JSESM

ISSN:2583-3294

Journal of Scholastic Engineering Science and Management

April 2022, Volume 1, Issue 2 pp: 7-23

"Naturalistic Amelioration of Cogeneration Boiler Efficiency in the Tract of Sugar Production Plant"

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ABSTRACT

The efficiency of boiler has vociferously heightened in the course of considering the apposite thermal strictures. By using this type of plants, we save natural resources like coal, water because the by-product of sugar cane i.e., Bagasse is used as raw material for combustion. By erecting the plant as per the design, it results in the reduction of atmospheric pollution and increases the power generation and the efficiency of the plant increases. By these designs, the step-by-step process of power generation will be in a progressive level such that interruption in power generation will not happen and fault identification and rectification will be easy for any working individual the captioned integrated sugar and cogen power project is sternly feasible and commercially viable, in respect of benefits from trade international market.

Keywords: *Cogen plant, Bagasse, Coal, Boiler Efficiency*

1. INTRODUCTION

The origin of Indian sugar industry dates back to 1930, when the first sugar factory was set up in the pre-independence era. Over the last 76 years, the sugar industry partakes steadily grown and has become the backbone of the agricultural and rural economy in India. Today, sugar is the second largest agro processing industry, next to the textile industry. India is one of the largest producers of sugar in the world, with a production of over 25 million tonnes. Sugar factories are located mostly in the rural India. They act as centres of development, provide largest direct employment in the rural areas and contribute substantially to the Central and State exchequers. The prospects of earning foreign exchange from export of sugar are also quite high Sugar factories in India have capacities ranging from 1250 TCD to 10000 TCD. The Indian sugar industry has developed indigenous capabilities for design, manufacture, supply, operation and maintenance, R&D and cane development. The major stakeholders of this industry in India are Ministry of Agriculture, Govt. of India, Ministry of Consumer Affairs, Food and Public Distribution, federations of cooperative and private sector sugar factories at the national and the State levels, sugarcane growing farmers, equipment and technology suppliers, research institutions, consultants and service providers, financial institutions and Central / State Governments. A total of 701 sugar factories are in operation today, with additional sugar factories under implementation in different parts of the nation. The crop yield per hectare and recovery has improved, particularly in the last decade. Sugar factories in India are spread over the entire country; however, 92% of them are located in 9 States viz., Uttar Pradesh, Bihar, Punjab and Haryana in the north, Maharashtra and Gujarat in the west and Karnataka, Andhra Pradesh & Tamil Nadu in the south. More than 80% sugars factories are below 3500 TCD capacity and balance have higher capacities. About 44% of the Indian sugar factories are in the cooperative 9% in public sectors and balance 47% in the private sector. The Ministry of Consumer Affairs, Food & Public Distribution, and Government of India revised the standard specifications for sugar plant & equipment, in the year 1987. The special committee finalized specifications for economical capacity of 2500 TCD, expandable to 3500 TCD, employing higher-pressure boiler and turbine configuration and efficient equipment, with a potential to export incidental surplus power to the grid. The Indian sugar industry was de-licensed in the year 1998 vide press note No. 12 issued by the Government of India, Ministry of Industry, Department of Industrial Policy and Promotion, on August 31, 1998. The sugar industry stands deleted from the list of industries requiring compulsory licensing under the provisions of Industries Development and Regulation Act, 1951. However, in order to avoid unhealthy competition among sugar factories to procure sugarcane, a minimum distance of 15 km would continue to be observed between and existing sugar factory and a new factory, by exercise of powers under the Sugar Control Order, 1966. The entrepreneurs, who wish to de-license their sugar factory, would require filing an Industrial Entrepreneur Memoranda (IEM) with the secretariat of industrial assistance in the Ministry of Industry, as laid down for all de-licensed industries, in terms of the press note dated August 2, 1991, as amended from time to time. Entrepreneurs who have been issued Letter of Intent (LoI) for manufacture of sugar need not file an initial IEM. In such cases, the LoI holder shall only file Part B of the IEM at the time of commencement of commercial production against the LoI issued to them. It is however open to entrepreneurs to file an initial IEM (in lieu of LoI / industrial license held by them) if they so desire, whenever any variation from the conditions and parameters stipulated in the LoI / industrial license is contemplated. The statistics on economic and commercial performance for the industry is quite fluctuating.

2. COMPANY PROFILE

Sri Chamundeswari Sugars Limited (SCSL), incorporated in December 1970, is promoted by Dr. N. Mahalingam of the 'Sakthi Group' Coimbatore; Tamil Nadu SCSL started its operation to manufacture sugar with an installed capacity of 1250 TCD in 1974 at K.M. Doddi, Maddur Taluk, Mandya District in Karnataka. It undertook expansion of its sugar manufacturing capacity from 1250 TCD to 2400 TCD in 1986 and further to 4000 TCD in 2006.

In the year 2002-03, the company set up a distillery unit to manufacture rectified spirit, denatured sprit and extra neutral alcohol from molasses with an installed capacity of 50 kilo litres per day (KLPD). Along with the Distillery Plant, biogas and bio-compost units has been setup to treat and add value to the effluent form the distillery. The bio-compost unit was put up to produce Bio-fertilizer by biologically assimilating wastewater effluent into Press-mud organically without causing any damage to environmental factors. It is one of the model units in India, which are treating effluents.

Fig.1.1: Foyer View of Sri Chamundeswari Sugars Limited

3. PROCESS PLANT DETAILS

The objectives of the sugar plant of the proposed integrated project are mainly to manufacture quality sugar for national & international markets at optimum operating and energy efficiencies, as well as provide raw materials for co-gen power plant. The integrated venture will push the product, which has highest realization in the market. The design of the sugar mill would match the latest and modern technologies, being employed for the co-gen power plant. At the same time, the flexibility of operation, expansion and diversification, also will be available.

Chemical Reaction:

Sugar Cane + Inhibition Water ⟶ Raw Juice + Bagasse

(100 %) + (30 %) ⟶ (103 %) + (27 %)

In Mandya Region (Karnataka) Sugar Breed – VCF517

VCF62175

Table 1: Details of Process Plant

SL.NO	Particulars	Value
1	Sugar cane crushing capacity	4000TCD
2	Sugar produced	8.5-10.5% 9 Tons average for every 100 Tons
3	Molasses for Distillery	4-5%
4	Bagasse	25-30%
5	Imbibition water flow	30-35% (Avg. 48 TPH)
6	Temperature	70^0 C
7	Raw Juice	60-75%

3.1.Process plant machinery

Cogeneration power plant will house the steam turbine generator and its auxiliaries, the condenser and its auxiliaries, the control room; the boiler feed pumps, the electrical equipment room (distribution transformers, switchgear, and motor control centres), battery room, etc. The steam turbine generator will be supported on a reinforced concrete pedestal. The building superstructure will be RCC construction. Pitched roof will be provided to facilitate drainage. Proper air conditioning will be provided for the control room. For all other areas adequate ventilation system will be provided as per the State regulations. Special precautions will be taken for air intake and exhaust for the emergency diesel area and for the battery room.

ISSN:2583-3294

Table 2: Machines of Process Plant

SL. No	Machines	Number
1	Crushing Mills	4
2	Juice Buffer Collection Tank	1
3	Primary Heater	4
4	Reaction Vessel	1
5	Secondary Heater	4
6	Clarifier	1
7	Vacuum Filter	1
8	Clear Juice Heater	1
9	Multiple Effect Evaporators	10
10	Vacuum Pan Crystallizer	9
11	Crystallizer	13
12	Centrifugals	15
13	Raw Sugar Melter	1
14	Hopper	2
15	Sizer	6

3.2.Cogen plant details

The cogen power plant effluents will also be treated in a separate effluent treatment plant & the discharges will be maintained as per the latest norms of the MPCB & CPCB. The liquid effluents generated from the Cogen power plant will be mainly from boiler blow down, cooling tower and water treatment plant blow downs, wash water and other sewage effluents. The cogen power plant will have installed capacity of 26 MW of Double extractions – cum condensing type turbine and will employ 87 kg/cm2 and 5400C configurations. Bagasse generated from cane crushing, excluding handling losses and bagacillo requirements will be available for operation of the high-pressure boiler during season for 160 days. Saved bagasse will be used during the off-season period of about 27 days. The auxiliary steam consumption for the power plant will be for soot blowing and other auxiliary consumptions like Steam Jet Air Ejector (SJAE) & Gland Steam Condenser (GSC) at high pressure, for HP heater at medium pressure and for de-aerator at low pressure. The auxiliary power consumption for the power plant will be about 9% & 9.5% of generation during season and off-season period respectively.

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Fig.1.2: COGEN Plant

Table 3: Details of Cogeneration Plant

SL. No	Particulars	Details
1.	Plant Capacity	26 MW
2.	Plant Utilization	7.5 MW
3.	Export to Grid	17.5 MW
4.	Steam Generator	Babcock and Wilcox (Thermax)
5.	Fuel Used	Bagasse, Biogas, coal
6.	Turbine Type	Extraction Type impulse Turbine

Boiler and Fuel Details:

- Number of Boilers-01
- Type of Installation- Outdoor
- 100 % Bagasse (135TPH)
- 100 % Imported Coal (110.7 TPH)
- Feed water Eco Inlet Temperature 210^0C
- Dosing System Tank Capacity: 300 Liter
- Safety Relief Valve SOOT Boiler system Pressure: 49 Kg/Cm^2

A steam boiler generates steam at the desired rate at the desired pressure and temperature by burning fuel in its furnace. A steam boiler is a complex integration of furnace, superheater, preheater, evaporator, economizer and air preheater along with various auxiliaries. The evaporator is that part of steam boiler where phase change occurs from liquid to vapor, essentially at constant pressure and temperature.

ISSN:2583-3294

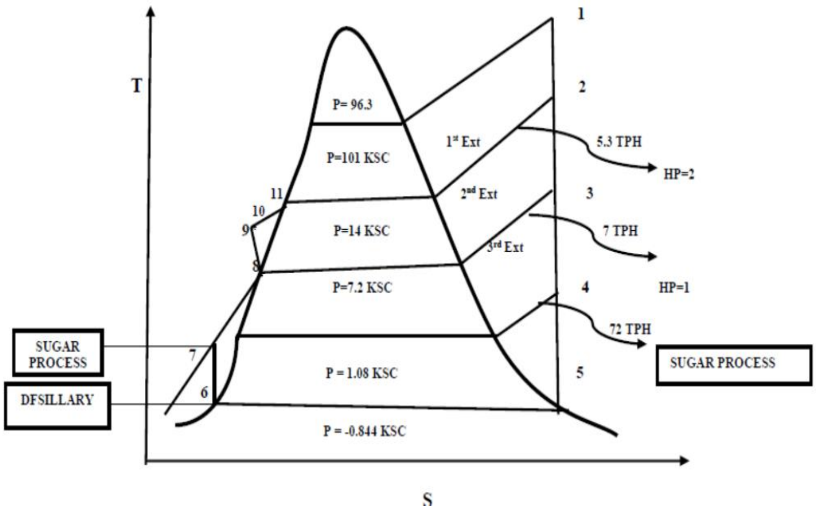

Fig.1.3:T-S Diagram

4. STEAM GENERATOR EFFICIENCY

The boiler (steam generator) efficiency is defined as

$$\eta_{Boiler} = \text{form steam} \frac{\text{Rate of energy absorption by water}}{\text{Rate of energy release by combustion of fuel}}$$

$$\eta_{boiler} = \frac{w_s(h_1 - h_{11})}{w_f * CV}$$

Fig.1.2: Temperature-Entropy (T-S) Diagram (Actual Rankine Cycle)

Table 4: Particulars of Turbine and Heaters

Where w_s is the steam generation rate and w_f is the fuel consumption rate and CV is the calorific value of the fuel.

The values of the variables are tabulated below:

Table 5: Steam Generation Variables

Sl.No	PARAMETERS	VALUE
1	Q_{in} (kW)	117482.536
2	h_1 (kJ/kg)	3430
3	h_{11} (kJ/kg)	830
4	w_s (kg/s)	26.75

Coal Cost = 8500/Ton.

Table 5: Particulars of Turbine and Heaters

Description	26 MW			15.6 MW		
Boiler	Pressure (Kg/Cm^2)	Temperature (^0C)	Flow Rate (TPH)	Pressure (Kg/Cm^2)	Temperature (^0C)	Flow Rate (TPH)
	107	540±5	135	101	524	96.3
Turbine	104	540	132	100	521	94.2
1St Extraction (HP-2)	20.3	335.8	9.36	14	307	5.3
2nd Extraction (Sug+Dist) + (HP-1)	9.59	262.9	10.56 9.11	7.2	253	7.24 7 (HP-1)
3rd Extraction (Sugar+Deaerator)	2	135	72.8 10.15	1.08	139	72
Condenser Flow	0.934	37.57	19.92	-0.844	52	2.7

- **Calculations:**

i. Boiler Efficiency

$$W_S = 26.75\ Kg/s$$

$$h_1 = 3430\ KJ / Kg$$

$$h_{11} = 830\ KJ / Kg$$

$$W_{f\,(Bag.)} = 47\ TPH$$

$$W_{Beg} = 13.06\ Kg/s$$

$$GCV = 2150\ KCa/Kg$$

$$= 2150 \times 4.182$$

$$= 8995.6\ KJ/Kg$$

So, $Q_{in} = W_g \times GCV$

$$= 13.06 \times 8995.6$$

$$\boxed{\mathbf{Q_{in} = 117{,}482.536\ KW}}$$

NCV=1800

$$\eta_{boiler} = \frac{w_s(h_1 - h_{11})}{w_f * CV}$$

$$= \frac{26.75\,(3430-830)}{13.06\,(2150\times4.184)}$$

$$\boxed{\eta_{Boiler} = 59.2\ \%}$$

The efficiency of the steam generator came to be 59.2 % which implies that only 59.2 % of the energy on the fuel is taken by the feed water. The ideal efficiency of the steam generator on Bagasse is 71 % which shows that the boiler is running in 3 % lower efficiency as provided by the manufacturer.

ii. Rate of Heat

To find out Power P:

$$\text{Heat Rate} = \frac{\text{Net Heat Used to produce Power}}{\text{Net Power Produced}}$$

$P_{Net} =$ 15.6-(Auxillaries+BEP+CEP)

$$= \frac{Qin-(ms2nd)\times h}{P} \qquad =$$

15.6-2.45

$$= \frac{117482.536-(20\times2760)}{13.16\times1000}$$

$P_{Net} = 13.16$ MW

$$= 4.73 \frac{KJ/S}{KW}$$

Heat Rate = 4.73 × 3600

$$= 17{,}034.78 \frac{KJ}{KWH}$$

$$= \frac{17{,}034.78}{4.184}$$

$$\textbf{Heat Rate} = \mathbf{4072.126 \frac{KCal}{KWH}}$$

It indicates that, the heat supply of 4072.16 Kcal/KWH is required to produce 1 KW of Power.

4.1.Heat balance sheet for boiler

Heat Input = GCV= 2150 Kcal/Kg = 100%

Heat Utilized in the form of:

- Output Heat
- Condensation loses
- Sensible heat loss
- Un-burnt solid loss (α) (2-3%)

- Incomplete combustion loss (β) (0.5-1%)
- Radiation loss (γ) (0.5-1%)

a) **HEAT INPUT (Q_i)**

$$\mathbf{Q_i = GCV = 2150\ KCal/Kg}$$

b) **HEAT UTILIZED**

1. **Condensation Loss**

L_c=GCV-NCV

= 2150-1800

L_c = 350 Kcal/Kg

$L_c = 350 \times 0.97 \times 0.9 \times 0.9$

$$\mathbf{L_c = 274.995\ Kcal/Kg}$$

2. **Sensible loss (L_s)**

$$\mathbf{L_s = [(1-w)\ (1.4m_a-0.13)\ +0.5]\ (T_g-T_a)}$$

Where,

W = Weight of the moisture in Bagasse 50% = 0.5

m_a = mass of air ratio = 1.4 (1.3-1.6)

T_g = Temperature of flue gas at chimney = 178^0C

T_a = Ambient Temperature = 28^0C

$L_s = [(1-0.5)\ (1.4\times1.4-0.13)\ +0.5)]\ (178-28)$

L_s = 212.25 Kcal/Kg of Bagasse

$L_s = 212.25\times0.97\times0.9\times0.9$

$$\mathbf{L_s = 166.7648\ Kcal/kg\ of\ Bagasse}$$

3. **Boiler Efficiency**

$$\eta_\beta = \frac{\mathrm{GCV-LOSES}}{\mathrm{GCV}}$$

$$\eta_\beta = \frac{\text{Heat Available}}{\text{Heat Supplied}}$$

$$\eta_\beta = \frac{GCV-(GCV-NCV)-Ls}{GCV}$$

$$\eta_\beta = \frac{NCV-Ls}{GCV} \times \alpha\beta\gamma$$

$$\eta_\beta = \frac{1800-212.25}{2150} \times 0.97 \times 0.9 \times 0.9$$

$$\boldsymbol{\eta_\beta = 0.5802 \rightarrow 58.02\ \%}$$

Hence, Heat Output = Q_{out} = GCV × $\boldsymbol{\eta_\beta}$

= 2150 × 0.5802

Q_{out} = 1247.43 Kcal/Kg of Bagasse

4. **Un-burnt solid loss (α)**

Un-burnt solid loss (α) = 3% of GCV

= 3/100 × 2150

Un-burnt solid loss (α) = 64.5 Kcal/Kg

5. **Incomplete Combustion Loss (β)**

Incomplete Combustion Loss (**β**) = 1 % of GCV

= 1/100 × 2150

Incomplete Combustion Loss (β) = 21.5 Kcal/Kg

6. **Radiation Loss (γ)**

Radiation Loss (**γ**) = 1 % of GCV

= 1/100 × 2150

Radiation Loss (γ) = 21.5 Kcal/Kg

7. **Unaccounted Loss**

Unaccounted loss = 2150-(1247.43+274.995+166.765+64.5+21.5+21.5)

Unaccounted loss = 353.31 Kcal/Kg

ISSN:2583-3294

- **Heat Balance Sheet Particulars**

The Calculated values of heat input and heat output has been tabulated.

Heat Input			Heat Utilized		
Particulars	**Kcal/Kg**	**%**	**Particulars**	**Kcal/Kg**	**%**
GCV	2150	100	Heat Output	1247.43	58.02
			Condenser Loss	274.995	12.79
			Sensible Heat Loss	166.765	7.76
			Un-burnt solid loss (α)	64.5	3
			Incomplete Combustion Loss (β)	21.5	1
			Radiation Loss (γ)	21.5	1
Total	2150	100 %		2150	100 %

4.2.Boiler efficiency improvement

We can enhance the GCV of Bagasse by reducing the moisture content in the fuel. As of now 50% moisture Bagasse is using as fuel.

It reduces the moisture content to 42%.

Let W = Moisture content in 1 Kg weight wet of Bagasse

D = Dry quantity of Bagasse = 1-W

$$\therefore D=1-W \longrightarrow (1)$$

x = weight of partially dried wet Bagasse

w! = Actual weight of moisture in 'x' quantity of Bagasse

$$D=x-w$$

$$\frac{X-W!}{X} = \frac{D}{X}$$

$$1-\frac{w!}{X} = \frac{D}{X}$$ Where $\frac{W!}{X}$ = % of moisture in

quantity of Bagasse

$$1-W_1 = \frac{D}{X}$$

$$\Longrightarrow D = x - xW_1 \longrightarrow (2)$$

By equation 1 & 2

$$x - xW_1 = 1 - W$$

$$\boxed{x = \frac{1-W}{1-W1}}$$

Where, x = weight of a dried moisture

W = Initial weight of a moisture

W_1 = Weight of a moisture after dry

Here, W = 50% $\Longrightarrow$ 0.5, W_1 = 42% $\Longrightarrow$ 0.42

$$x = \frac{1-0.5}{1-0.42} = 0.8621 \text{ Kg of Bagasse}$$

Initially S= 0.2 for 1 Kg of Bagas

$$\boxed{x = 0.8621 \text{ Kg}}$$

$$\therefore \text{S is increased} = \frac{0.2}{0.8621} = 2.32\ \%$$

$$\boxed{S = 0.0232 \text{ Kg}}$$

$$\therefore GCV = (1-W) \times (4600-1200S)$$

$$= (1-0.42) \times (4600-1200\times0.0232)$$

$$\boxed{GCV = 2640.16 \text{ Kcal/Kg}}$$

For 0.8621 Kg of Bagasse,

$$GCV = 2640.16 \times 0.8621 = 2276.08 \text{ Kcal.}$$

So, calorific value enhances after drying

$$NCV = 4250-1200S-4850W$$

$$= 4250-1200\times0.0232-4850\times0.42$$

$$NCV = 2185.16 \text{ Kcal/Kg}$$

$$NCV = 2185.16 \times 0.8621$$

ISSN:2583-3294

NCV = 1883.826 KCal

Then,

$$\alpha = 0.97\ (3\ \%)$$
$$\beta = 0.99\ (1\ \%)$$
$$\gamma = 0.99\ (1\ \%)$$

Sensible Heat Loss:

$$L_s = [(1\text{-}W)\ (1.4\ m - 0.13) + 0.5]\ (T_g - T_a)$$

$$= [(1\text{-}0.42)\ (1.4 \times 1.4\text{-}0.13) + 0.5]\ (178\text{-}28)$$

$L_s = 234.21$ Kcal

$$\eta_b = \frac{NCV - Ls}{GCV} \times \alpha\beta\gamma$$

$$= \frac{1883.826 - 234.21}{2276.08} \times 0.97 \times 0.99 \times 0.99$$

$\eta_b = 0.6890 \Longrightarrow 68.90\%$

Then,

$$SFR = \frac{GCV - \eta b}{H - h}$$

$$= \frac{2276.08 - 0.6890}{830 - 194}$$

SFR = 2.4

For steam of 96.3

$$= \frac{96.3}{2.4}$$

$$= 40.125\ TPH$$

Bagasse supplied to the boiler

$$= \frac{40.125}{0.8621}$$

Bagasse supplied to the boiler with 42 % Moisture = 46.54 TPH

ISSN:2583-3294

CONCLUSION

In the long run, as per the technical point of view the efficiency of boiler has effusively enhanced in the course of considering the pertinent thermal strictures. Bagasse otherwise a refuse, if used as cogeneration fuel is proved to have been technically feasible, economically viable for the competitive industrial environment of sugar industries, environmentally friendly because of greenhouse neutral emissions and acceptable regarding social matters. By using this type of plants, we save natural resources like coal, water because the by-product of sugar cane i.e., Bagasse is used as raw material for combustion. By erecting the plant as per the design, it results in the reduction of atmospheric pollution and increases the power generation and the efficiency of the plant increases. By these designs, the step-by-step process of power generation will be in a progressive level such that interruption in power generation will not happen and fault identification and rectification will be easy for any working individual. As par with technical view the captioned integrated sugar and cogen power project is sternly feasible and commercially viable, in respect of benefits from trade international market.

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