STARTUP THE FIRST 330 MWe CFB UNIT IN RUSSIA AT NOVOCHERKASSKAYA TPP

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Abstract - The first CFB boiler was constructed at unit # 9 of Novocherkasskaya TPP of Rostov region. The boiler was delivered and partially manufactured by JSC "EMAlliance". Engineering and manufacturing of the boiler critical parts and its equipment were made by AMEC Foster Wheeler Company. It is a typical Foster Wheeler "compact" design one through boiler with INTREX superheaters. The 330 MWe turbine was delivered by "Turboatom", Kharkov, Ukraine. The main fuel is Anrtacite Culm (AC) with variable ash content and low volatiles (4%). Short description of project details, boiler data, heat and water-steam scheme are presented in the paper. The main results of startup operation also were done.

THE FIRST RESULTS OF STARTUP OPERATION

The main fuel is Anrtacite Culm (AC) with variable ash content and low volatiles, alternative fuel is Kuznetskiy hard coal. Main fuel characteristics (typical and designed data) are presented in table 1.

Table 1 – Elemental composition of origin fuel

Parameter	Typical values for AC	Designed data	
		AC	Kuznetskiy coal
Moisture, %	12.70	9.0	7.0
Ash, %	25.65	26.0	18.6
Sulfur, %	1.61	1.31	1.3
Carbon, %	57.01	61.1	66.6
Hydrogen, %	1.47	1.18	2.8
Nitrogen, %	0.85	0.52	0.8
Oxygen, %	0.71	0.97	2.9
Lower heating value, kcal/kg (MJ/kg)	4908 (20.46)	5000 (20.89)	6000 (25.07)

Based on several AC probes analysis performed in 2016, actual range of the AC heating value was revealed at level 4500 – 5100 kcal/kg within ash variety of 24 – 35 % and moisture of 6 – 12 %. In table 2 main characteristics of the boiler are presented. Key components of the boiler are furnace, solid separators, INTREX chambers, cross-over ducts and convective cage. These elements are consist of the gas-tight membrane walls. In the upper part of the furnace wingwalls are located, ECO and reheater I/II surfaces can be found within the convective cage area. Integrated bed ash heat exchangers (INTREX) are acting as the final stage of the superheater. Sketch of the boiler design is given in figure 1

Table 2 – Characteristics of the boiler

Parameter	Dimension	Value	
		AC	Kuznetskiy coal
Main steam flow	kg/s	277.8	277.8
Main steam pressure	MPa	24.5	24.5
Main steam temperature	^0C	565	565
Reheat steam flow	kg/s	227.3	227.1
Reheater inlet steam pressure	MPa	3.873	3.873
Reheater inlet steam temperature	^0C	300	300
Reheater outlet steam pressure	MPa	3.67	3.67
Reheater outlet steam temperature	^0C	565	565
Feed water temperature	^0C	280	280
Spray water flow	kg/s	13.9	13.9
Calculated fuel consumption	kg/s	38.6	31.8
Limestone consumption	kg/s	3.4	2.6
Ash flow	kg/s	13,4	8,3
Recirculated ash flow	kg/s	6.7	4.2
Air flow for combustion	nm^3/s	279.7	271.6
Flue gas flow	nm^3/s	288.4	261.7
Preheated air temperature	^0C	310	314

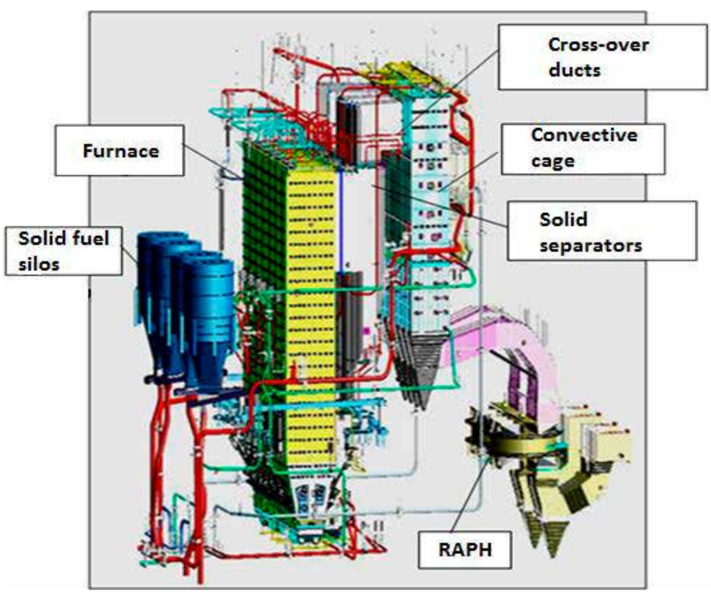


Fig.1 – Sketch of the Novocherkassk TPP unit#9 CFB boiler (FW data)

In the late 2015 erection of the main equipment was completed and primary commissioning events took place. At the period from April 29th till may 01st of 2016 comprehensive testing was performed. During first startup experience high deviation of the furnace bed temperature (up to 150 °C) was revealed: maximal values were registered in the middle area of furnace cross section and the points of minimal temperature values located near the side walls (figure 2).

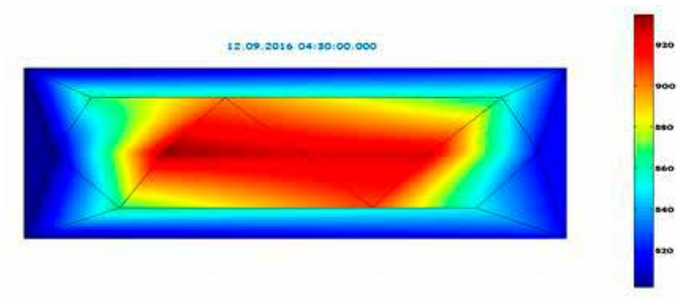


Fig.2 – Furnace bed temperature gradient

Flue gas duct temperature value analysis revealed good correspondence between calculated and actual values. Typical furnace temperature profile is given in figure 3. A significant difference is observed for temperatures in the separators. The actual value of the temperature in the separators is much higher than the one at the outlet of the furnace, indicating the burning of fine particles in the separators.

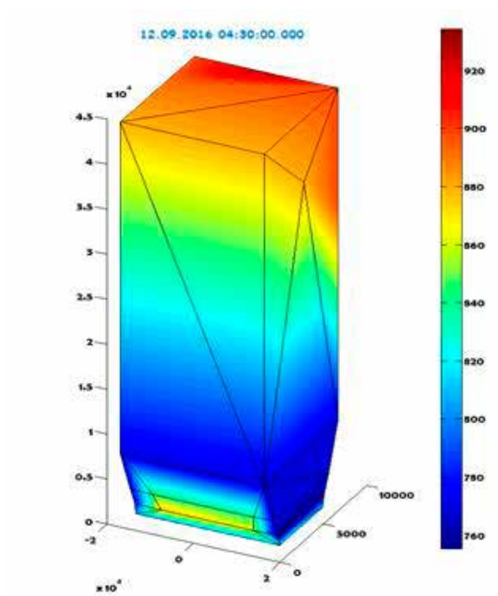
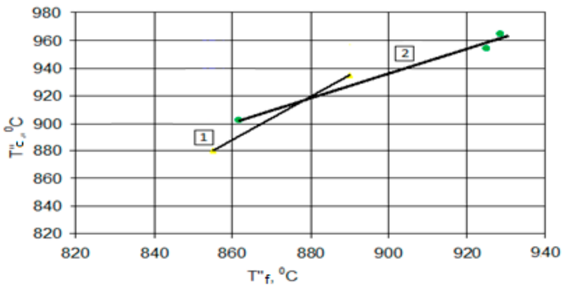


Fig. 3 – Typical furnace temperature profile

Also this phenomenon was registered at Chinese CFB boilers with anthracite combustion [1]. Figure 4 shows the dependence of temperature values in cyclones against the temperature at the furnace outlet.



1 – AC firing boilers in China,
2 – data for 70 and 90 % BMCR cases, Novocherkassk TPP

Fig. 4. Temperatures in the cyclones and at furnace outlet during combustion of low grade fuels

According to G. Yue (2006) when a share of particles smaller than 0.4 mm reached about 63 % the temperature rise exceeded 50 °C, and at the same share as low as 15 % corresponding value dropped down to below 30 °C. Increasing of air flow from 40 to 44 m^3/h (according to G. Yue (2006) ceteris paribus leads to a slight increase in temperature rise (from 28 °C to 36 °C). It is pointed out in the paper that one of the main influencing factors was particles size distribution. It`s also stated that on the existing boilers it`s extremely difficult to completely avoid coal burn-out in the cyclones. M. Fang (2006) implemented boiler mode, which allowed increasing boiler efficiency by almost 2% due to reduction of heat losses caused by unburned carbon.

A possible reason for the temperature growth in the cyclones could be a substantial share of fines in the fuel. Figure 5 provides requirements for coal PSD stipulated by "Amec Foster-Wheeler» (FW) company. Both actual coal samples PSD curves are close to each other. The average particle size is about 1 mm, which is close to FW design data. But a share of fines is significantly higher: a share of particles less than 0.2 mm is approximately 15%, whereas it should not exceed 5 % according to FW requirements. Also high (up to 10%) is a share of coarse particles (larger than 6 mm), which should not be present at all.

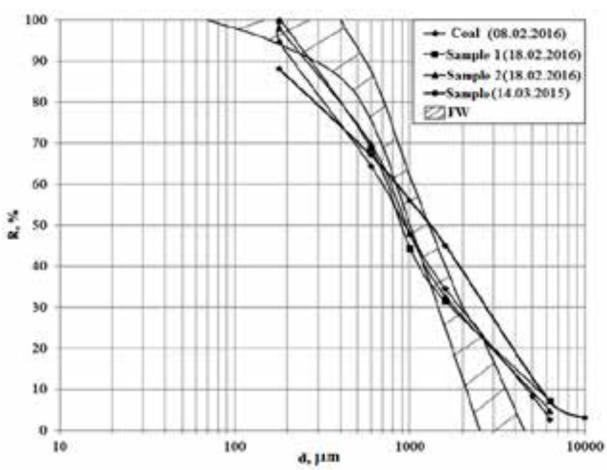


Fig. 5. Anthracite PSD curves

Analysis of bottom ash samples as well as circulating bed material and bed agglomerates was also carried out. Inspections made after boiler shutdowns revealed some flat coarse particles on the bed surface. They could originate from a split rock that was present in the coal fed. Adjusting the coal crushers managed to significantly reduce the formation of flat ash particles.

The average size of bottom ash particles is 1 - 2 mm, which corresponds well to the typical values for CFB boilers. The presence of coarse particles in the coal as well as an excessively coarse sand resulted in a high average bed particle size (about 1 mm). Moreover, while a share of particles larger than 6 mm in the fuel is 3 – 6 %, in the bottom ash it already reaches 15 %. Circulating ash particles (Table 3) have an average size of about 0.15 mm. The PSD curve slope is rather steep which indirectly indicates that the cyclones efficiency is quite high. The unburned carbon was only found in the bottom ash samples. In the upper seal (so called, wall seal), sample mass loss in the burn-out test was as low as 0.01% in total. According to FW data carbon content in the bottom and fly ash is 3% and 4.84 %, correspondingly. Thus, with some reservations it can be concluded that coal burn-out in the bed is almost complete, circulating ash also contains no carbon except for coarse particles.

Total heat duty of the INTREX superheaters was slightly higher than design data. This was the result of elevated solids temperature and consequently temperature difference along the tube bundles. Solids circulation rate estimated on the basis of INTREX heat balance was shown to be 1400 – 1500 kg/s or 5,0 kg/m^2·s based on the furnace cross section.

Analysis of experimental data on the heat balance for heating surfaces of the boiler steam circuit was performed by VTI own method at 90 % BMCR mode. Comparison of FW design data with actual boiler parameters was also fulfilled. Figure 6 depicts a comparison of heat balance items.

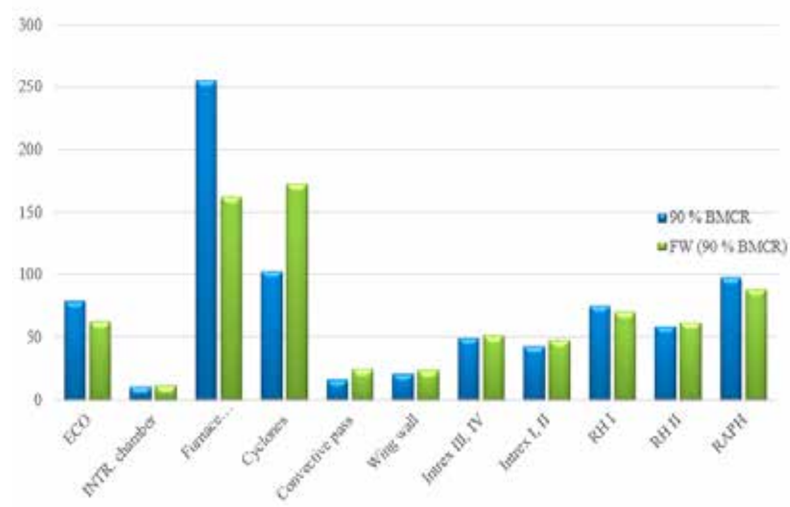


Fig. 6. Elementwise heat duty comparison at 90% BMCR

The calculation of the boiler (furnace and gas passes) material and heat balance was performed for 90 % BMCR case using VTI own software. The results showed good correspondence with measured data (Table3).

Table 3: Comparison of predicted and measured data

№	Parameter	Dimension	Measured data	Predicted data
1.	Cyclone outlet gas temperature	°C	961	968
2.	Reheater 1 outlet gas temperature	°C	485	568
3.	ECO outlet gas temperature	°C	360	380
4.	Flue gas temperature	°C	138	138
5.	ECO outlet water temperature	°C	318	318
6.	Furnace walls inlet water temperature	°C	325	325
7.	Furnace walls outlet steam temperature	°C	391	391
8.	Crossover ducts outlet steam temperature	°C	432	432
9.	Wingwalls inlet steam temperature	°C	445	446
10.	Wingwalls outlet steam temperature	°C	463	463
11.	INTREX III, IV inlet steam temperature	°C	463	463
12.	INTREX III, IV outlet steam temperature	°C	517/514	517/514
13.	INTREX I, II inlet steam temperature	°C	510/501	508/503

The values of key heat balance items only differ slightly from the design data and correspond well to boiler parameters at a load close to nominal.

The first boiler startup routines were associated with some impediments. Namely, at early stages while heating up the bed it was troublesome to reach bed temperatures required for stable anthracite ignition. This was primarily due to low set points for the gas pressure fed to start-up burners and, as a result insufficient heat introduced into the furnace while heating an inert bed material. Furthermore, excessive primary air flow after the boiler ventilation alongside with the limited primary air temperatures (by the wind boxes and furnace grid reliability requirements) cooled down the bed and incidentally shifted the start-up burners flame higher up prohibiting further increase of the bed temperature. It was also established that initially prescribed temperatures for start of coal feeding were understated and reliable coal ignition in the system was reached at temperature level exceeding 650 °C.

Multiple refractory defects were registered at the lower furnace (around the inlet points and burners openings), cyclones with the inlet ducts and in the INTREX chambers. In addition, there was a significant number of tubes fistulas on the furnace screen walls, INTREX tube bundles and screen wall tube break off form the manifold.

After emergency shutdowns resulting in continuous loss of fluidization during subsequent boiler start-up partial bed agglomeration was observed.

A significant part of these deficiencies was overcome which allowed to ensure the stable boiler operation and successful completion of unit comprehensive testing for 72 hours.

At the end of 2016 a full-scale refractory recovery was done, while complete coal crushers replacement is planned to start at the beginning of 2017. A schedule for adjustment of boiler operation regimes is developed and should be implemented in 2017. The withdrawn experience of unit erecting and commissioning will create conditions for widespread introduction of CFB technology in Russia.

NOTATION

PSD particle size distribution

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