STUDY ON INFLUENCE OF ENERGY EFFICIENCY OF A STEAM BOILER BENSON ON ENVIRONMENTAL POLLUTION

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Abstract: This paper presents a case study on the influence of the energy efficiency of a steam boiler of 330 MW energy group on the environment. The Benson boiler works with powdered lignite. We present the results of experimental measurements on immission and emissions of pollutants resulting from burning lignite: SO2, NOx, PM10, PM2.5, TSP. Experimental measurements were performed on the boilers of 330MW power units of the thermoelectric plant of Rovinari.

Keywords: lignite, emissions of pollutants, SO2, NOx, ash, PM10, PM2.5, TSP.

1. INTRODUCTION

The energy groups of 330MW thermoelectric plant in Rovinari work with powdered lignite. The lignite reaches directly from the central mining area of the coal basin of Gorj. The construction is of tower boiler (Figure 1) and has a height of 92 m. In the lower part of the boiler it is located the combustion chamber, while in the lower parts are located surfaces for heat exchange. The boiler has a nominal steam flow rate of 1035 tons / oră. The preparation of lignite dust is carried by 6 fan type mills DGS 100.

Fig. 1 - Benson Boiler
The coal combustion air is introduced by 2 air fans Axial type. To increase the air temperature are provided two rotary air heaters. The flue gases resulted are discharged with 2 axial gas fans. The resulting slag by burning coal is discharged at the bottom of the boiler with a conveyor type Kratzer. The ash contained in the flue gas is retained in two horizontal electric filters. The installation of the slag and ash discharge has the following technical features:

- ash discharged from the electrostatic filters 28,05 kg/s; 150°C;
- ash discharged from funnel chimney 0,55 kg/s; 150°C;
- ash discharged from funnel chimney at the disengages of electrostatic filters 11,11 kg/s; 150°C;
- ash discharged from the funnels under preheater rotary air 2,22 kg/s; 310°C;
- amount of slag discharged from the combustion chamber 4,44-8,33kg/s; 20°C.

The Bagger pumps stations ensure the evacuation of the central slag and ashes. Ash and slag deposits are located 2-5 km from the central area of 478.9 ha occupied by Balta Uncheaşului, Cicani - Beterega, Gîrla. The flue gases are discharged into the atmosphere through smokestacks of power boilers which have a high 120 m.

2. EXPERIMENTAL MEASUREMENTS

For total suspension particles (TSP) the limit values and the alert thresholds and action under environmental law are presented in Table 1

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Limit values</th>
<th>The period of mediation</th>
<th>Limit Protection (recaptors)</th>
<th>Year entry in force</th>
<th>Threshold alert</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSP</td>
<td>500</td>
<td>30 min</td>
<td>Population</td>
<td>Actual</td>
<td>350</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>24 h</td>
<td>Population</td>
<td>Actual</td>
<td>175</td>
</tr>
<tr>
<td></td>
<td>75</td>
<td>1 year</td>
<td>Population</td>
<td>Actual</td>
<td>52,5</td>
</tr>
</tbody>
</table>

Table 2 shows the parameters of physical dispersion of the chimneys and the corresponding emissions for steam boilers of power plant Rovinari.

<table>
<thead>
<tr>
<th>Chimney</th>
<th>Flue gas temperature [0C]</th>
<th>speed gas [m/s]</th>
<th>Real flue gas flow [Nm3/h]</th>
<th>Real flue gas flow [mc/h]</th>
<th>The level of oxygen in the flue gas [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chimney 1- boilers3and4</td>
<td>143,00</td>
<td>19,12</td>
<td>2432417,36</td>
<td>4161816,20</td>
<td>7,5</td>
</tr>
<tr>
<td>Chimney 2-boilers 5and6</td>
<td>143,00</td>
<td>19,24</td>
<td>2495742,29</td>
<td>4012258,40</td>
<td></td>
</tr>
<tr>
<td>Chimney 1-boiler4</td>
<td>143,00</td>
<td>9,85</td>
<td>1287356,12</td>
<td>2073549,38</td>
<td></td>
</tr>
<tr>
<td>Chimney 2-boiler 5</td>
<td>143,00</td>
<td>9,48</td>
<td>1295839,86</td>
<td>1944985,18</td>
<td></td>
</tr>
</tbody>
</table>
Sampling for gaseous pollutants was performed by pump shown in Figure 2.

Fig. 2 - Pump for gaseous pollutants sampling

By the chimneys of boiler from the energy groups are dispersed into the environment large amounts of pollutants: SO$_2$, NO$_x$, CO$_2$, dust ash. These pollutant substances have harmful effects on human health and on the environment. For inclusion of emissions into the emissions limits set by environmental legislation, the energy units of the thermoelectric plant Rovinari were equipped with flue gas remediation technologies.

Table 3 presents the results of experimental measurements for pollutants discharged into the atmosphere by dispersion chimney No.1.

Table no. 3 pollutants emissions related to release chimney no. 1

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Mass flow [t/an]</th>
<th>Dried gas flow [Nm$^3$/h]</th>
<th>The level of oxygen in the flue gas [%]</th>
<th>Concentration in emission [mg/Nm$^3$]</th>
<th>Limit on emission [mg/Nm$^3$]</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO$_2$</td>
<td>73426,00</td>
<td>2.213.528,20</td>
<td>6,2</td>
<td>189,02</td>
<td>200</td>
<td>&lt;VL</td>
</tr>
<tr>
<td>NO$_x$</td>
<td>8486,00</td>
<td></td>
<td></td>
<td>421,36</td>
<td>500</td>
<td>&lt;VL</td>
</tr>
<tr>
<td>TSP</td>
<td>1007,00</td>
<td></td>
<td></td>
<td>52,26</td>
<td>50</td>
<td>&gt;VL</td>
</tr>
<tr>
<td>PM$_{10}$</td>
<td>348,50</td>
<td></td>
<td></td>
<td>21,22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PM$_{2.5}$</td>
<td>109,00</td>
<td></td>
<td></td>
<td>5,65</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4 presents the results of experimental measurements for pollutants discharged into the atmosphere by dispersion chimney no.2

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Mass flow [t/an]</th>
<th>Dried gas flow [Nm³/h]</th>
<th>The level of oxygen in the flue gas [%]</th>
<th>Concentration in emission [mg/Nm³]</th>
<th>Limit on emission by HG 440/2010 [mg/Nm³]</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂</td>
<td>70854,00</td>
<td>2,247,138,00</td>
<td>6,2</td>
<td>190,40</td>
<td>200</td>
<td>&lt;VL</td>
</tr>
<tr>
<td>NOx</td>
<td>8512,00</td>
<td></td>
<td></td>
<td>441,28</td>
<td>500</td>
<td>&lt;VL</td>
</tr>
<tr>
<td>TSP</td>
<td>1113,00</td>
<td></td>
<td></td>
<td>54,12</td>
<td>50</td>
<td>&gt;VL</td>
</tr>
<tr>
<td>PM₁₀</td>
<td>402,00</td>
<td></td>
<td></td>
<td>28,37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PM₂,₅</td>
<td>128,50</td>
<td></td>
<td></td>
<td>6,18</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. CONCLUSIONS

Issues on environmental protection on the cases of thermoelectric plant Rovinari’s boilers are related on the pollutant emissions of these facilities. Pollutant emissions depend on the technical condition and of the conditions they are exploited.

**Economic operation of boiler**

Economic operation of the boiler means, for the same production of energy, less and cheaper fuel burned in the furnace and lower energy consumption of the auxiliary boiler equipment.

The two are, in turn, subject to the following:

- High Gross yield of boilers;
- Technological consumption of small boiler;
- Low consumption of hydrocarbons;
- Small number of starts; short duration of impulses.

**Operation with high gross yield of the boiler**

The Gross yield of the boiler depends on the size of heat loss. The main losses of the heat boiler are:

- Loss with heat from flue gases discharged on chimney (q2);
- Losses with radiation outward (Q5);
- Loss with heat discharged from the boiler as slag and ashes (Q6);
- Loss with non-burned chemical and mechanical substances (q₃ and q₄).

The yield (ƞₖ) calculated of boiler and the corresponding losses from loads of 100%, 70% and 40%, the operation only on coal with calorific value of 1,600 kcal / kg, are:
Load 100%
\[ \eta_k = 88,23 \% \]
\[ q_2 = 8,14 \% \]
\[ q_{3,4} = 1,03 \% \]
\[ q_5 = 0,208 \% \]
\[ q_6 = 0,658 \% \]

Load 70%
\[ \eta_k = 90,12 \% \]
\[ q_2 = 7,73 \% \]
\[ q_{3,4} = 1,02 \% \]
\[ q_5 = 0,347 \% \]
\[ q_6 = 0,302 \% \]

Load 40%
\[ \eta_k = 90,05 \% \]
\[ q_2 = 7,48 \% \]
\[ q_{3,4} = 1,02 \% \]
\[ q_5 = 0,574 \% \]
\[ q_6 = 0,302 \% \]

Heat losses decrease with the load, which is why gross yield, computed, of the boiler load is higher at 40% as respect the one at 100% load. This is, however, not a reason to operate at 40% load. To function economically with the boiler means to is to operate as close to the yield calculated on the irrespective load.

The losses of heat from flue exhaust chimney increase with gas temperature at the chimney, with flue gas flow.  

*Small number of starts, small duration of the starting.*

Starting from cold condition is three times longer than the longest starting from hot state. This is a good reason to create the possibility of starting the boiler from hot state.  

*SO\textsubscript{2} and NO\textsubscript{x} from flue gases.*

SO\textsubscript{2} in the flue gas depends on the percentage of sulfur in the fuel. The decreasing of the SO\textsubscript{2} content in the flue gas, to discharge into the atmosphere, is achieved by means of desulphurization plants that treats flue gas after releasing the boiler (after electrostatic filters).  

NO\textsubscript{x} formed in the combustion chamber, where high temperatures favor the oxidation of nitrogen from fuels and from the combustion air. It increases with increasing of excess air in the furnace and decreases with decreasing of it. The exaggerated decrease of excess air on the one hand can lead to incomplete combustion (occurrence of CO in the flue gas), and secondly, to increase flue gas temperatures in the furnace and the appearance of slagging.

CO from flue gases is limited, for safety and economic reasons, to a maximum of 200 mg / Nm\textsuperscript{3}.

Modernization to increase efficiency by improving combustion.
- Effective arrangement of vortex combustion in a zone located furthest at the end of the furnace
- Eliminating leaks which will eliminate future false air penetration into the furnace that produces a serious imbalance in the proper functioning and control of the combustion process.
- The provision of slits in the walls of the furnace, over the recirculation mouths of furnaces gases, for future tertiary air redistribution.
BIBLIOGRAPHY


