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Economical Aspect in Optimization of Multi-Fuel Boiler

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Abstract: *The main purpose of the project is to evaluate the performance of the boiler and to evaluate the percentage does the boiler accessories involved in improvement of the boiler efficiency, used in the thermal power plant in RINL, and suggested how economically the power is generated by using the by-products available in the Visakhapatnam steel plant. In this report the various benefits and limitations in using the different fuels in the boiler furnace are discussed.*
Keywords: *RINL, blast furnace, coke oven batteries*

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I. Introduction

Visakhapatnam Steel Plant, The first coast-based Integrated Steel Plant of India is located 26km southwest of Visakhapatnam city, in Andhra Pradesh in India. In this plant every department is inter linked. Generally main the steel plant is to increase their production inorder to do that capacity of Blast Furnace and Coke Oven department is to be increased. Our focus is mainly on BF, Coke Oven department and Thermal Power Plant.

1.1Coke Ovens And Coal Chemical Plant (Co And Ccp):

Coke is manufactured by heating of crushed coking coal in the absence of air at a temperature of 1000c and above for about 16 to 18 hours. At VSP there are three coke oven batteries, 7m tall and having 67 ovens each. The carbonization takes place at 1000°c to 1050°c in absence of air for 16 to 18 hours. The useful coal chemicals are extracted in coal chemical plant from C. O. Gas. After recovering the coal chemicals the gas is used as a by-product fuel by mixing it with gases such as BF Gas, LD Gas etc.

1.2. Facilities

1. There are 4 batteries, each having 67 ovens.
2. The volumetric capacity of each oven is 41.6 m^3.
3. Dry Coal charge /Oven is 32 tons.

1.3 Sailent Features

1. Largest and technologically unique Coke Oven Batteries in the country at the time of commissioning.
2. 7 metre tall coke ovens batteries.
3. Selective crushing of coal to improve the coke quality.
4. 100% Dry Quenching of coke using Nitrogen gas.
5. Power generation, from the waste heat recovered, at BPTS (Back Pressure Turbine Station).

1.4 Capacity

1. Production capacity for 3 Batteries-2.635 Mt of Gross coke per annum 2.261 Mt of BF Coke per annum.

1.5 Blast Furnaces (Bf):

Hot metal is produced in the Blast Furnaces, which are tall vertical furnaces. The furnace is named as Blast Furnace as it runs with a blast at high pressure and temperature. Raw Materials such as sinter, iron ore lumps, fluxes and coke are charged from the top and hot blast at 1100°c to 1300°c and 5.75 KSCG pressure is blown almost from the bottom. VSP has two 3200 cu meter. Blast Furnaces namely Godavari and Krishna named after the two rivers of AP.

1.6 Facilities

1. One Blast Furnace of 3820 cum. useful volume.
2. One Blast Furnace of 3200 cum. useful volume.
3. One Blast Furnace of 3813 cum. useful volume.

1.7 Sailent Features

BF-1

1. BF Cooling elements (Cast Iron Staves & Copper Staves).
2. High heat zone copper staves.
3. Circular type with full castable runner system (flat cast house).
4. Hydraulic Drilling Machine, Mud Gun, Manipulators.
5. New scrubber with annular gap element for better gas cleaning.

BF-2

1. Conveyorised charging of Blast Furnaces.
2. On-line correction of coke moisture and batch weights.
3. Circular cast house with four tap holes and no slag notch.
4. Gas Expansion turbines for power generation by utilizing the blast furnace gas top pressure.
5. Automation with Programmable Logic Controllers (PLC).

BF-3

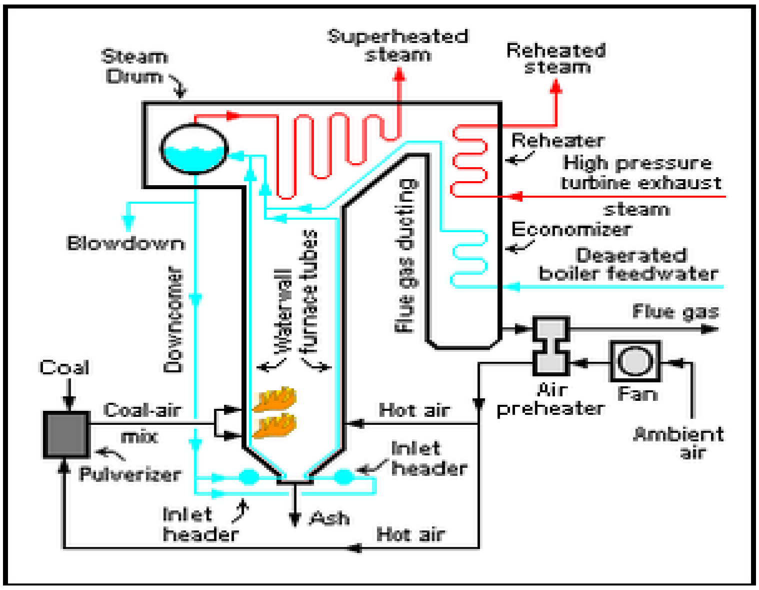
1. BF Cooling elements (Cast Iron Staves & Copper Staves).
2. Pulverized Coal Injection System.

1.8 Capacity

1. Production capacity- 2.5 MT per annum for BF-1
2. Production capacity -1.7 MT per annum for BF-2
3. Production capacity -2.5 MT per annum for BF-3.

II. Boiler

As boiler generates steam at the desired pressure and temperature by burning fuel in the furnace. It is a complex integration of furnace, Superheater, Reheater, Boiler or Evaporator, Economizer, Stokers, Dust Collectors, Ash Handling equipment, and Chimney. The boiler is the place where the phase change occurs from liquid (water) to vapour (steam), essentially at constant temperature and pressure. So the term “boiler” is traditionally used to mean the whole steam generator.



The salient design data of the boilers are
Boiler capacity - 330 T/HR
Fuels fired - pulverized coal, BFG, COG, HSD, HFO
SH steam pressure - 100 Kg/cm^2

SH steam temperature - 540^o C
Feed water temperature - 150^o C
All the boilers are identical and designed for multi-fuel firing with pulverized coal, BFG and COG. The boilers are designed for combination firing.

III. Fuels Used In The Boiler

1 Blast furnace gas
2 Coke oven gas
3 Pulverized coal
4 HSD (High Speed Diesel) – starting purpose
5 HFO (Heavy Fluid Oil) – stabilizing purpose

3.1 Blast Furnace Gas

Blast furnace (BF) gas is a gaseous by product which is generated while producing hot metal (liquid iron) in a blast furnace. The operation of the blast furnace is controlled to produce hot metal of a specified quality and during this production BF gas comes out from the furnace top.

3.2 BF gas has the following characteristics

1. Very low calorific value (CV) in the range of 700 to 850 Kcal/Cu m (2930 to 3556 Kilojoules/Cu m). CV is very much dependent on the coke rate.
2. It has a high density. It is around 1.250 Kg/Cu m at the standard temperature and pressure (STP) which is 0 deg C and 1 atm. Pressure. This density is highest amongst all the gaseous fuel. Since the density is higher than the density of air it settles in the bottom in case of a leakage.
3. It has low theoretical flame temperature which is around 1455 deg C.
4. It has low rate of flame propagation. It is lower than any other common gaseous fuel.
5. BF gas burns with a non luminous flame.
6. Auto ignition point of BF gas is around 630 deg C.
7. BF gas has lower explosive limit (LEL) of 27% and upper explosive limit (UEL) of 75% in an air gas mixture at normal temperature and pressure.

3.3 Advantages In Using The Blast Furanace Gas As Fuel

1 There is no need to buy the Blast Furnace gas as it is available the plant as by-products in the Blast Furnace
2 Plenty of gas is available in the steel plant. Blast Furnace generates 1500-1700 Cu/ton of hot metal of BF gas is generated during the process.
3 No ash is produced in the furnace.
4 As there is no loss heat in the ash and the efficiency of the boiler is increased.
5 There will be less pollution when compared to the coal fired boiler.

3.4 Disadvantages in using the blast furanace gas as fuel

1 The Blast Furnace gas is not separately generated or purchased as it is obtained as a by-product. If the Blast Furnace plant under maintenance then gas will be unavailable.
2 As the calorific value is low and requires the large volumes to meet the required demand when compared to coke oven gas.
3 It has low rate of flame propagation. It is lower than the other gaseous fuels
4 I require large storage tanks even to generate a few MW.

3.5 Coke Oven Gas

Coal is converted into coke by heating the prepared coal blend charge in the coke ovens in the absence of air at a temperature of 1000oC-1050oC for a period of 16-19 hours. The volatile matter of coal liberated during carbonization is collected in gas collecting mains in the form of raw coke oven gas passing through stand pipes and direct contact cooling with ammonia liquor spray. After extracting all by-products finally coal or Coke Oven gas is collected.

IV. Advantages In Using The Coke Oven Gas As Fuel

1 It is obtained as the byproduct during the carbonization of the coal in the coke oven batteries.
2 It has high calorific value and a limited volume is enough to generate the desired power.
3 No ash is formed.

4.1 Disadvantages In Using The Coke Oven Gas As Fuel

As limited amount of gas available as the same gas is used in the carbonization of coal, only excess gas is used to generate power.High cost involves in the storage of the coke oven gas.

[NOTE: benefits and limitations in using pulverized coal as fuel is generally known and available to all**]**

V. Calculations

In an multi-fuel boiler with Blast furnace gas, Coke oven gas and Pulverized coal as fuels. The efficiency of the boiler is calculated

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VI. Heat Distribution

6.1 Heat Supplied By Fuel

Blast furnace gas = $M \times C.V$
= $117.26 \times 800\ Mcal/hr$
= $109.0257\ MW$

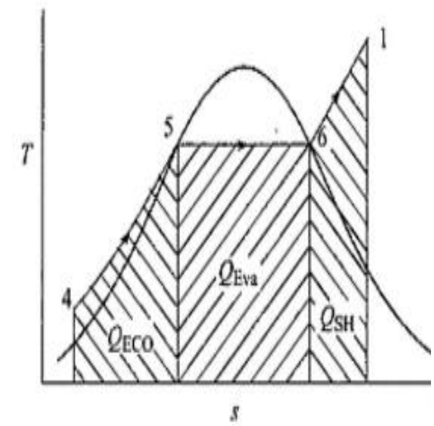
Coke oven gas = $M \times C.V$
= $14.485 \times 4520\ Mcal/hr$
= $76.0932\ MW$

Pulverized coal = $M\ \times C.V$
= $10 \times 3538.24\ Kcal/sec$
= $148.04\ Mjoules/sec$
= $148.04\ MW$

total heat supplied = $\mathbf{333.1589}\ \boldsymbol{MW}$

heat distribution in the boiler:

Heat absorbed in Economizer = $h_5 - h_4$
Heat absorbed in Evaporator =$h_6 - h_5$
Heat absorbed in Superheater = $h_1 - h_6$



T_1 = 158.417°C
T_4 = 545.42°C

Therefore the corresponding enthalpies are

H_4 = 667.67 KJ/kg
H_1 = 3499.55 KJ/kg

Since the 1-4 is a constant pressure process and the pressure is 8.562MPa, therefore from steam table,

h_f = h_5 = 1342.82 KJ/kg
h_g = h_6 = 2749.01 KJ/kg

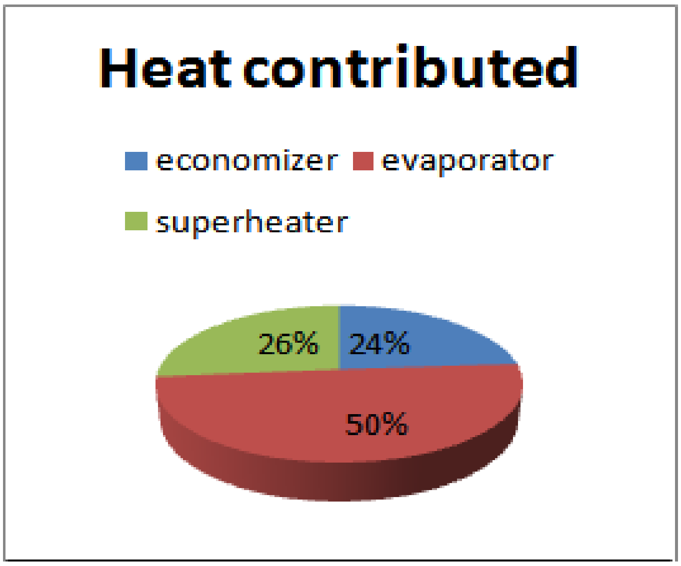
Heat absorbed by the Economizer = h_5-h_4
= 675.15 KJ/kg

Heat absorbed by the Evaporator = h_6-h_5
= 1406.19 KJ/kg

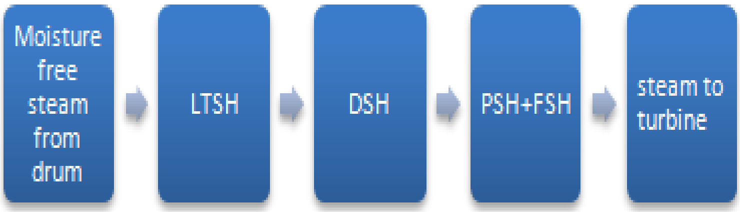
Heat absorbed by Superheater = h_1-h_6
= 750.54 KJ/kg

Total heat absorbed = 2831.74 KJ/kg

Percentage of heat absorbed by the Economizer = 23.85%
Percentage of heat absorbed by the Evaporator = 49.65%
Percentage of heat absorbed by Superheater **= 26.5%**



Heat Distributed By The Superheater



Steam temperature before LTSH = 299.750 C
Enthalpy before LTSH (h_3) = 2749.01 KJ/kg
Steam temperature before DSH = 432.87 C
Enthalpy before DSH (h_5) = 3208.98 KJ/kg
Steam temperature after DSH = 342.04 C
Enthalpy after DSH (h_6) = 2924.47 KJ/kg
Steam temperature after PSH+FSH = 542.45 C
Enthalpy after FSH (h_4) = 3499.55 KJ/kg

Heat absorbed in LTSH $= \boldsymbol{m_s \times (h_5 - h_3)}$
$= 79.82 \times (3208.98 - 2749.01)$
= 36.714 MW

Heat removed in DSH = $\boldsymbol{(m_{s+w} \times h_6) - (m_s \times h_5)}$
$= (83.44 \times 2942.47) - (79.82 \times 3208.98)$
= **10.59 MW**

Heat absorbed in PSH+FSH = $\boldsymbol{m_{s+w} \times (h_4 - h_6)}$
$= 83.44 \times (3499.55 - 2924.47)$
= **47.984 MW**

Heat Recovered By Air Preheater:

Primary air flow rate = 30.484 T/hr
= 8.467 kg/sec
Secondary air flow rate = 126.361 T/hr
Total air flow rate = 156.845 T/hr
Primary air inlet temperature = 44 C
Secondary air inlet temperature = 40 C
Primary air outlet temperature = 262.95 C
Secondary air outlet temperature = 160.34 C

Heat recovered by primary air

$= m \times C \times (T_{out} - T_{in})$

$= 8.467 \times 1.005 \times (160.34 - 44)$

= 1 MW

Heat recovered by secondary air

$= 35.1 \times 1.005 \times (262.95 - 40)$

= 7.825 MW

Heat recovered = 8.825 MW

Readings Obtained Through Analysis Of Boiler:

Superheated steam flow = 287.37 T/H
Superheated steam pressure = 87.310 kg/cm^2
Superheated steam temperature = 545.42 C
Feed water temperature = 158.17 C
Feed water flow = 202.92 T/H
Spray water flow = 13.059 T/H
Coke oven gas flow = 14.485 knm^3/hr
Blast furnace gas flow = 117.26 knm^3/hr
COG calorific value = 4520 kcal/ knm^3
BFG calorific value = 800 kcal/ knm^3
Coal flow = 10 kg/sec

Calculating The Efficiency Of The Boiler (Direct Method):

Heat required for raising steam

Superheated steam pressure = 90.36 kg/cm^2
= 8.8643 MPa
Superheated steam temperature = 545.42 C
Enthalpy corresponding to above = 3499.55 KJ/kg
Enthalpy corresponding to feed water temperature
= 667.67 KJ/kg

Total heat required to raise the steam

$= m_s \times h_{super} - m_w \times h_f$

$= (79.72 \times 3499.55) - (56.366 \times 667.67)$

= **241.35 MW**

TOTAL HEAT SUPPLIED = $\mathbf{333.1589\ MW}$

Efficiency of a boiler

$= \frac{\textbf{heat require to raise the steam}}{\textbf{total heat supplied}}$

$= \frac{241.35}{333.1589}$

= 72.44%

VII. Optimization Solution To Problem

7.1 Problem:

We observed the multi-fuel boiler with BF gas, Coke Oven gas and pulverized coal as fuels. Cost of construction of such boiler is high, cost of the fuel as goes high when the years passes by losing their efficiency and ash handling becomes difficult.

VIII. solution

We suggest to use the boiler with fuels BF gas and coke oven gas. As we need no spend any cost for fuel as they are available as byproducts in the plant. Construction of such boiler become less expensive as it does not require any ash handling system and ESP (electro-static plates).

Fuel proportion that can be used in the boiler is that

1. BF gas
2. 80% of BF gas and 20% of CO gas
3. 80% of BF gas and 20% of HFO - stabilization

If the production of CO gas in the Coke Oven Department exceed desired limit it may not be used further, in order to utilize the CO gas effectively the boiler should be designed to utilize in the plant for power generation. As the CO gas cannot be released directly into the atmosphere it should be fired before releasing into the atmosphere.

Salient Features Should Add To The Plant:

- Tubular Air Heater
- High Energy Arc (HEA) Ignitors.
- No electro static precipitators.

IX. Conclusion

In this project, an attempt was made to find out the values of the heat distributed in the various accessories of boiler and thus finding the efficiency of the boiler. In this project we found the optimum method to generate power by utilizing the available byproducts in the plant.

Summary of heat balance in multi-fuel fired boiler in TPP

Input / output parameter	Value (%)
Total heat supplied (coal, BFG and COG)	333.1589 MW (100%)
Heat absorbed in boiler (Economizer, Evaporator and Superheater)	241.35 MW (72.44%)
Heat recovered in air preheater	8.825 MW (2.65%)
Heat losses	24.91%

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