COMBUSTION EFFICIENCY - BOILER

We all know the golden rule for fuel combustion in boiler i.e. Triple-T = TIME, TEMPERATURE & TURBULENCE. Normally major boiler efficiency game changer values during design calculations are predicted parameters like Unburnt Carbon Losses, Flue Gas Temperature at APH- Air Preheater outlet, Excess Air requirement, Ambient Temperature, Air temperature increment in Fan, Fuel Ultimate & Proximate Analysis, Fuel Sieve Analysis for fines %

In Boiler Operation & Design, it plays a big role & changes the performance of boiler when any changes in operational inputs OR wrong design input considered for calculation.

Time: Residence Time – depend on Furnace height, Furnace volume, Fixed Carbon in fuel, Flue gas mass quantity, Gas Velocity and Unburnt carbon losses

Temperature: Furnace Temperature, Ignition Temperature, Deformation Temperature

Turbulence: Air Pressure, Flue Gas Pressure

1. **Residence time** is influenced by Furnace temperature, Furnace volumetric loading, Flue gas velocity in furnace, Particle density, Particle size distribution, Excess Air
2. Refractory applied on Water wall in Furnace Area to increase furnace temperature & to compensate Less Residence Time and Less furnace volume
3. Residence Time is inversely proportional to Furnace Exit Gas Temperature-FEGT, Furnace Pressure, Unburnt Carbon Losses and Carryover in fly ash, Furnace exit gas velocity
4. If Residence time of fuel particle in furnace is low, then it escape combustion zone and unburnt carbon in fly ash increases, hence Unburnt carbon in fly ash will depend upon residence time of particles in furnace

5. **Unburnt Carbon Losses** is directly proportional to higher fines% in fuel, higher fixed carbon% in fuel, lower volatile matter% in fuel, higher furnace gas velocity,
6. Unburnt Carbon Losses is inversely proportional to Furnace / Bed temperature, Excess Air, Furnace Height, Front Ash / Bed Ash% discharge, Residence time
7. Unburnt Carbon in kg/kg of Fuel = (GCV X Unburnt Carbon Loss %) /(8079 x 100) = e.g. (2175 x 3)/(8079 x 100) = 8.08 gm/Kg of Fuel
8. Loss of Ignition (LOI) calculation is based on Unburnt Carbon Loss. During boiler design / initial stage, both LOI & Unburnt Carbon Loss should be clearly identified to know the exact deviation from design performance of boiler and actual fuel quantity variation.
9. High furnace fluctuation (e.g. Slop - Spent wash operated boiler in Distillery) shall reduce the boiler performance by increasing unburnt carbon loss.

10. ID Fan Power consumption is directly proportional to Negative Furnace Pressure i.e. Higher Negative Pressure means Higher Fan power
11. FD Fan Power consumption is inversely proportional to Negative Furnace Pressure i.e. Higher Negative Pressure means Lower Fan power
12. Higher excess air reduces unburnt carbon loss but increases dry fuel gas loss. Fuel with higher fixed carbon to volatile ratio, more excess air is required.

13. **Combustion Efficiency** is directly proportional to Residence time and High Turbulence
14. Normally, combustion efficiency is relate with Un-burnt Carbon Losses based on Fixed carbon v/s Volatile Matter OR Fuel Reactivity:

a. Ratio of Fixed Carbon v/s Volatile Matter is directly proportional to Un-burnt carbon loss. It means Higher Fixed Carbon means Higher Unburnt carbon loss. Unburnt carbon loss is totally depends on Fuel Analysis.
b. For higher ratio of Fixed Carbon v/s Volatile Matter OR Fuel Reactivity, Furnace/ Bed temperature in AFBC kept high to reduce unburnt carbon losses but NOx formation increases. Furnace temperature & Excess air contribute to increase in NOx formation.
c. Wood Chip, Bagasse, Other Biomass combustion efficiency – 99.0 to 99.5% & Unburnt Carbon Loss– 2.5 to 4.0%
d. Low GCV Coal combustion efficiency – 98.0 to 99.0% & Unburnt Carbon Loss– 3.5 to 5.5 %
e. High GCV Coal combustion efficiency – 98.5 to 99.0% & Unburnt Carbon Loss– 5.5 to 8.0%
f. Coal with High Ash content>45% like Washery reject combustion efficiency – 95.5 to 96.5% & Unburnt Carbon Loss – 4.5 to 6.0%
g. Char & Pet coke combustion efficiency– 92.0 to 94.0% & Unburnt Carbon Loss– 9.0 to 12.0%
h. Normally, AFBC Boiler combustion efficiency is taken 95% while CFBC Boiler combustion efficiency is taken 98%. CFBC boiler having better performance in terms of combustion efficiency & emissions over AFBC Boiler. The combustion efficiency of CFBC boiler is less sensitive to variations in fuel sieve analuysis & operating parameters.

15. Loss from Steam Coil Air Preheater- SCAPH due to supply of steam is not considered in performance calculation. This loss is calculated as

Loss due to preheating the air by steam = Mass flow of steam used to preheat the air X (Enthalpy of steam supplied to air preheater - Enthalpy of water/steam discharged from air preheater)

16. Incomplete combustion of the carbon in the form of Carbon Monoxide– CO in Flue gas leaving the furnace is generally considered NIL i.e. ZERO. This is a direct loss of fuel which was not taken in account.

17. Density of Fly ash is normally lower than Bottom ash & Collection ratio split between Fly ash & Bottom ash is depend on the Density of Fuel, Method of fuel firing, Furnace Loading, Furnace gas velocity, Ash Chemical Analysis, Ash Particle Size Distribution. Higher density of fuel particles tends to burn on bed instead of suspension, producing more bottom ash.

Ash Distribution Calculation Input	Unit	Ash Collection Area	Ash Collection % at different area
Total Fuel fired	kg/hr	Front / Bed / Bottom Ash	20 to 35%
Ash % in Fuel fired	%	Economiser Hopper Fly Ash	5 %
Unburnt carbon Loss	%	APH Hopper Fly Ash	5 %
GCV of Fuel fired	Kcal/kg	ESP-1st Field Hopper Fly Ash	45%
Unburnt Carbon	Kg/Hr	ESP-2nd Field Hopper Fly Ash	15%
Ash Generated	Kg/Hr	ESP-3rd Field Hopper Fly Ash	5 %
Total Ash Generated	Kg/Hr	ESP-4th Field Hopper Fly Ash	5 %

UN-BURNT CARBON LOSS % in ASH CALCULATION

Fuel Fired	kg/hr	40000	40000	24000	24000
Fuel GCV	kcal/kg	2175.0	2175.0	4650.0	4650.0
Heat released by fuel	kcal/hr	87000000	87000000	111600000	111600000
Total Un-burnt carbon loss % considered in calculation	%	**2.5**	**3.5**	**6.5**	**8.5**
Heat wasted as unburnt carbon loss	kcal/hr	2175000	3045000	7254000	9486000
Carbon calorific value	kcal / kg of carbon	8080	8080	8080	8080
Un-burnt carbon weight loss as carbon	kg/hr	269.18	376.86	897.77	1174.01
Ash % considered in Fuel	%	**1.80**	**1.80**	**20.00**	**20.00**
Total Ash Generated	kg/hr	720.00	720.00	4800.00	4800.00
Ash discharge from Bottom / Bed / Front	%	**20.00**	**20.00**	**30.00**	**30.00**
Ash Quantity released from Bottom / Bed / Front	kg/hr	144.00	144.00	1440.00	1440.00
Un-burnt carbon % considered Bottom / Bed	%	**5.00**	**5.00**	**8.00**	**8.00**
Ash quantity with Un-burnt in bottom ash = bottom ash quantity / (1- unburnt carbon in bottom ash)	kg/hr	151.58	151.58	1565.22	1565.22
Un burnt carbon quantity in bottom ash	kg/hr	7.58	7.58	125.22	125.22
Un-burnt carbon in fly ash = Un-burnt carbon total weight - Un-burnt carbon quantity in bottom ash	kg/hr	261.60	369.28	772.55	1048.79
Ash discharge in Fly Ash	%	**80.00**	**80.00**	**70.00**	**70.00**
Ash quantity carryover in Fly Ash	kg/hr	576.00	576.00	3360.00	3360.00
Ash quantity with Un-burnt in Fly ash = Ash quantity in Fly Ash + Un-burnt carbon in fly ash	kg/hr	837.60	945.28	4132.55	4408.79
Un-burnt Carbon Loss % in fly ash	%	**31.2**	**39.1**	**18.7**	**23.8**

LOSS ON IGNITION- LOI CALCULATION

CARBON LOSS VALUE= (% ASH x LOI x 8080)/{(100-LOI) x GCV}	%	**2.5**	**3.5**	**6.5**	**8.5**
ASH % IN FUEL =	%	**1.8**	**1.8**	**20**	**20**
FUEL GCV =	Kcal/Kg	2175	2175	4650	4650
CARBON CALORIFIC VALUE=	kcal/kg of carbon	8080	8080	8080	8080
LOSS ON IGNITION= 100/((% ASH x 8080 / (GCV*CARBON LOSS))+1)	%	=100/((1.8*8080/(2175*2.5))+1)	=100/((1.8*8080/(2175*3.5))+1)	=100/((20*8080/(4650*6.5))+1)	=100/((20*8080/(4650*8.5))+1)
LOI =	%	**27.2**	**34.4**	**15.8**	**19.7**

RESIDENCE TIME CALCULATION

Flue Gas Quantity Generated	Kg /Hr	135000	135000	135000	135000	150000
Gas Temperature in Furnace	ºC	825	900	825	825	825
Furnace Pressure / Flue Gas Pressure	MMWC	-5	-5	-40	40	-5
Flue Gas Density considered	Kg/Nm3	1.280	1.280	1.280	1.280	1.280
Corrected Flue Gas Density in Furnace	Kg/Nm3	1.279	1.279	1.275	1.285	1.279
Furnace Volume taken upto centerline of Superheater	m3	450.00	450.00	450.00	450.00	450.00
Residence Time upto centerline of Superheater	Sec	**3.82**	**3.57**	**3.80**	**3.83**	**3.44**
Total Furnace / Combustion Chamber Volume	m3	625.00	625.00	625.00	625.00	625.00
Residence Time for Total Furnace Volume	Sec	**5.30**	**4.96**	**5.28**	**5.32**	**4.77**

MIXED FUEL FIRING COMBINATION CALCULATION

Fuel Fired in Combinatio n	Fuel GCV in Kcal/kg	Each Fuel Fired Quantity at 100% MCR in Kg/hr	Fuel % of combination on HEAT BASIS %	Fuel Fired quantity for % of combination on HEAT BASIS in Kg/hr	Fuel Fired quantity for % of combination on WEIGHT BASIS %
Bagasse	2175	40000	65	26000.0	83.2
Coal	4650	15000	35	5250.0	16.8
			100	**31250.00**	**100.00**
Mixed Fuel GCV for % of Combination on WEIGHT BASIS in Kcal/kg					**2590.80**

MIXED FUEL ANALYSIS COMBINATION RATIO

Carbon %	23.25	x	0.832	+	48.50	x	0.168	=	27.49
Hydrogen %	3.25	x	0.832	+	5.40	x	0.168	=	3.61
Sulphur %	0.00	x	0.832	+	0.40	x	0.168	=	0.07
Nitrogen %	0.00	x	0.832	+	0.90	x	0.168	=	0.15
Oxygen %	21.75	x	0.832	+	11.30	x	0.168	=	19.99
Moisture %	50.00	x	0.832	+	20.00	x	0.168	=	44.96
Ash %	1.75	x	0.832	+	13.50	x	0.168	=	3.72
Total	**100.00**				**100.00**				**100.00**
GCV - Kcal/kg	2175	x	0.832		4650	x	0.168	=	2590.80
Boiler Efficiency %	71.2	x	0.65		82.5	x	0.35	=	75.16
Un-burnt Carbon Loss %	2.5	x	0.65		4.5	x	0.35	=	3.20
Excess Air %	30	X	0.832		25	X	0.168	X	29.16

M/s Unite Energy Corporation LLP is keen to provide the Boiler Spares, Sales & Services, Retrofit & Site Repairs of Boiler & Auxiliaries, Performance Evaluation, Shop & Site Fabrication, Erection & Commissioning, Design Modification & Feasibility Study, Consultancy & troubleshooting support to mitigate the irregularities in the plant, minimize breakdown & downtime and improvise design & system performance to improve the overall plant's health and performance.

Regards

Pramesh Kumar Jain
Chief Executive- Technical
Mobile: **+91 9868499319**
Email: **pramesh.uniteenergy@gmail.com**

Unite Energy Corporation LLP,
Ghaziabad, U.P., INDIA