BASIC DESIGN - KNOWLEDGE

We have experienced a lot of basic engineering errors, their justification, then Rectification and Alteration, Later Replacement and finally Failure in the same pattern.

These all above sequences give us a deep knowledge, experience on someone else's cost but most of the time, we do not know the root cause because if it gets highlighted, A question mark will arise on the whole engineering & implementation system.

BOILER DESIGN SELECTION & CALCULATION SEQUENCE

1. BOILER GENERAL CONFIGURATION SELECTION

a) Steam Circuit

i) Radiant Super Heater
ii) Inter stage Attemperator
iii) Convective Super heater

b) Water Circuit

i) Deaerator
ii) Boiler Feed Water Pump
iii) HP Heater
iv) Economiser
v) Steam Drum

c) Primary Air Circuit

i) FD Fan / PA Fan
ii) SCAPH
iii) Air Pre-Heater & Air Pre-Heater Bypass
iv) Wind box / Air inlet Hopper / Stoker

d) Secondary Air Circuit

i) SA Fan
ii) SCAPH
iii) Air Pre-Heater & Air Pre-Heater Bypass
iv) Furnace – Over Fire Air / Spreading Air

e) Flue Gas Circuit

i) Furnace
ii) Radiant Superheater
iii) Connective Super heater
iv) Boiler Bank / Evaporator / Screen Tube
v) Economiser
vi) Air Pre-Heater
vii) ESP / Bag Filter / Wet Scrubber / MDC
viii) ID Fan
ix) Chimney

ROLE OF VARIOUS PARTS / EQUIPMENTS

1. **FURNACE:** Furnace absorbs major parts of the heat generated through heat transfer by radiation. Residence time is selected during furnace design to ensure fuel gets time to burn completely before leaving the furnace. In Tubes, Water converts to steam and two phase steam and water mixture enters in Steam Drum through Risers. This process is called circulation and this water to steam ratio is called circulation ratio. **If calculation goes wrong, then this improper ratio of Steam & Water mixture leads to Flow Assist Corrosion failure (FAC failure).**

2. **SUPER HEATER:** Correct design of the Superheater is very essential. Superheater absorbs heat by radiation and by convection. Uneven heat / gas flow / steam flow distribution leads to imbalance in superheater and leads to tube failure, Header Sagging & Distortion. If superheater pressure drop is very low, it means steam distribution is not proper. A correct pressure drop ensures good distribution of steam to individual tubes. During Superheater design, following consideration taken:

    a. Final steam temperature & Boiler operating load range for steam temperature
    b. Superheater surface area required & Material grade for superheater
    c. Radiant / Convection selection based on gas temperature
    d. Steam flow rate (mass flux / velocity) through the tubes w.r.t. permissible steam pressure drop to control tube metal temperatures
    e. Coil arrangement and spacing of tubes in Superheater w.r.t. Fuels & Ash Properties

    Radiant - Platen Superheater considered for
    a. High Steam temperature
    b. Wide load range for Superheater Steam temperature control
    c. Low Furnace Exit Gas Temperature (FEGT)
    d. Minimize Attemperator Spray water flow quantity

3. **BOILER BANK**: To compensate the shortage of heat transfer surface in the furnace to get the desired saturated steam flow rate, boiler bank is added.

4. **ECONOMISER**: Installed after Boiler Bank/Evaporator. Feed water temperature at Economiser outlet should be 20 to 30 degC below from saturation temperature of boiler drum water @ drum operating pressure.

5. **Attemperator**: It used to control steam temperatures. To get the desired steam temperature at partial load operation, Superheater Heating Surface Area will increase. In this case, at full load operation, we get high steam temperature. As a general design guideline, restrict the difference between steam temperature before & after (inlet and outlet) Attemperator water spray to below 30 ^{o}C.

6. **Boiler Design**: To Start boiler design, essentially required Inputs are
   a) Fuel Ultimate Analysis, Type of Fuel, Type of Fuel Firing system
   b) Required Un-burnt Carbon loss, Weight of Air based on Fuel
   c) Boiler Specification, Site details like Ambient temp, Sea level, Humidity
   d) Boiler pressure parts selection like Furnace, Superheater, Economiser
   e) Performance selection & Process Design
   f) Boiler Efficiency, heat losses and credits (heat balance)are calculated as a percent of the heat input, the Efficiency = 100 - % Losses + % Credits. The following losses are to be determined.
      1. Loss in dry products of combustion
      2. Loss due to moisture in air
      3. Loss due to moisture from fuel
      4. Loss due to water vapor in gaseous fuels
      5. Loss due to moisture from hydrogen in fuel
      6. Loss due to Sensible heat in ash
      7. Loss due to unburned combustible
      8. Loss due to radiation and convection
      9. Other Losses & Heat credits

Boiler Efficiency Sample Calculation:

Ambient Temperature: 30 degC
Relative Humidity: 70%, Moisture in air (M) kg/kg dry air: 0.01878
Excess Air: 30%

Fuel Bagasse Ultimate Analysis:

1. Carbon % **23.50**
2. Hydrogen % **3.25**
3. Oxygen % **21.75**
4. Sulphur % **0.00**
5. Nitrogen % **0.00**
6. Moisture % **50.00**
7. Ash % **1.50**
8. GCV -HHV **2250** Kcal/Kg

Bagasse Constituent		O_2 Required per kg of Constituent	O_2 Required per kg of fuel	Products of combustion - kg/kg fuel			
				CO2	H20	SO2	N2
Carbon	0.2350	**2.664** (C+O2 – CO2) (12.01+32 – 44) or (1+32/12.01- 44/12.01) or (1+2.664 –- 3.663)	0.6260	0.862	-	-	-
Hydrogen	0.0325	**7.937** (2H2+O2 – 2H2O) (4.032+32 – 36.032) or (1+32/4.032 – 36.032/4.032) or (1+7.937 –- 8.937)	0.2580	-	0.293	-	-
Oxygen	0.2175	-	-0.2175	-	-	-	-
Sulphur	0.0000	**0.998** (S+O2 – SO2) (32.06+32 – 64.06) or (1+32/32.06 – 64.06/32.06) or (1+0.998 –- 1.998)	0.0000	-	-	0.000	-
Nitrogen	0.0000	-	-	-	-	-	0.000
Moisture	0.5000	-	-	-	0.500	-	-
Ash	0.0150	-	-	-	-	-	-
Total	1.0000	-	**0.6665**	0.862	0.793	0.000	0.000

O_2 required per kg of Carbon = 0.2350 x 2.664 = 0.6260
O_2 required per kg of Hydrogen = 0.0325 x 7.937 = 0.2580

Molecular Weight: C – 12.01, O_2 -32, H_2 – 2.016, S – 32.06

The Chemical equations: C + O_2 -- CO_2, S + O_2 -- SO_2, $2H_2$ + O_2 -- $2H_2O$

Product of combustion (kg/kg fuel) CO_2 = (0.2350 x 44)/12 = 0.862
Product of combustion (kg/kg fuel) H_2O = (0.0325 x 36)/4 = 0.293

Total O_2 required per kg of fuel shall be obtained by deducting the oxygen present in the fuel
Theoretical O_2 required = 0.6665 kg/kg of Bagasse

Stoichiometric dry air kg/kg fuel fired = O_2 kg/kg fuel x 4.3103= 0.6665 x 4.3103= 2.8728
(Approx. 23.2 % Oxygen by weight present in air -- 100/23.2 = 4.3103)

Calculated weight of wet air kg/10^6 kcal fired = Stoichiometric dry air kg/kg fuel x 1.013 x 10^6 /HHV =2.8728 x 1.013 x 10^6 / 2250 = 1280.87 kg/10^6 kcal

Wet combustion (A) air kg/10^6 kcal fired = Calculated weight of wet air x (1+Moisture in air) x (1+Excess Air/ 100)/1.013
= 1280.87 x (1+0.01878) x (1+30/100)/1.013 = 1674.63 kg/10^6 kcal fired

Normally, Solid combustible loss (% heat loss) for Bagasse is 1.5%

Solid combustible loss (% by weight of fuel) C’ = Solid combustible loss (% heat loss) x HHV/ 8080 = 1.5 x 2250 /8080 = 0.4177

Combustible loss correction factor C = 1 - C' /100 = 1- 0.4177/100 = 0.9958

Combustible air kg/10^6 kcal fired = C x A = 0.9958 x 1674.63 = 1667.60 kg/10^6 kcal fired

Fuel in products as Flue Gas, kg/ 10^6 kcal fired (F) = 10^4 (100 - % ash - % solid combustible weight loss)/HHV = 10^4 (100 – (0.0150x100) - 0.4177)/2250
= 435.92 kg/10^6 kcal fired

Total Products as Flue Gas, kg/10^6 kcal fired (P) = (C x A) + F
= (0.9958 x 1674.63) + 435.92 = 2103.52 kg/10^6 kcal fired

Exit Flue gas temperature (Tg) = 150 degC
Ambient air temperature Ta / Fuel temperature Tf = 30 degC,
hence Tg – Ta / Tf = 120 degC

MOISTURE IN FLUE GAS:
Wa- H_2O in air = Moisture in air X Combustible air kg/10^6 kcal fired
= 0.01878 x 1667.60 = 31.32 kg/10^6 kcal

Wc- H_2O in fuel, surface and inherent = Moisture % in fuel x 10^6 / HHV
= 0.50 x 10^6 / 2250= 222.22 kg/10^6 kcal

Wh- H_2O formed by combustion of H_2 = Hydrogen % in fuel x 8.94 x 10^6 / HHV
= 0.0325 x 8.94 x 10^6 / 2250 = 129.13 kg/10^6 kcal

Total moisture in Flue Gas products = Wa + Wc + Wh
= 31.32 + 222.22 + 129.13 = 382.67 kg/10^6 kcal

Total Dry Flue Gas Weight: Pd - dry gas
[Total Products as Flue gas (P)-(Wa+Wc+Wh)]= 2103.52 – 382.67
= 1720.85 kg/10^6 kcal

SUMMARY OF HEAT LOSS:

Loss-dry gas = 0.24 Pd (Tg – Ta)/10^4 = 0.24 x 1720.85 x (120)/10^4 = 4.96 %

Loss, H2O in fuel, surface & inherent moisture = Wc x (Moisture Vapor Enthalpy @Tg Value + ((Flue Gas Temperature Cp @ Tg Value x Tg) - Tf))) / 10^4
= 222.22 x (663.1 + ((0.491 x 150) - 30))) / 10^4 = 15.70 %

Loss, H2O from combustion of H2 = Wh (663.1+ (0.491 x Tg – Ta)) / 10^4
= 129.13 (663.1 + (0.491 x 150-30))/ 10^4 = 9.13 %

Loss, H2O in air = 0.491 Wa (Tg – Ta)/10^4 = 0.491 x 31.32 (150-30)/10^4 = 0.18 %

Loss, un-burnt carbon for Bagasse = 1.5 %

Loss, Radiation as per ABMA chart = 0.38 %

Loss, un-accounted for Bagasse = 0.25 %

Total Losses = Sum of all losses as above = 32.1%

Boiler Efficiency = 100 – (4.96 + 15.70 + 9.13 + 0.18 + 1.5 + 0.38 + 0.25) = **67.90 %**

1. ESP INLET HIGH FLUE GAS TEMPERATURE

According to various experiments, best suitable range of ESP Inlet Flue Gas temperature is 150 deg C to 165 Deg C. ESP Inlet Flue gas volume will change w.r.t. Inlet Flue Gas temperature. An increase in Inlet flue gas temperatures than design is directly proportional to the ESP inlet gas flow rate and migration velocity and reduces dust particle contact time, hence reduced ESP collection efficiency and performance.

2. Water wall panel corner tube failure: Expansion

3. Super heater header sagging / distortion: Expansion, Flow Imbalance, High Attemperator Spray Water Flow rate

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Regards

Pramesh Kumar Jain
Chief Executive- Technical
Mobile: **+91 9868499319**
Email: **pramesh.uniteenergy@gmail.com**
Unite Energy Corporation LLP, Ghaziabad, U.P., INDIA