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Evaluation of Efficiency in Steam Generator of C3 Power Plant at Cap Des Biches in Dakar

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Abstract: The aim of the present study is to determine the efficiency of the power plant boiler steam C3 Cape deer and to evaluate the impact of it. We chose to calculate the return by the empirical formula of Martin which is based on two important parameters which are the temperature at the exit of the chimney and the ambient temperature. The calculation of these efficiencies allowed us to make comparative studies with data from the manufacturer and we have detected anomalies. On this basis we made a number of recommendations for improvement of the groups in normal, the application will lead to an optimization of the real exploitation of groups and a performance improvement. We gave various reasons for poor performance of steam generators and recommendations that can be used both in production efficiency on compliance with operating instructions. Solutions have been proposed after diagnosis with particular emphasis on compliance with operating instructions and maintenance schedule.

Key words: Boiler efficiency, boiler results, facilities, heating value, power generation, power plant, steam generator

INTRODUCTION

In a context marked by increased shedding and strongly felt by all sectors at national, Senelec needs to optimize its power generation which will satisfy customers and to revive economic activities severely shaken (Bonnet *et al*., 2005).

To do this, the government of Senegal has implemented a stimulus plan that is called “TAKKAL” to fill the energy deficit by making the rental of short-term group (Aronofsky, 1954) on the one hand and also by restoring the entire system of SENELEC mainly thermal production.

To this end, we focus on the rehabilitation component of the thermal system. We will particularly study the power plant with steam. It is called C3 and located twenty-three kilometers from Dakar at “Cap des Biches”.

This power plant consists of three groups referred to as 301, 302 and 303 (Bell and Partridge, 2003).

We will put special emphasis on the efficiency of a boiler which is an essential parameter in the operation of a steam plant for the production of electrical energy.

There are several methods to evaluate the performance of a boiler in a steam power plant. Martin has proposed an empirical formula to determine the efficiency of a boiler. The model has been described and is based on the temperature at the outlet of the chimney and the ambient temperature (Wongsuwan *et al*., 2001).

This is why we will proceed to evaluate the efficiency of the boiler by the empirical formula of Martin and we will make a comparative study with data from the manufacturer in order to suggest improvements.

The calculations of boiler efficiency of the three groups of the power plant steam have been made in July 2010. This is the period during which, Senelec had problems with fuel quality that has significantly degraded the performance of our facilities and plunged the country into a blackout.

In doing so, we exploit the time sheets of the operating parameters of the three groups.

The steam generator: The steam generator in the steam power plant is the element that produces the steam needed to drive the steam turbine (Kolin, 1991).

The transformation of water into steam takes place in it by heat exchange between water and gases from combustion. This heat exchange is effected through heat recovery such as saving, the tube bundle, tube screens and superheaters. Thus the maximum of calories generated by the combustion is collected by water and steam. This allows us to have a good performance in the steam generator.

The boiler efficiency (ASHRAE, 2005) is the ratio of the power contained in the fuel and the thermal power transferred to the heating water. It is its instantaneous efficiency when the burner is working. It is also called useful yield.

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This is an instantaneous efficiency that can vary depending on operating conditions of the boiler (water temperature, burner output from the power of the boiler). The boiler manufacturer must provide its value at rated load and under ideal combustion conditions (nominal output) in their documentation

Drawing of study device: We study the performance of the steam boiler of C3 power plant which is important thermal equipment.

To do this, it's important to present the thermal equipment which is the steam boiler.

An industrial boiler includes the following essential parts:

- A combustion chamber where the tubes of shields will receive the products heat of combustion allowing the evaporation of water and its passage to the beam evaporating (Dicker and Smits, 1988).
- The beam evaporating where the heat exchange and the gradual evaporation of the water-steam will continue.
- The superheaters are completing the phase of formation of superheated steam required for the user.
- The economizer allows saving the combustible with pre-heating the feed water prior to transport to the boiler drum.
- To ensure the combustion, necessary air is sent into the combustion chamber by one or more motor-blowers.
- The motor exhaust fans are involved in the extraction of fumes from the boiler.

A drawing of study device which is called monohydric circuit will allow us to make a brief description.

It highlights the relationship between the boiler and different other equipment and Auxiliary of the power plant.

To calculate the efficiency of the boiler we use empiric Formula of Martin with the following parameters:

Tc: Chimney outlet temperatureºC
Ta: Room temperatureºC

We will use the data for these parameters recorded during in a day in order to evaluate the efficiency of each of the three groups of C3 power plant.

We will do a comparative study with data from the manufacturer in order to propose improvements

METHODOLOGY

The C3 power plant is equipped with automatic programs that record at any time the different values of its parameters during operation. We will use the data for these parameters recorded during in a day. Then we will use the empiric formula of Martin with the parameters which interest us to calculate the efficiency of boiler of each of three groups of C3 power plant at cap des biches in Dakar.

RESULTS

Decline in performance of steam generators: The fuel must be prepared so as to reach the nose of the burner in its flash point. Otherwise, it will not ignite so there will be droplets of fuel in the combustion chamber. these unburned are deposited on the tubes screens, sometimes this could lead to subsequent hot spots on the tubes then lead to a breakthrough of tubes thus unavailability of the slice and more, you lose fuel because some did not participate in combustion. This could increase the specific consumption.

The fuel must not be too hot because of the potential spray, vapor lock in the fuel circuit and the risk of coking in the burners.

The air, against, should be well warmed up before being introduced into the combustion chamber. Usually it is heated so that when it mixes with the fuel, the equilibrium temperature of the mixture is greater than the temperature of the flash point of the fuel (about three times) if it is not case, the mixture will not ignite, we return to the previous case.

Fuel is often composed of basic chemicals that when react with oxygen in the air, forming compound substances and also generates heat. If the air is not enough, the reactions are not so total. All the calories of fuel are not used:

$$C + O_2 \text{ gives } CO + Q1 \quad (1)$$

$$C + O_2 \text{ gives } CO_2 + Q2 \quad (2)$$

The reaction 1 is incomplete and gives off a quantity of heat Q1 and the reaction 2 is complete and released an amount of heat Q2. We note Q2>Q1.

In general in this case, it also consumes more fuel. This incomplete combustion also presents risks because CO carried in the boiler flue gases may at any time react with air and cause reactions inside the steam generator. To avoid this, it usually study with an excess air of about 3%.

Evaluation of the boiler efficiency by the empirical formula of martin: To avoid risk of corrosion at low temperature in air heaters and so as not to be at the dew point at the exit of the chimney, let the smoke escape at a temperature of 165ºC about and this will optimize the performance of the steam generator defined by the empirical formula of Martin.

Table 1: Variation of performance with the chimney outlet temperature

Tc	165ºC	200ºC
N	94%	92%

$$N = 100 - (Tc\text{-}Tamb) / 20 - 1$$

Tc: Chimney outlet temperature
Tamb: Room temperature

Suppose that one of the air heaters not working properly, so we will have a temperature rise of the gas fireplace. By Martin formula, we see that the yield will increase

For an increase of 35ºC on the gas temperature at the stack, there is a 2% loss on performance. So you lose 1% efficiency for a 50ºC on the temperature of exhaust gases.

We apply the formula to determine MARTIN performance of the steam generator in each group. There is none of them reaches the maximum efficiency of 94% according MARTIN method.

The Table 1 shows that the three groups are not too successful because yields do not reach 94%. The Fig. 1 highlights the operating principle of a steam power plant. We note that the ambient temperature has an impact on performance, when the stack temperature is constant, the yield increases with temperature.

When the temperature is fixed, the performance decreases when the temperature of the stack increases. For group 301, the temperatures of the chimney are all below 165ºC that is the temperature optimum performance set by Martin. They are even below the dew point temperature that is approximately equal to 150ºC. There is a risk of corrosion sulfuric low temperatures.

The yield calculated from the empirical formula of Martin is between 93 and 94%, we deduce that the group 301 is powerful despite its age. Throughout the day on July 19, 2010, it exceeds more than 93%. It is about the same value 94% at 11 h. The performance of the group 301 is zero between 9 and 10 h because the group 301 broke down between in this band. This explains the yield zero in this interval. This failure is due to an outbreak in poor condenser vacuum from 08 H 15 min. The presence of algae caused the incident. The coupling is finally intervened to 10H 07 min.

Results obtained and confined in Table 2 show that performance of group 301 are acceptable. The values obtained are similar to Martin's efficiency fixed at 94%

We note that the ambient temperature has an impact on performance, when the stack temperature is constant, the yield increases with temperature.

When the temperature is fixed, the performance decreases when the temperature of the stack increases.

For group 302, the temperatures of the chimney are well above 165ºC that is the temperature optimum performance set by Martin and they far exceed the dew point which is substantially 150ºC and the risk of sulfuric corrosion low temperature will not take place but the high temperature corrosion known as vanadic corrosion could occur.

The yield calculated from the empirical formula of Martin is less than 90% to 17 h except where the performance took a value greater than 100%, which is an anomaly in the real world as a zero temperature at the exit of the chimney indicates non-functioning of the group.

The group 302 has crashed between 9:00 and 10:00; this explains the yield zero in this interval. This failure is due to an outbreak in a very low ball from 16 H 52 min. The lack of water has caused the incident. The coupling was finally reached to 17 H 39 min. The yield is zero to 17 h because there was an outbreak of group 302.

The level of the ball is very low, which resulted in a outbreak to 16 h 52 min, so the group broke down 302.

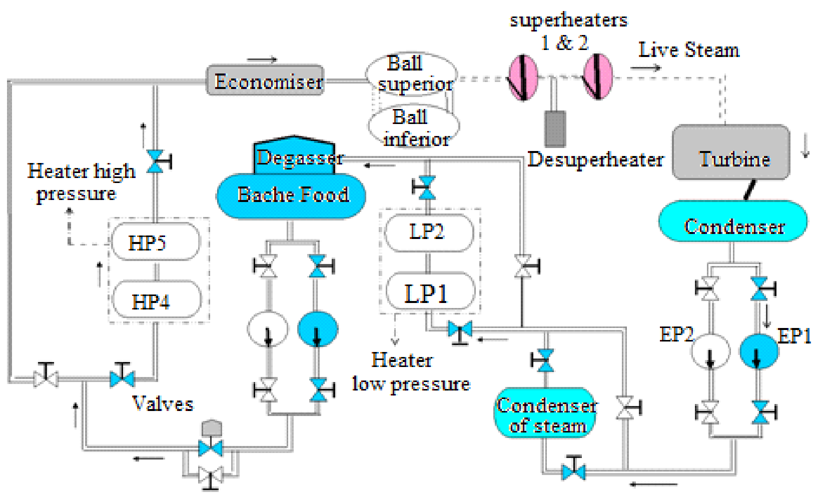

Fig. 1: Monohydric circuit of group 301 SLICE

Table 2: Calculating boiler efficiency of the group 301

Schedule	T chimney outlet temperature (ºC)	Ta room temperature (ºC)	Efficiency (%)	Martin efficiency (%)
1	137	26	93.4	94
2	136	26	93.5	94
3	135	26	93.5	94
4	135	26	93.5	94
5	135	26	93.5	94
6	136	26	93.5	94
7	134	26	93.6	94
8	135	26	93.5	94
9	0	28	0	94
10	0	28	0	94
11	134	28	93.9	94
12	135	20	93.7	94
13	135	31	93.8	94
14	133	31	93.9	94
15	133	31	93.9	94
16	135	31	93.8	94
17	136	28	93.6	94
18	137	28	93.5	94
19	137	28	93.5	94
20	136	28	96.6	94
21	136	30	93.7	94
22	135	30	93.7	94
23	136	30	93.7	94
24	137	30	93.6	94

Table 3: Calculating boiler efficiency of the group 302

Schedule	T chimney outlet temperature (ºC)	Ta room temperature (ºC)	Efficiency (%)	Martin efficiency (%)
1	238	26	88.4	94
2	242	26	88.2	94
3	240	26	88.3	94
4	234	26	88.6	94
5	242	26	88.2	94
6	237	26	88.4	94
7	240	26	88.3	94
8	242	26	88.2	94
9	231	28	88.8	94
10	231	28	88.8	94
11	234	28	88.7	94
12	232	30	88.9	94
13	26	31	88.9	94
14	26	31	89.3	94
15	26	31	89.3	94
16	26	31	89.3	94
17	26	28	100.4	94
18	26	28	89.6	94
19	26	28	89.6	94
20	26	28	89.1	94
21	28	30	89.1	94
22	28	30	89.1	94
23	28	30	89	94
24	30	30	89	94

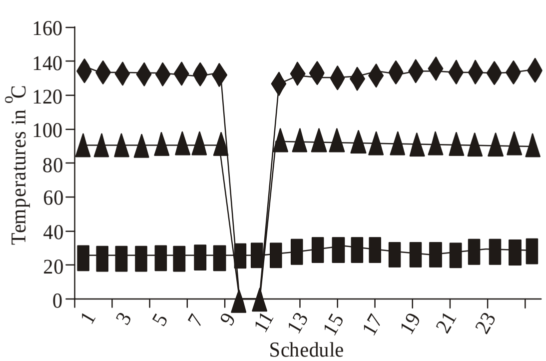

Fig. 2: Results of efficiency for group 301

The Fig. 2 highlights a good evolution of the boiler efficiency of group 301 except the moment where the failure occurred between 9:00 and 10:00. Evolution is almost constant.

The results in Table 3 indicate the bad performance of group 302 with values that are below 90%.

We note that the ambient temperature also has an effect on performance. When the temperature of the chimney is constant, the yield increases with room temperature.

When the room temperature is fixed, the performance decreases when the temperature of the chimney increases. The yield calculated from the empirical formula of Martin is less than 90% except between 13 to 14 h at which time; the performance slightly exceeded 90%. It can be

Table 4: Calculating boiler efficiency of the group 303

Schedule	T chimney outlet temperature (ºC)	Ta room temperature (ºC)	Efficiency (%)	Martin efficiency (%)
1	252	26	87.70	94
2	252	26	87.70	94
3	252	26	87.70	94
4	252	26	87.70	94
5	253	26	87.65	94
6	254	26	87.60	94
7	251	26	87.75	94
8	252	26	87.70	94
9	252	28	87.80	94
10	250	28	87.90	94
11	0	28	0	94
12	0	30	0	94
13	210	31	90.05	94
14	210	31	90.05	94
15	232	31	88.95	94
16	233	31	88.90	94
17	231	28	88.85	94
18	232	28	88.80	94
19	217	28	89.55	94
20	233	28	88.75	94
21	236	30	88.70	94
22	237	30	88.65	94
23	238	30	88.60	94
24	239	30	88.55	94

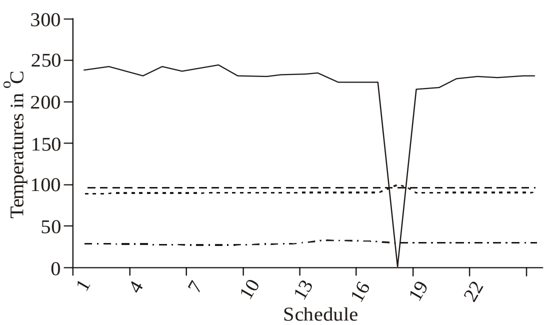

Fig. 3: Results of efficiency for group 302

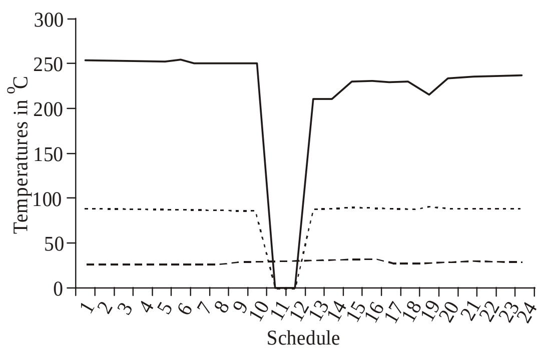

Fig. 4: Results of efficiency for group 303

concluded that the group 303 is not effective. The performance of the group 303 has a value of zero between 11 and 12 h since it broke down because of the presence of algae.

The group 303 has crashed between 10:30 ET 11 hours. This explains the yield zero in this interval.

This failure is due to an outbreak in poor condenser vacuum from 10 H 30 min. The presence of algae caused the incident. The coupling is finally intervened to 12H 34 min.

Figure 3 shows that the values of the boiler efficiency of group 302 are homogeneous and vary almost constantly, but they do not reach the value of Martin by 94% therefore group 302 is not performing.

- The values obtained for the boiler efficiency of group 303 are confined in Table 4 and show that the 303 group is not performing because the values are all below 94% which is Martin's efficiency.
- Figure 4 shows the evolution almost constant and nearly uniform of performance of the boiler of group 303 despite the bad performance according the results.

DISCUSSION

We provide conditions for overriding optimize the performance of steam generators:

- The heating value of fuel should be good to maximize the specific consumption
- Good combustion to collect the maximum energy in the fuel and optimize the amount of fuel injected.
- Proper operation of heat recovery equipment so that the heat exchange between water and the exhaust is optimum
- Good insulation (to prevent heat loss)
- Sealing of valves and pumps (to avoid loss of hot water and steam)

C Compliance with operating instructions
C Respect of the maintenance plan

CONCLUSION

Calculating of boiler efficiency of each of all three groups the C3 power plant in steam at Cap des Biches has shown that the values of efficiency are inferior at 94%. Among the three groups, group 301 is the most efficient according to the values obtained from the boiler efficiency of each group of the power plant with steam.

NOMENCLATURE

301: name of a slice steam

C The first indicates the plant (3: Third Central)
C The last two indicate the group (01)

we read
301: Group 01 of central 3
302: Group 02 of central 3
303: Group 03 of central 3

Latin letters:
C3: Central 3
N: Yield MARTIN
RT: Room temperature
Tc: Temperature of the chimney
Greek letters
0 yield

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