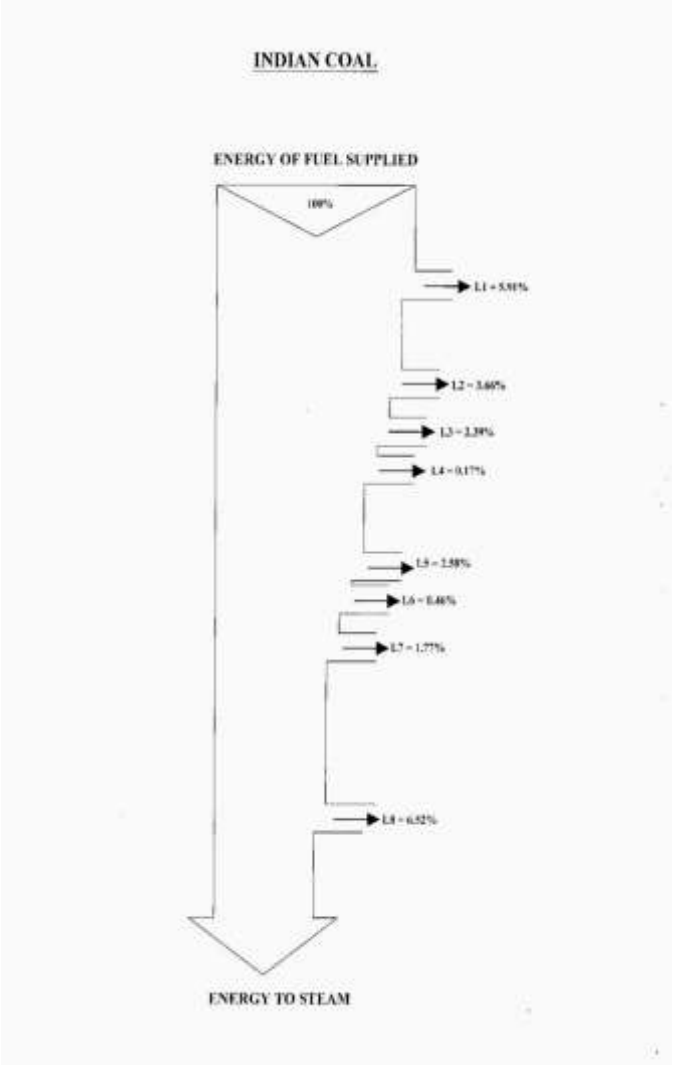
2. ASME Standard: PTC-4-1 Power Test Code for Steam Generating Units
3. IS 8753: Indian Standard for Boiler Efficiency Testing

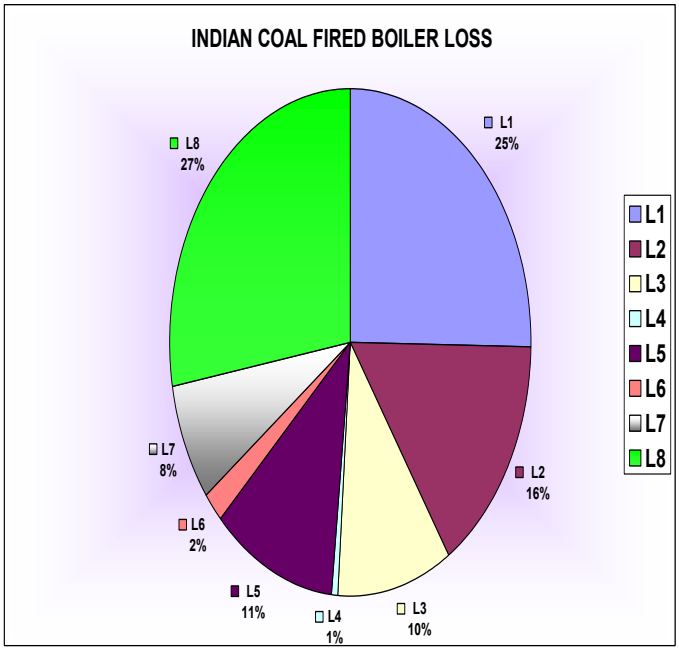
SUMMARY OF MASS AND VOLUME ANALUSIS OF ALL TYPES OF FUEL USED IN BOILER

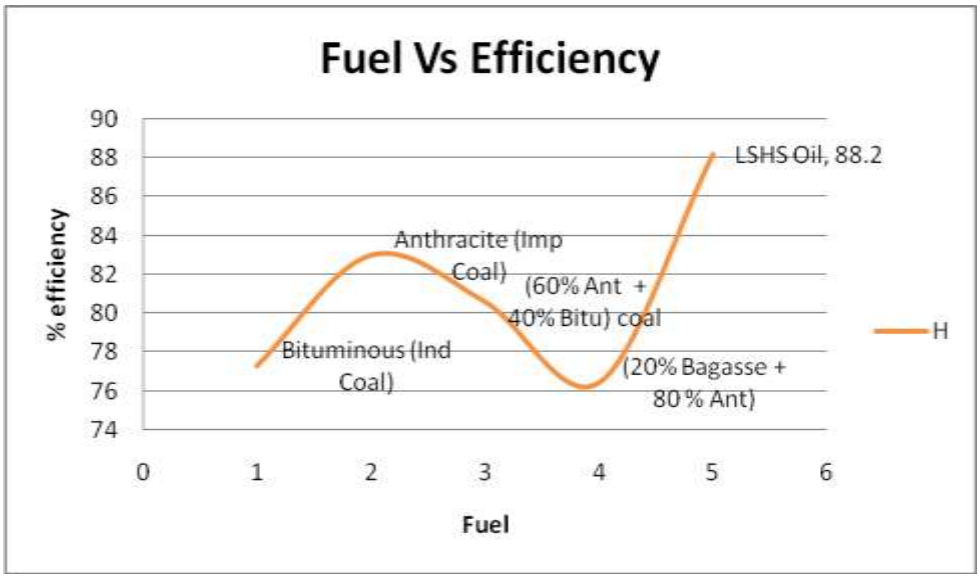
% Mass and % Volume Analysis													
Fuel	**Total Mass of Dry Flue Gas**				**Total Mass**	**% Mass Analysis**				**% Volume Analysis**			
	CO2	**SO2**	**O2**	**N2**		**CO2**	**SO2**	**O2**	**N2**	**CO2**	**SO2**	**O2**	**N2**
Bituminous **(Ind Coal)**	1.46	0.01	0.5704	5.728	7.768	18.86	0.126	7.31	73.7	13.02	0.006	6.94	79.98
Anthracite **(Imp Coal)**	1.85	0.007	0.7429	7.4613	10.06	18.52	0.07	7.32	74.09	12.77	0.03	6.94	80.26
(60% Ant + 40% Bitu) coal	1.74	0.008	0.6934	6.96	9.401	18.5	0.089	7.37	74.04	12.75	0.04	6.99	80.22
(20% Bagasse + 80 % Ant)	1.36	0.006	0.5962	6.54	9.54	17.95	0.079	7.21	73.90	12.45	0.03	6.21	79.89
LSHS Oil	3.08	0.01	1.5616	15.68	20.33	15.14	0.049	7.67	77.14	10.3	0.023	7.18	82.5

SANKEY DIAGRAM OF **Bituminous** (INDIAN COAL) FIRED BOILER

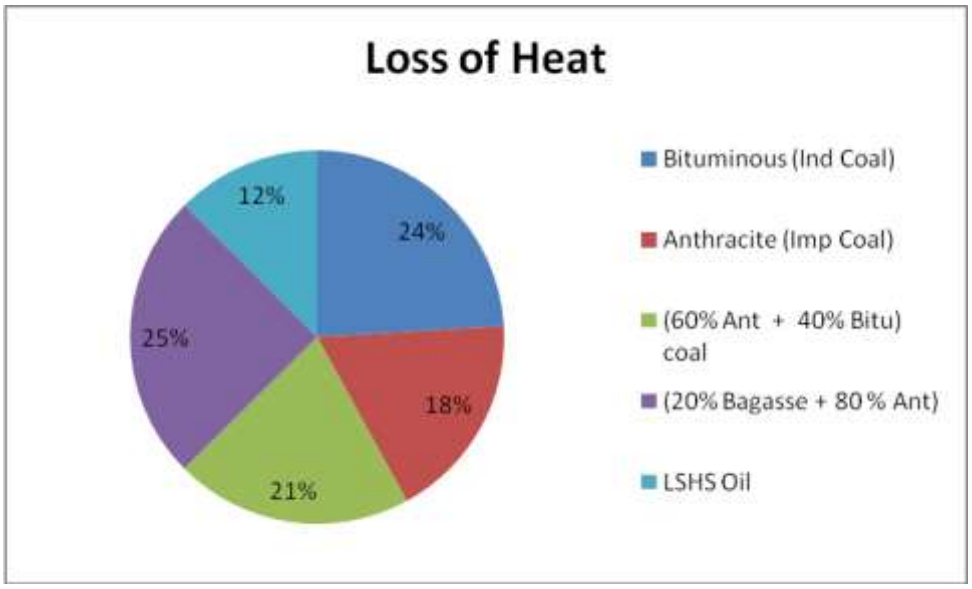


PIE CHARTS FOR **Bituminous** (INDIAN COAL) FIRED BOILER





Fuel vs Efficicency Graph



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