

# STUDY ON PERFORMANCE MEASUREMENTS OF LIGNITE-FIRED STEAM BOILERS

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**Abstract:** This paper presents a case study on the performance measurements carried out for the steam boiler of a 330 MW power unit operating on lignite. The measurements were conducted on Unit No. 4 at the Turceni Thermal Power Plant, part of the Oltenia Energy Complex

**Keywords:** 330 MW power unit, live steam, boiler feedwater, flue gas analysis, conventional fuel

## 1. INTRODUCTION

The 330 MW power units operate on solid fuel—lignite. The steam boiler of the 330 MW unit is of the BENSON type, with a nominal capacity of 1035 t/h. For pulverized coal preparation, the boiler is equipped with six coal mills, each with a capacity of 100 t/h. For boiler start-up and to ensure flame stability, the boiler is fitted with burners operating on natural gas. Figure 1 shows the basic schematic of the BENSON boiler.

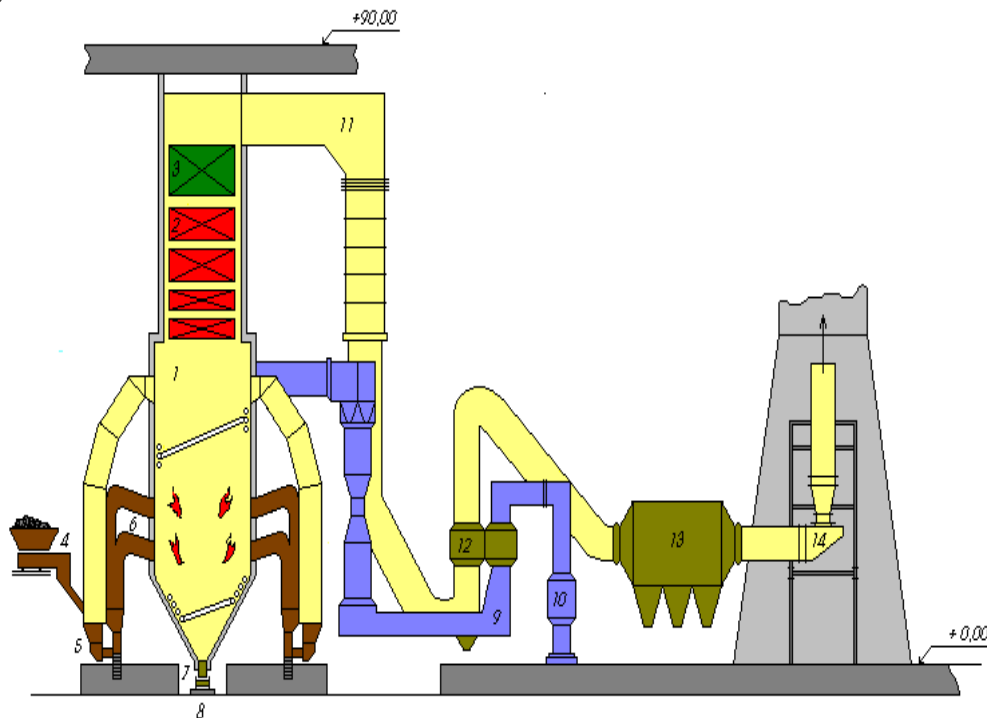


Figure 1. Schematic diagram of the steam boiler.

## 2. EXPERIMENTAL MEASUREMENTS

The Benson boiler is of tower type, with once-through forced circulation and intermediate reheating, featuring a single upward flue gas path. It uses lignite as the primary fuel and natural

gas and fuel oil as secondary fuels. The heat exchange surfaces, in the order in which they are traversed by water and steam, are as follows:

- for superheated steam:
- economizer
- evaporator
- superheater 1
- superheater 2
- superheater 3
- for reheated (intermediate superheated) steam:
- reheater 1 (RH 1)
- reheater 2 (RH 2)

The live steam temperature is controlled by two injections of feedwater taken from the discharge of the feed pumps before the high-pressure heaters, while the temperature of the reheated steam is controlled by a feedwater injection taken from the body of the feed pump. The air required for combustion is supplied by two axial fans that draw air from the atmosphere. Before entering the boiler, the air is preheated using flue gases in two rotary air preheaters of the Ljungström type. Upstream of the rotary air preheaters, to avoid the acid dew point, the air is preheated by recirculating hot air from the air preheater (APH) to the fan inlet. The flue gases are extracted from the furnace by two axial flue gas fans.

Table 1 presents the parameters of the water–steam circuit recorded during the testing period.

<b>N0</b>	<b>PARAMETER / QUANTITY</b>	<b>U.M</b>	<b>Power of the 240 MW power unit</b>
1.	Superheated steam flow rate	t/h	691,5
2.	Superheated steam pressure	At bar	178,8 175,3
3.	Intermediate superheated steam temperature	°C	521,5
4.	Feedwater flow rate	t/h	671,5
5.	Feedwater pressure	At bar	226,2 221,8
6.	Feedwater temperature	°C	237,0
7.	Reheated (intermediate) steam flow rate	t/h	652,28
8.	Cold reheat steam pressure	At bar	32,6 32,0
9.	Cold reheat steam temperature	°C	314,7
10.	Hot reheat steam pressure	at bar	31,7 31,1
11.	Hot reheat steam temperature	°C	517,0
12.	Ratio $W_2/W_1 \times 100$	%	66,8
13.	Useful heat produced by the boiler	Gcal/h	476,0
14.	Ratio $(Q_u/Q_u^n) \times 100$	%	70,1

Table 2 presents the data regarding the boiler's fuel supply.

N0	PARAMETER / QUANTITY	U.M	Power of the 240 MW power unit
1.	Solid fuel flow rate	t/h	265,9
2.	Lower heating value	kcal/kg kJ/kg	2066 8650
3.	Initial moisture content	%	42,78
4.	Initial ash content	%	17,25
5.	Number of mills in operation	-	4
6.	Average mill discharge temperature	°C	160
7.	Average mill throughput	t/h	66,5
8.	Gaseous fuel flow rate	Nm <sup>3</sup> /h	1200
9.	Lower heating value of fuel gases under standard conditions (0°C and 760 mmHg)	kcal/ Nm <sup>3</sup> kJ/ Nm <sup>3</sup>	8594 35981
10.	Natural gas pressure downstream of the pressure regulating valve (VR)	bar	0,365
11.	Calorific contribution of gaseous fuel	%	1,84

Table 3 presents the values of the actual and corrected specific heat and conventional fuel consumption.

N0	PARAMETER / QUANTITY	U.M	Power of the 240 MW power unit
1.	Total live steam flow rate at boiler outlet	t/h	691,5
2.	Ratio of live steam flow rate to nominal live steam flow rate	%	66,8
3.	Total heat consumption	kW Gcal/h	658048 565,82
4.	Specific heat consumption	kWh/kg kcal/kg	0,9516 818,24
5.	Specific conventional fuel consumption	gcc/kg	116,9

### 3. CONCLUSIONS

- The boiler was operated at loads ranging between 691.5 t/h and 951.8 t/h, corresponding to 66.8% to 92.0% of the boiler's nominal load.
- The maximum boiler load was 951.8 t/h (92.0% of the nominal load, Dn).
- The regenerative high-pressure feedwater preheating system was in operation, with the feedwater temperature at the boiler inlet reaching 251.0°C at maximum boiler load.

- The boiler heat output ( $Q_u$ ) ranged from 476.0 to 645.7 Gcal/h, representing 70.1% to 95.2% of the nominal heat load (678.6 Gcal/h)
- The superheated steam parameters varied within the following ranges: temperatures between 521.5 and 534.0°C, and pressures between 177.9 and 182.8 atm.
- During the measurements, the boiler operation was stable in terms of the variation of the parameters in the water–steam and air–flue gas circuits.
- The unit operated under automatic control during the tests.
- The quality of the solid fuel used during the measurements, in terms of lower heating value (1917–2066 kcal/kg), was higher than that of the design coal range (1400–1800 kcal/kg).
- All tests were carried out with a minimal calorific contribution from natural gas (below 2%).
- The coal mills were available. The boiler operated with five mills at maximum and intermediate load (excluding mill 3), and with four mills at minimum load (excluding mills 1 and 4).
- At maximum boiler load, the average air temperature at the inlet of the APH (air preheater) was 39.6°C
- At maximum boiler load, the average hot air temperature (downstream of the APH) was 279.7°C, below the design value (318°C at nominal load).
- The air flow supplied in a controlled manner through the air fans accounted for approximately 64% of the total air flow entering the boiler, while the remainder up to 100% represented total air infiltration occurring in the boiler, mainly through leakages in the solid fuel supply and milling system.
- The flue gas fans ensured furnace operation under negative pressure, achieving efficiencies ranging from 48.8% to 52.0% for FD fan 2 (VG2), and from 45.9% to 50.1% for FD fan 1 (VG1), with the higher values being recorded at maximum boiler load, where the flue gas flow rates are also the highest.
- The unburned carbon content in slag varied between 39.05% and 46.19%, very high values that depend mainly on the combustion process and the fineness of coal grinding in the mills. A relatively high degree of wear of the milling elements was observed, along with a number of operating hours that can explain this situation.
- The use of a fuel with a higher calorific value than the design range reduced, through its lower ash content, the negative influence on efficiency.
- The boiler efficiency ranged from 84.13% at minimum load to 86.49% at maximum load.
- The specific conventional fuel consumption recorded during the measurement period ranged from 112.1 to 116.9 gce/kg of steam, with the minimum value being observed at maximum load.

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