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The Improvement A Sealing of the Regenerative Air Preheaters of the Coal Boiler and Its Effect on Boiler Efficiency

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ABSTRACT: A regenerative air heater is an auxiliary equipment for steam boilers where some of the heat released by the combustion of the fuel is returned to the boiler furnace instead of lost in the environment. The flue gas heat is used to heat the combustion air in the boiler and at the same time reduce the flue gas temperature. This reduces the heat loss of the flue gas and increases the efficiency of the boiler. For better heat exchange in the heater it is very important to have it sealed, which is controlled by the oxygen content in the flue gas after the heater. The paper presents changes inoxygen content in the flue gas, thepercentage of air leakage in the regenerative air heater and the flue gas temperature, after improving the sealing and replacement the baskets in the regenerative air heater. Improved air heater sealing reduces air leakage from 17.46 to 1.3% and reduces O_2 content in flue gases after air heater from 6.3 to 3.5%, which directly affects the boiler efficiency. The measured values are shown in the diagrams and the efficiency of the boiler is calculated on the basis of them. The analysis and conclusions are presented at the end of the text.

KEYWORDS: Air heater, Sealing, Boiler efficiency.

I. INTRODUCTION

The air heater is a heat surface where part of the heat from the flue gas is used in the steam boilers to heat the combustionair. With the air heater 7 to15% of the heat released during combustion of the fuel, it returns to the steam boiler furnace, instead of being lost in the environment. In this way heat losses due to the flue gas are reduced and boiler efficiency is increased.

When usingfossil fuels (coal, oil, gas) with similar conditions in the furnace, whilereducing the flue gas temperature for 56^0C, theboilerefficiency increases for almost 2,5 percent points. This corresponds to an increase in boiler efficiency of nearly 2 percentage points for each increasein the hot air temperature by 56^0C[1]. In addition, using heated air during combustion accelerates the ignition of low quality and wet fuels, improves the conditions and efficiency of the combustion process and increases the mean temperature difference in the flue gas ducts for a full range of the boiler load.

Depending on the methods of heat transfer from flue gasto air, the air preheatersmay be recuperative and regenerative. The subject of analysisin this paper are regenerative airpreheaters, i.e. the Ljungstrom. The model of analysis are regenerative air preheaters type RVP 9.8, installed in the Power Plant Bitola, unit 3. The air preheater is designed with two sections, one used of the flue gas and second for air. Specially corrugated heating elements, baskets are tightly placed in thesector compartment of the rotor. The rotor diameter is 9,8m, turns at a speed of 1,53 rpm.and is divided into gas channels and air channels. When gas flows through the rotor, it releases heat and delivers it to the heating elements and then the gas temperature drops. When the heated elements turn to the air side, the air passing through them is heated and its temperature is increased. By continuing to maintain such a circulation, the heat exchange is achieved between gas and air. As the rotor slowly revolves the mass of the elements alternatively through the air and gas passage, heat is absorbed by element surfaces passing through the hot gas stream. These are the same surfaces are carried through the air stream. In the boilerare installed two air preheaters tagged RVP A and RVP B, on two symmetrical lines of ducts for hot air and flue gas.Between the gas and air sections,is the sealingpart, where the air leakage from the air to the gas sideis stopped. The sealing part or so-called sealing of the regenerative

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air preheater has a significant influence on the gas parameters after the air heater and of the air leakage, and these will be analyzed below.

II. SEALING OF THE AIR PREHEATERS

The sealing of air preheaters is to preventair leakage from the air side into the gas side. The quality of the sealing is estimated based on the amount of air leakage. The air leakage calculation takes into account the oxygen containsin the gas measured before and after the air preheater, using the following formula:

$$AL=0,9 \ x[(O_{2gl}-O_{2ge})/(21-O_{2gl})]x\ 100\ [\%] \quad (1)$$

where are:

AL[%] - air leakage,

O_{2ge}[%]–O_2 percent in the gas before (entrance) the air preheater,

O_{2gl}[%] - O_2percent in the gas after (leave) the air preheater.

The sealing of the air preheater is very important for the proper and efficient work of the Power Plant because hasinfluences on:

Temperature of the primary and secondary air.Poor sealing reduces the temperature of the primary and secondary air, and this affects of the mills' capacity, especially when are used wet coalsfor combustion.

Capacity of the ID fans(Induced fans).Poor sealing causes air leakage from the air side into the gas side in the air preheater, increases the amount of flue gas and increases the load of the ID fans. Insufficient capacity of the ID fans causes load limitation of Power Plant [2].

Flame stability in the furnace.Insufficient fan capacity cause poor flame stability, insufficient underpressure in the furnace, flame pulsation and inability boiler to operate at full load i.e. reduced production.

Increasing NOx production and losses due to combustion etc.

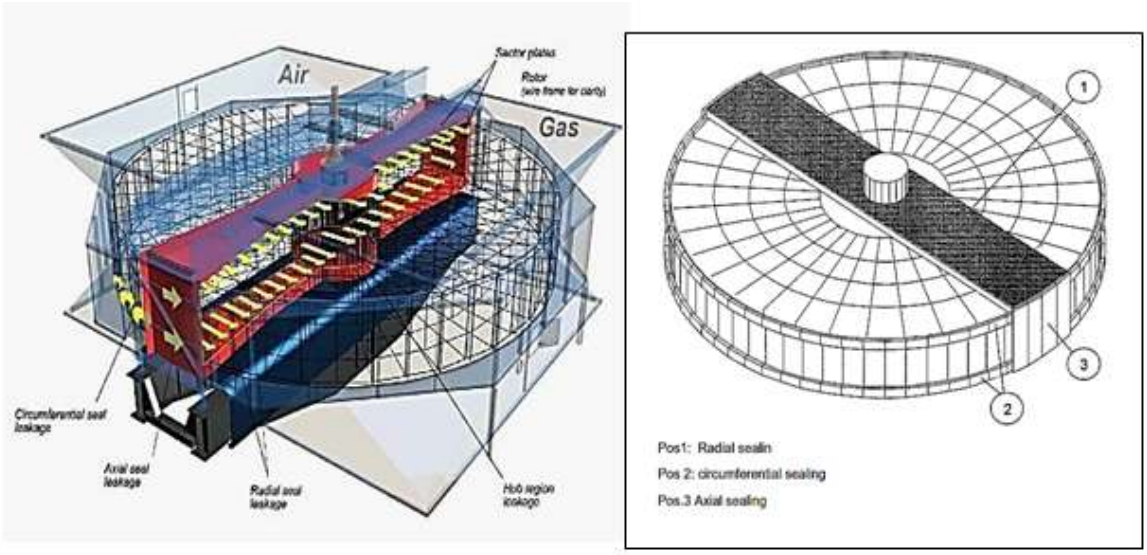

Figure 1. Sealing of the air preheater[3,4]

In order to improve sealing of theair preheater was implemented the following measures [4] (fig.1):

1. Improving the radial sealing with installing a new upper and bottom sector plates. They provide sealing from the upper and bottom side in the air preheater, while the baskets pass through the air toward the gas side and vice versa. The position of the sector plates is defined depending on the gas temperature and they work automatically. The effect of radial sealing is achieved together with the radial walls of the rotor. To improve the sealing efficiency, were installed protection sheets with 100mm (fig.2) on the radial walls, from the hot and cold side,of the air heater. They reduce the radial gap between the rotor and stator and improve the sealing of the air preheater.
2. Improving the axial sealing, by replacing the existingwith a new one, which is consists of two side plates placed on diametrically opposite sides, in the area of a pass from air side to the gas side and opposite. The target of this sealing is to reduce the axial gap between the rotor and air preheaterhousing. In the new mechanisms, the adjustment is performing individually with spring connected with the side plates.

3. Installing the circumferential sealing for prevention of the air and gas flowaround the air preheater rotor. This is achieved by installing thin sealing plates inside the air preheater housing (fig.3). The sealing plates are perforated on one side and placed on two levels, on the hot and cold side, opposite each other. Adjustment on this sealing is done only in cold, i.e. when Power Plant is shut down. In hot condition the adjusted gap is reduced, due to the dilatation of the rotor and housing.

Figure 2. Protection sheets for improvement of the radial sealing

Figure 3. Thin sealing plates for improvement of circumferential sealing

The performance of the air preheater before and after repairing of the sealing, wasdetermined by comparing the results from O_2 measurement, air leakage-AL, the Air Side Efficiency-ASE and the Gas Side Efficiency-GSE. GSE and ASE are indicators of the internal condition of the air preheater. As conditions inside the air preheater worsen (baskets wear, ash plugging, etc.), the gas side efficiency degreases. This is generally accompanied by an increase in exit gas temperature and a decrease in air preheater air outlet temperature, resulting in an increase in unit heat rate [5].

The calculation of the ASE and GSE is according following formulas

$$ASE = [(T_{al}-T_{ae})/(T_{ge}-T_{ae})]x100\ [\%] \quad (2)$$

$$GSE = [(T_{ge}-T_{gnl})/(T_{ge}-T_{ae})]\ x\ 100\ [\%] \quad (3)$$

$$T_{gnl}= [ALxC_{pa}\ x\ (T_{gl}-T_{ae})/(100xC_{pg})] + T_{gl}[^0C] \quad (4)$$

where are:

T_{ae}-Temperature of air entering air preheater,
T_{al} - Temperature of air leaving air preheater,
T_{ge} – Temperature of gas entering air preheater,
T_{ngl} – Gas outlet temperature corrected for no leakage,

III. THE PLATES PROFILE IN THE AIR PREHEATER BASKETS

The heating surfaces of the air preheater are baskets filled with profiled plates, arranged in four levels. The baskets from the first three levels are called hot and last cold baskets. The replacement of the baskets and increasing the heating surface in the regenerative air preheater by 30 %, is one of the measures to reduce the flue gas temperature.

The platesprofiles in the new baskets are different from the old one. Namely, the old profile "N" from the first two levels has been replaced with profile "DU". In the middle and cold levels (fig.4) they are replaced with "NF" profile. Due to the low-temperature corrosion, the profile plates in the baskets from the middle and cold level are made with material Corten, resistant of the low-temperature corrosion.

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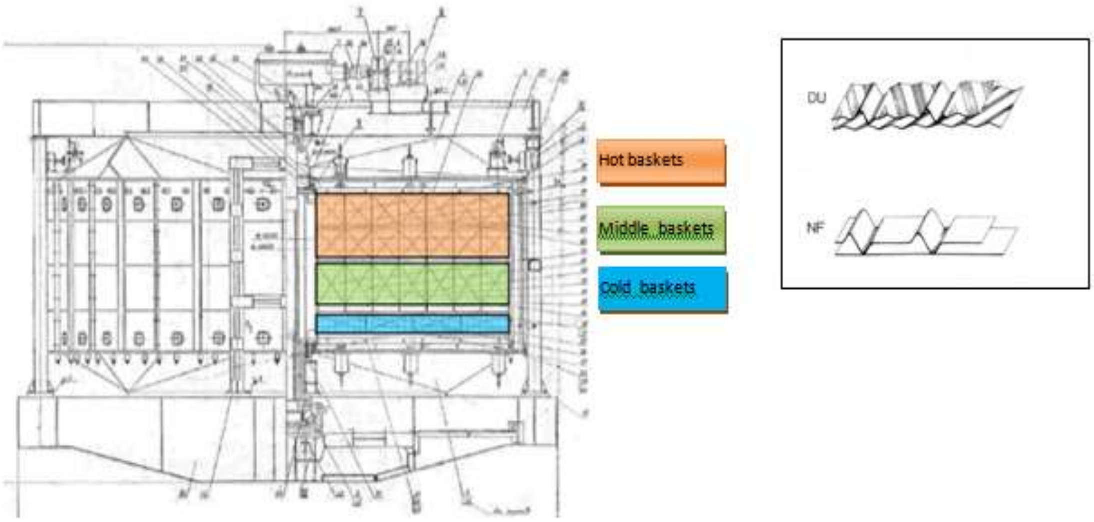

Figure 4. Disposition and profile of the baskets with profiled plates in regenerative air preheater RV-9,8[3]

IV. RESULTS OF MEASUREMENT AND COMMENTS

In order to evaluate themeasures taken on regenerative air preheaters, measurementswere made before and after measures taken, under similar operating conditions of the boiler, i.e. the same boiler load, coal quality, and other conditions.

There were performed grid measurements of the O_2content in the flue gas, before and after regenerative preheaters, RVP A and RVP B and before and after taken measures. The measurements were made at the same places of the flue gas ducts (fig.5).

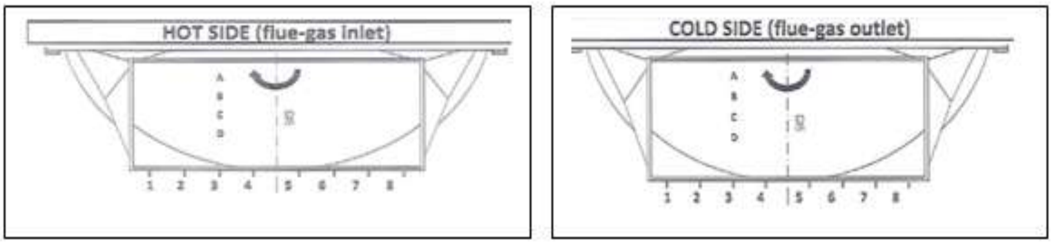

Figure 5.Disposition of the measurements points for control measurements before and after measures taken at the RVP A and RVP B [6,7]

Grid measurements of O_2beforereplacement of the sealing in air preheater [6] are shown on fig.6,7,8 and 9.

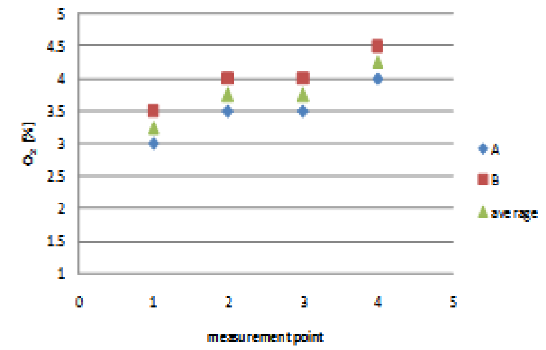

Figure6. *O_2 content at RVP A inlet*

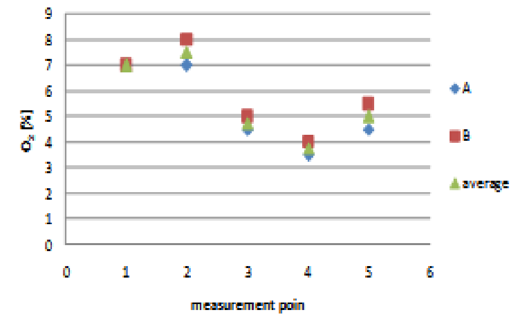

Figure 7. *O_2 content at RVP A outlet*

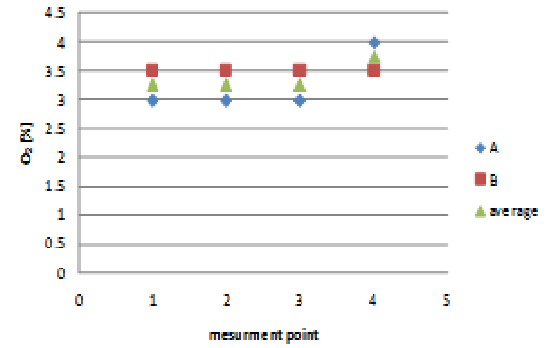

Figure 8. *O_2 content at RVP B inlet*

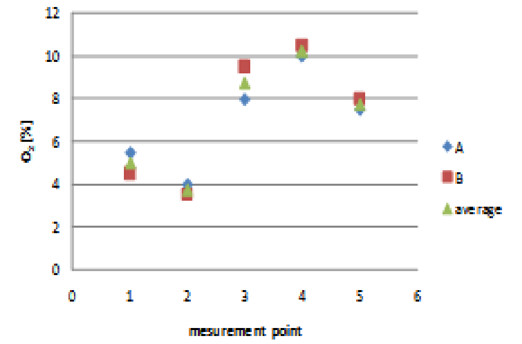

Figure 9. *O_2 content at RVP B outlet*

The average increase of the O_2 in the air preheaters before replacement the sealing is shown at fig.10 and 11.

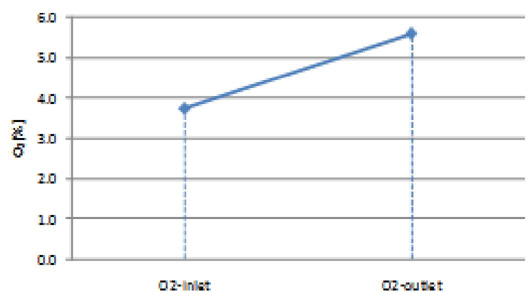

Figure 10. *O_2 increase at RVP A*

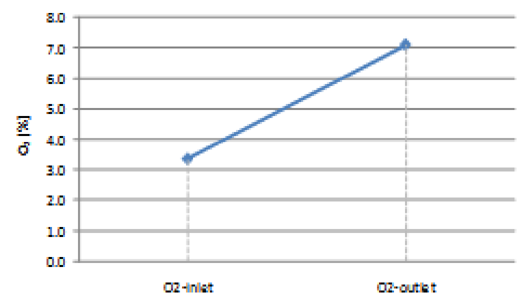

Figure 11. *O_2 increase at RVP B*

The measurements results after replacementthe sealing inthe air preheaters[7] are shown on fig.12,13,14, 15.

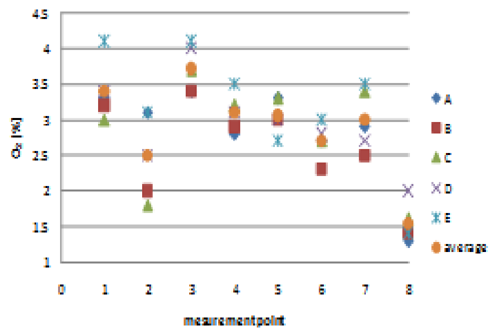

Figure 12. O_2 *content at RVP A inlet*

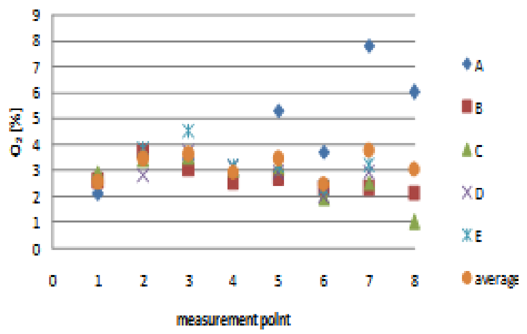

Figure 13. O_2 *content at RVP A outlet*

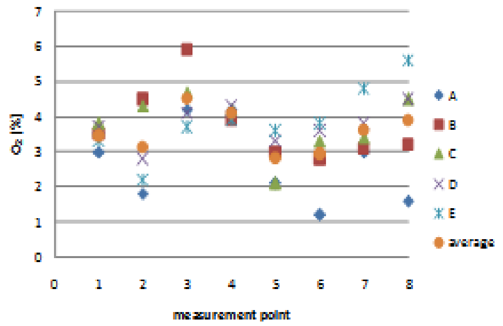

Figure 14. O_2 *content at RVP B inlet*

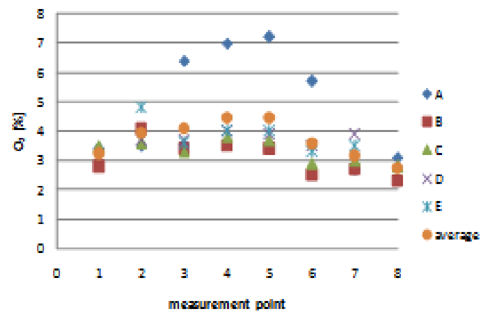

Figure 15. O_2 *content at RVP B outlet*

The average increase of the O_2 in the air preheatersafter replacement of the sealing is shown at fig.16and 17.

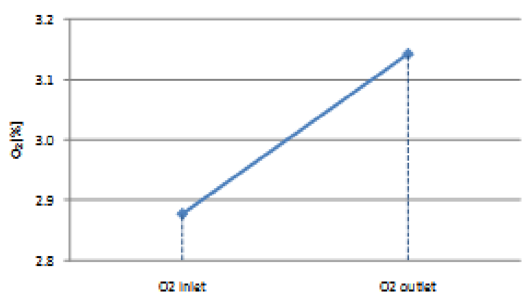

Figure 16. O_2 *increase at RVP A*

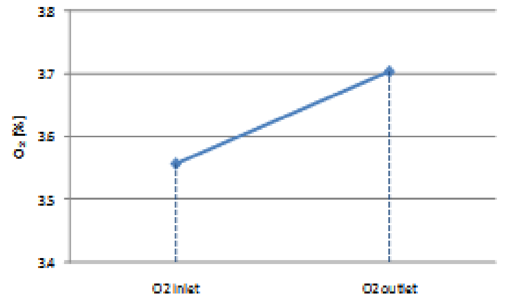

Figure 17. O_2 *increase at RVP B*

The results in the abovediagrams show that prior taking measures to replacesealing at the air preheaters, the increase of O_2 in RVP A was 1,9%, in RVP B 3,7%, and the average increase was 2,8%. This increasein O_2 after the air preheater is due to the poor sealing of the air preheater and leaking large amount ofhot air into the gas side. The calculation of the air leakage according to (5) shows that RVP A leakage is 12%, and RVP B, 26,8 %.

After replacing and improving the sealing, results were significantly better. Namely increase of O_2 in both air preheaters was 0,3%, and the air leakage at RVP A was 1,3%, and in RVP B 1,6%, or 1,4%on average. Also we can summarize, the increase in O_2 before the measures taken on air preheaters was 2,8%, and after 0,3% (fig.18), and changes of the air leakage were 17,4% before and 1,3% after improvement of sealing (fig.19).

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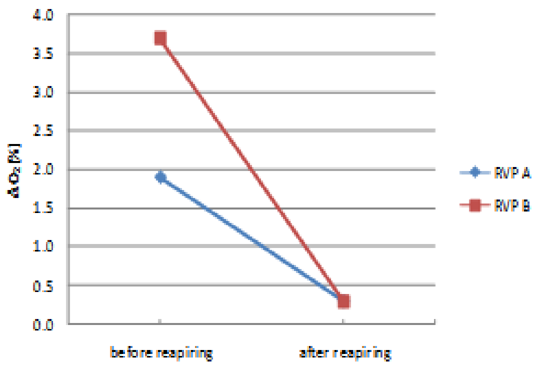

Figure 18. *O_2increasing before and after sealing improvement*

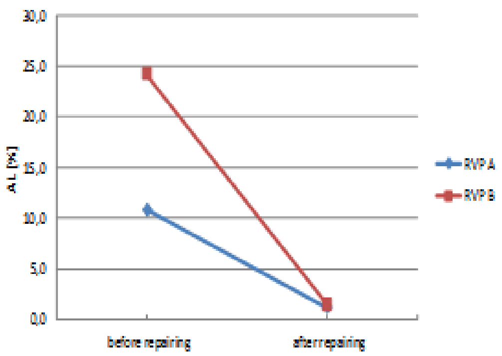

Figure 19. *Airleakage before and after sealing improvement*

After repairing the air preheater sealing and the baskets replacing with different profiles, i.e. the first two levels with DU and one middle and cold level NF, Gas Side Efficiency increased from 30,5 to 42,5 and Air Side Efficiency from 96,5 to 99,1 (fig.20).

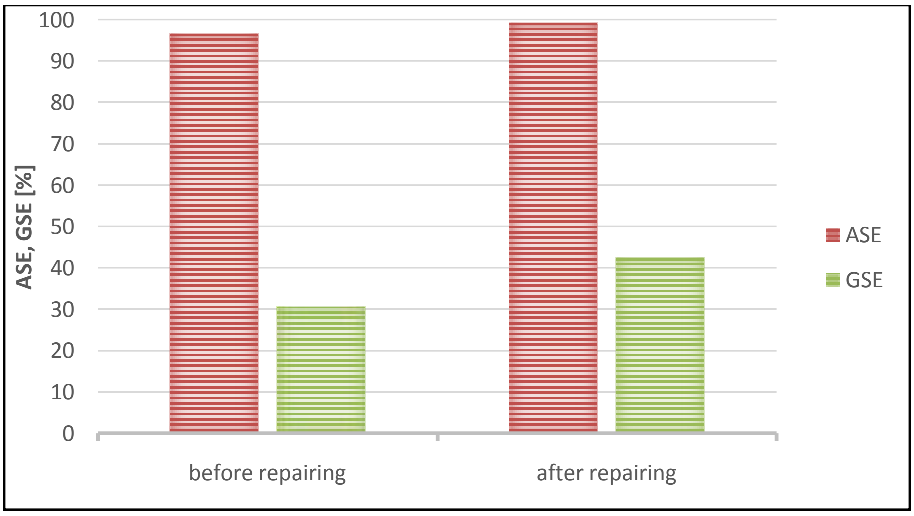

Figure 20.GSA and ASE on the air preheater before and after repairing

From figure 20, can be inferred that, by replacing the profiles of air preheater, the heat transfer rate can also be increased, thus making the air preheater for effective.

With improved air preheater sealing, reduced air leakage and replaced baskets with different profiles enabled a reduction in flue gas temperature after the air preheater and increased boiler efficiency.Namely flue gas temperature has been reduced from 207^{0}C to 191^{0}C (fig.21) and boiler efficiency increased from 85,9% to 87,4% (fig.22) according to the calculation [9,10,11].

V. CONCLUSIONS

From the measurementresults presented above andthe calculations results, which include data before and afterimproving the radial and axial sealing, installing the circumferential sealing and replacement basketswith a different profile, it can be concluded that:

- the. air leakage was reduced from 17,4 to 1,3% and efficiency of the air preheaterwas increased, especially Gas Side Efficiency from 30,5 to 42,5. Reducing theamount of flue gas allows reducing power consumption and costs,and increases boiler efficiency. By reducing air leakage from 30% to 10% the flue gas volume would be significantly reduced by 18% [2] and this would directly affects the ID fans unloading.
- O_2 content in the flue gas, measured after the air preheatersdecreases from 6,3% to 3,5%. Recalculation performed with both values for

O_2 showed an increase in boiler efficiency from 85.9% to 87.4% [9,10,11], see figure 22.

- Replacement of the baskets in the air preheater,with new with different profiles, increased the heat transfer rate and reducingthe flue gas temperature from207^{0}C to 191^{0}C. Changes the flue gas temperature in detail were analyzed in [10], namely reducing the flue gas temperature by 10^{0}C, allow increasing the boiler efficiency by 0,8 % and reducing coal consumption by 0,83 %.

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