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Onsite Coal Testing and Inspection for Cogeneration Power Plant of 5000 Tons Crushed Per Day of Cane-Sugar Integrated with 26 MW Co-Generation Unit

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Abstract:- The cogeneration plant uses bagasse and Coal as raw material for the electricity generation. The main function of cogeneration power plant in the sugar industry is to supply electricity to the industry and processed water and steam to the various other departments like Ethanol plant, Sugar industry, Distillery plant etc., Before using coal and bagasse in the furnace it has to be tested for its quality and testing is done in the lab. Both bagasse and coal tested before and after usage in the furnace to ensure its quality. Coal can be tested in two possible ways, namely ARB (air received base) and ADB (air dried base), it is adviced to do ARB test but, practically it does not work due to sticky characteristic of coal thus ADB test is done which gives almost nearer value that of the ARB with an error of 1 to 2% but in acceptable range. Caol testing is done and inspected for its quality, Inert moisture(IM) test, Ash Content(AC) test, Volatile moisture(VM) test, Fixed carbon determination, GCV Determination.

Keywords:- *5000 TCD of sugar, ARB, ADB, Ash, Volatality, GCV, Fixed carbon, Inert moisture.*

I. INTRODUCTION

The main function of cogeneration power plant in the sugar industry is to supply electricity to the industry and processed water and steam to the various other departments like Ethanol plant, Sugar industry, Distillery plant etc., The NSL sugars limited Produces of 26MW of power out of which about 9MW (full plant in working condition) of power will be utilized by the plant and remaining about 15-16MW will be sold to the state electricity board based on the home load which varies like 3MW to 5MW. Cogeneration first appeared in late 1880.s in Europe and in the U.S.A. during the early parts of the 20th century, when most industrial plants generated their own electricity using coal-fired boilers and steam-turbine generators. When central electric power plants and reliable utility grids were constructed and the costs of electricity decreased, many industrial plants began purchasing electricity and stopped producing their own. Cogeneration is on-site generation and utilization of energy simultaneously by utilizing fuel energy at optimum efficiency in a cost-effective and environmentally responsible way.

A. Heat-to-Power ratio

Heat-to-power ratio is one of the most vital technical parameters influencing the selection of Cogeneration system. If the heat-to-power ratio of industry can be matched with the characteristics of the cogeneration system being considered, the system optimization would be achieved in real sense.

Cogeneration System	Heat-to-power Ratio kWth/ke	Power Output	Overall Efficiency %
Back-pressure steam turbine	4.0 – 14.3	14 – 28	84 – 92
Extraction-condensing steam turbine	2.0 – 10	22 – 40	60 – 80
Gas turbine	1.3 – 2.0	24 – 35	70 – 85
Combined cycle (Gas plus steam turbine)	1.0 – 1.7	34 – 40	69 – 83
Reciprocating engine	1.1 – 2.5	33 - 53	75 - 85

Table 1. Heat-to-Power ratio

B. Coal/Bagasse yard

For any power plant fuel is essential to get heat. Upon which steam can produced in cogeneration power plant as name itself indicates power plant is not main business of industry, cogeneration power plant is one of the unit of the industry. The NSL sugar industry uses bagasse-the product of the sugar cane as fuel to burn in the furnace in combination with coal, in seasonal time about 7 to 9 months (september to may) sugar cane will be available so the power plant fully uses bagasse as the fuel, during that time coal will be shut off. During non seasonal time cogen uses fully uses coal as fuel. The coal and bagasse cannot be used directly in the furnace due to their characteristics.

II. EXPERIMENTAL DETAILS

A. Specification of cogeneration plant

1. Boiler (110 tph) Feed Pump

Quantity : 3nos
Make : KSB
Capacity: 53.42 cu.mtr/hr

2. Electro Static Precipitator (ESP)
Quantity: 2 nos.
Make : ALSTOM

3. Induced Draft Fan (ID)
Quantity: 2 Nos
Make : M/s.Flakt (India)
Type : Horizontal, Backward Curved, Radial

4. Forced Draft Fan(FD)
Quantity: 1 Nos
Make : M/s.Flakt (India)
Type :Horizontal, Backward Curved, Radial

5. Secondary Air Fan (SA)
Quantity: 1 Nos
Make : M/s.Flakt (India)
Type :Horizontal, Backward Curved, Radial

6. De-Aerator
Make :Ravi industries PUNE.
Quantity : 1 no.
Type : spray cum tray
Capacity: 135 Cum.mtr / hr

7. Feed Water Tank
Make : IJT
Capacity: 150 Cu.m

8. Retractable Soot Blowers
Item code :LRSB001 to LRB004
Make : BHEL

9. Rotary Air Lock Valve (ESP)
Make : Hyquip Rotolock (P) ltd.
Model No : HR:200:CE

10. Feed Water Transfer Pump
Quantity: 2nos.
Make : Beacon.
Model : BCP 80/260.

11. HP Heater
Make : M/s FLOEX
Type : Surface U tube.
Feed water quantity : 110T/hr.

12. HP Dosing System
Make : Positive metering pumps(P)
Flow : 0 to 15TPH
Tank capacity : 288Ltrs

13. LP Dosing System
Make : Positive metering pumps(P)
Flow : 0 to 15TPH
Tank capacity : 288Ltrs

15. Hydraulic Drive
Quantity: 2nos.
Make : NGT Engineering.
Drive : Twin (Hydraulic)

16. Air Compressor
Item code : ACR001
Make : Ingersoll-Rand

17. Coal Crusher
Make : Sayaji Iron & Engg. Co.Ltd
Impactor size : 800 mm dia x 600 mm width

B. Standards used

Standard Test Method for Moisture in the Analysis Sample of Coal is ASTM D3173 / D3173M - 17a

C. Coal/Bagasse

Because bagasse contains moisture content and coal will not be in uniform size and required size for the cogen.Thus before sending bagasse to the furnace the moisture content in it will be removed by using hot flue gas bypass taken from chimney to the dryer, in drier bagasse will fall from top and flue gases will be taken from the bottom as the bagasse and flue gas comes in contact, the heat content in the flue gases will be taken by the flue gases and thus bagasse will get dried and can be taken to the furnace through conveyer as shown below.

Fig 1:- Bagasse from sugar mill

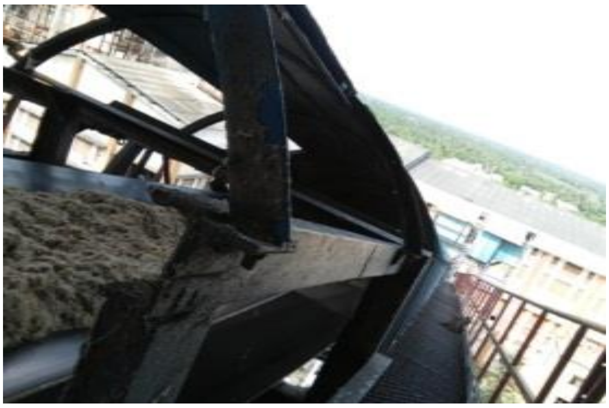


Fig 2:- Bagasse to the drier

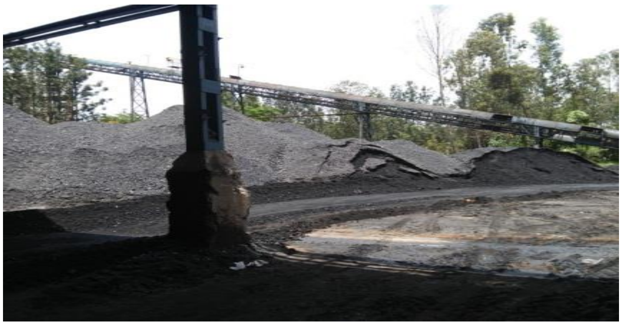


Fig 3:- Coal storage in yard

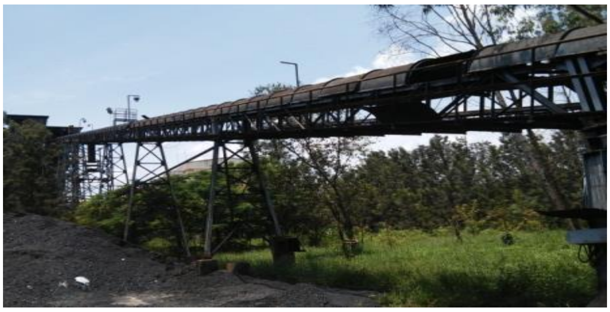


Fig 4:- Crushed Coal to furnace

From the above pictures it is clear how the bagasse is taken from the sugar mill, how it is dried, stored and sent to the furnace. Similarly coal is also sent to the furnace with some premodifications which includes storage, drying and crushing the below figures represents the how coal is stored, dried, crushed and sent to the furnace through conveyer.

When coal is imported the coal is left on open atmosphere to dry for 8 to 12 hours. Then it is sent to the crusher. In crusher the mechanical hammer is continously impinges on strong metal bar between which coal is fed and crushed due to hammering effect, coal is crushed to 20 to 22mm in size which is suitable to burn in furnace finally.

D. Coal testing and inspection

The coal used for the test is South indian moistured coal. The necessary equipments used for various tests

- *Weighing machine with closed chamber:* Equipped with a High Precision Strain Gauge Sensor System, Accuracy Resolution: 1g, 0.1oz , Minimum Weight: 1g or 0.0353oz.
- *Muffle furnace:* Tmax 1100 °C or 1200 °C Heating from two sides by ceramic heating plates (heating from three sides for muffle furnaces L 24/11 - LT 40/12) Ceramic heating plates with integral heating element which is safeguarded against fumes and splashing, and easy to replace.
- *Bomb Colorimeter:* As per IP – 12 Specifications. The colorimeter body and lid are machined from corrosion, resisting Stainless steel, capacity of 300ml.

III. RESULTS AND DISCUSSION

Before using coal and bagasse in the furnace it has to be tested for its quality and testing is done in the lab. Both bagasse and coal tested before and after usage in the furnace. Coal can be tested in two possible ways namely ARB (air received base) and ADB (air dried base), it is adviced to do ARB test but, practically it does not work due to sticky characteristic of coal thus ADB test is done which gives almost nearer value that of the ARB with an error of 1 to 2% but in acceptable range.The coal and bagasse sample is taken from the field before burning and after burning for testing purpose to the laboratory. And coal is made to dry in open atmosphere for 24 hours to get dried and then it is powdered mannually and passed through the mesh to get fine coal powder then taken to the lab and similar procedure is repeated for bagasse but 4 to 6 hours drying in open atmosphere is sufficient than that of coal.

Fig 5:- Coal sample before burning

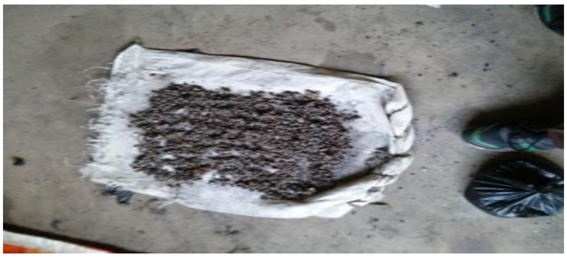


Fig 6:- Coal sample after burning

Coal for testing is taken before it is fed to the burner and residue after it burns as shown above. These coal samples were powdered to test as shown below.

Fig 7:- Powdered coal

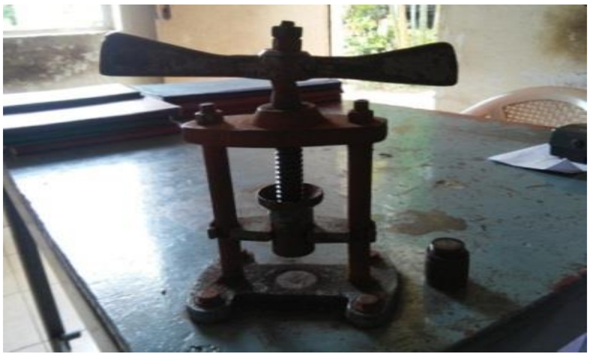


Fig 8:- Coal pressing vice to make coal pellet

The above all photos explains how coal is prepared for testing, coal pellet is made by using mannual pressing machine as shown in which that pellet is used for finding GCV (gross calorific value) of coal used and also test is conducted for many tests like Inert moisture, Ash content, Volatile moisture, Fixed carbon. And similar procedure is repeated for bagasse in same way.

A. Inert moisture (IM) test

For inert moisture test the coal sample about 10gm is taken in weighing glass plate and weighed (W2). Before coal is weighed in the weight of the empty glass plate is noted down (W1) as shown below.

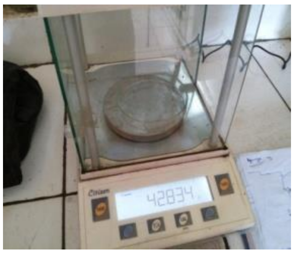


Fig 9:- Empty jar weight Fig 10:- Jar with coal

Thus we will get weight of coal on subtracting coal with jar and empty jar weight. After this coal is taken to the hot air oven and left for 1hour at 105ºC during this the moisture content in the coal will be removed due to hot air present in the oven then, taken back to find out the inert moisture content in the coal through below calculations.

Empty jar weight :W1
Jar with coal :W2
Weight after taken from oven :W3
% of Inert moisture $= 100 \div [(W_2 - W_1) \div (W_2 - W_3)]$
Normally the value of inert moisture comes form 10 to 25% depending upon coal quality. For example we have for one trial as follows.
W1 = 40.4g W2= 47.8g W3=47g
now we have
W2 –W1 = 7.4g and W2 –W3 = 0.8g and thus
$100 \div [7.4 \div 0.8] = 10.81\%$

B. Ash content (AC) test

Similar procedure is repeated for weighing of coal and weighed coal is taken to the Mufile furnace and left for 2 hours duration then calculation is done using below formula.

$$\% \text{ of Ash } = 100 \div [(W_2 - W_1) \div (W_3 - W_1)]$$

Generally ash content will be 5 to 15% depending upon the quality of coal.

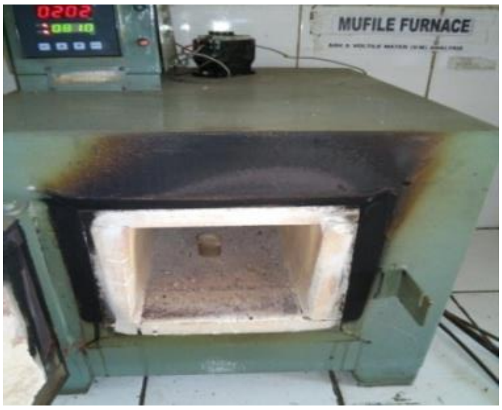


Fig 11:- Coal sample kept in muffle furnace

C. Volatile moisture (VM) test

For volatile moisture determination the coal sample is weighed as above taken in crusibel and kept in mufile furnace at 920oC for 7 minutes, and taken back for finding out volatile moisture as shown below.

Calculation is done as follows.

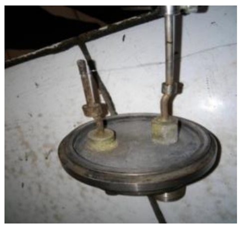
$$\% \text{ of volatile moisture } = 100 \div [(W_2 - W_1) \div (W_2 - W_3)]$$

Normally the volatile content in coal will be 30 to 50% depending upon quality of fuel.

D. Fixed carbon (FC)determination

The amount of burning quality of coal/bagasse depends upon the carbon content in it. If coal contains more carbon then it means to say it releases more heat upon combution similarly if it contains less carbon then heat release upon combution will be less. For finding out fixed carbon content we have as follows.

Fixed Carbon (FC) = (VM – IM – Ash content)
The fixed carbon content will be in the range 30 to 65% generally which again depends upon quality of the fuel.



E. GCV (gross calorific value) determination

It is necessary to know the amount of heat released when fuel (Coal/Bagasse) is burnt under atmospheric temperature and pressure further which we can decide the quality of fuel wether it is convinient/economical to use. So that fuel (coal) can be purchased. For calculating GCV the method adopted is Bomb Colorimeter. The pellet of nearly one gram is prepared as said earlier. This pellet is used in bomb colorimeter to find out GCV. The bomb colorimeter apparatus is used for this purpose. Initially a wire of 7cm and 10cm thread is taken, the pellet prepared is tied using thread taken already. there will be electrode bar in bomb colorimeter which can be taken out. Those electrodes were locked using wire and pellet is tied to that wire as shown below.

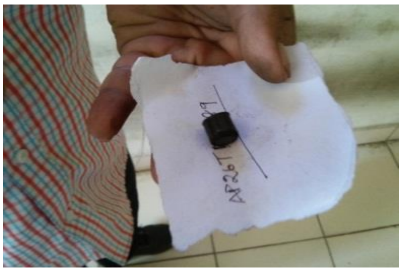


Fig 12:- Coal pellet

After inseting coal pellet for test bar the electrode bar/burning jar is tightened and this is imersed in water bath inside the bomb colorimeter and whole setup is tightened. Oxygen at 22Kg/cm^2 is passed to the burning jar from oxygen cylider to the testing jar. And stirrer is switched on so that heat distribution in water bath after coal pellet burning will be uniform.

Fig 13:- Electrode bar locked with wire
Fig 14:- Coal pellet which is tied to wire

After this the burning jar is inserted into bomb colorimeter, a thermometer is inserted to slot provided in the bomb colorimeter and the indicator knob is set to zero initially then after a moment fire button is pressed then there will be temperature rise in the indicator then release the fire button, technically when fire button is pressed an electric arc will be generated between burning jar electrode thus the thread starts burning which is followed by the coal pellet which increases the temperature of water bath indicated by the thermometer inserted. Then note down the increase in temperature which is used for GCV calculation as follows.
For calculation of GCV we have

GCV =Temperature rise X Water equivalent weight – Thread and wire weight Sample weight

Let us see on trial of calculation:
Temperature rise = 2.62 (in bomb colorimeter indicator)

Water equivalent weight = 2191, Thread and wire weight = 30.32g, Sample weight = 0.973g

$$\text{GCV} = [(2.62 \text{ X } 2191) - 30.32] \div 0.973$$
$$\text{GCV} = 5868.55 \text{ kcal/kg}$$

The above GCV is obtained for air dried base (ADB) but in actual case we have to do it for air received base (ARB) for this we have as follows:

$$\text{ARB GCV} = [(100 - \text{Total moisture}) \div (100 - \text{Inert moisture})] \text{ X ADB GCV}$$

For one trial:
Total moisure = 18.68, Inert moisture = 11.31 thus

we have

$$\text{ARB GCV} = [(100 - 18.68) \div (100 - 11.31)] \text{ X } 5868.55$$
$$\text{ARB GCV} = 5380.83 \text{ kcal/kg}$$

The above all the tests were conducted for bagasse in same way. But for bagasse IM will be in the range 45 to 55 %, VM will be in the range 40 to 60%, Ash content will be in the range 30 to 60 % but some what the 5 to 10 % moisture content will be removed in the dryer. Also it can be concluded that less heat will be released by the bagasse than that of the coal since it has less calorific value than that of the coal. The GCV of coal varies from 5000 to 6500 kcal/kg but bagasse GCV varies from 2000 to 4200 kcal/kg, hence bagasse has less heat release capacity.

IV. CONCLUSION

From all the above tests and Inspection it is clear that by pre-testing the imported coal before its acceptance gives an idea about the return from investment by knowing its various properties like moisture content, volatility, Fixed carbon, GCV etc., thus the quality of the coal and also this depends upon how the coal is dried for test, the time it left in the furnace during test. Not only the tests limited to these, sometimes when coal contains sulphur in excess quantity than limit permitted, then the imported quantity of the coal will be rejected without prior notice to the seller since it causes huge environmental pollution also the heat release rate is less. By all these we can come to conclusion that for a small cogeneration power plant like this by burning coal in mixture of the bagasse the economy in the plant is achieved by utilizing the natural resources effectively.

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