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Part 3

ASH AND SLAG HANDLING

3.2. Ash and slag handling systems at TPPs

3.2.3. Bottom ash/slag removal

3.2.3.2. Influence of slag removal technology on harmful emissions from power boilers

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THE SUMMARY

In the report the data confirming the worldwide tendency to increase of a share of coal for generating of the electric power are resulted. Similar process is observed in Russia, despite of rather low prices for natural gas.

Then coal is burning 2 variants of slag removal are possible: more often coal chambers with dry bottom are used, but for some coals it is expedient to close a part of screens by fire-resistant cover and use a wet bottom. The first variant is more preferable not only from the point of view of slag receiving, but also in ecological aspect: emissions of nitrogen oxides appear less then dry bottom furnaces are used.

Reconstruction results of two boilers, which were burning lignites, with their retrofit from liquid to dry slag removal, are resulted.

1. FUEL-POWER BALANCE

One of the major factors of power development in the nearest years will be, undoubtedly, increase of coal consumption in electric power producing. This process will concern, certainly, Russia because in our country it is impossible to recognize a today's condition of fuel and energy balance satisfactory. Really: the Great Britain which has closed almost all the mines produces at an import coal almost 35 % of the electric power. Japan which is practically has not the own coal, produces a 28 % of the electric power on an imported coal. And the Russia which is taking the second place in the world on proved stocks of coal (fig. 1), the fifth place in coal mining and exporting, receives only 25 % of common (in view of HPS and APS) electric power produced by coal plants [1].

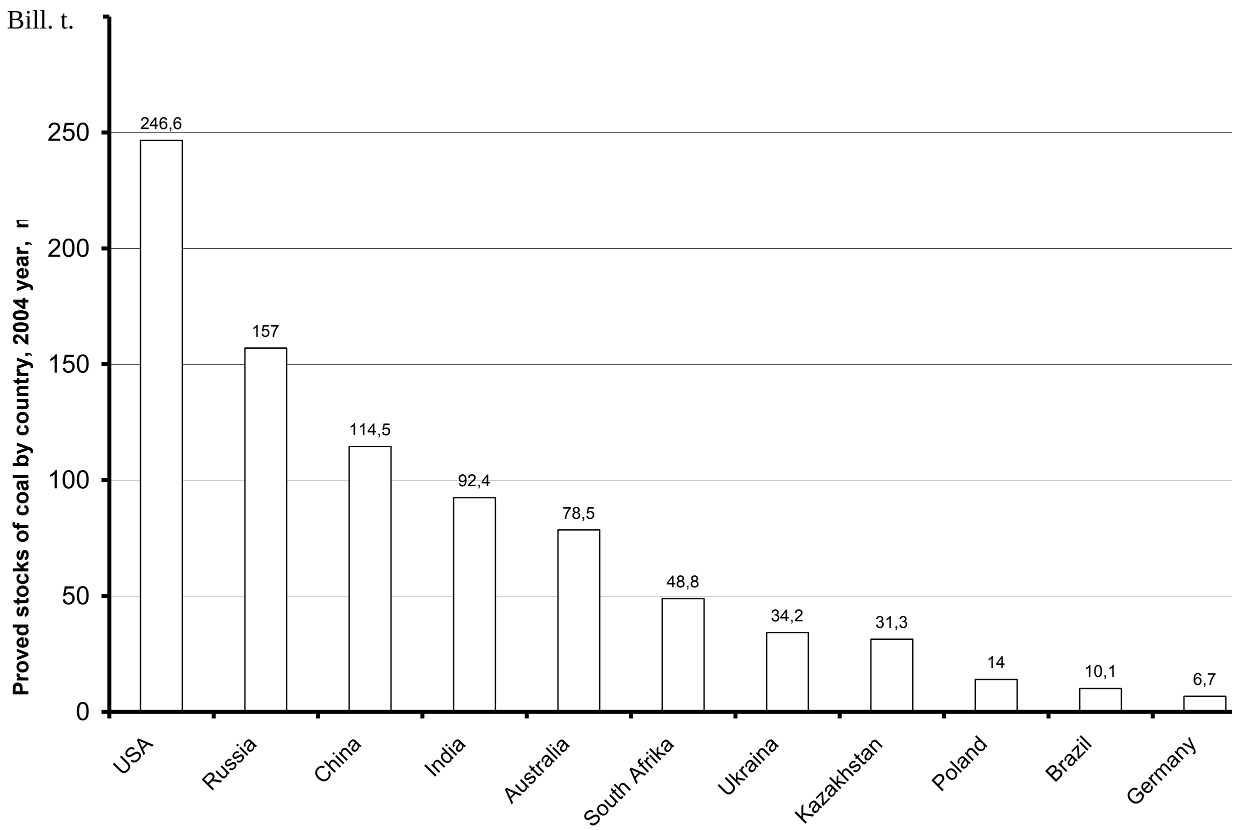

Fig. 1. Distribution of coal stocks

Extremely interesting situation appears in the USA where traditionally share of coal exceeds 50 % in structure of electric power producing. In one of the last numbers of magazine "Power" [2], according to Industrial Info Resources, it is informed, that for the period since 2000 to 2007 in power of the USA cardinal changes were outlined. On the diagram (fig. 2) it is visible, that in 2000 during input of new power units only 4 installations were coal units by total capacity 539 MW, that has made 0,8 % of total capacity produced on organic fuel (coal, gas, fuel oil, a biomass, solid waste, etc.). In the same year it has been put in operation 580 power units designed for natural gas (combined-cycle and a simple cycle gas turbine unit) by the common capacity 66657 MW.

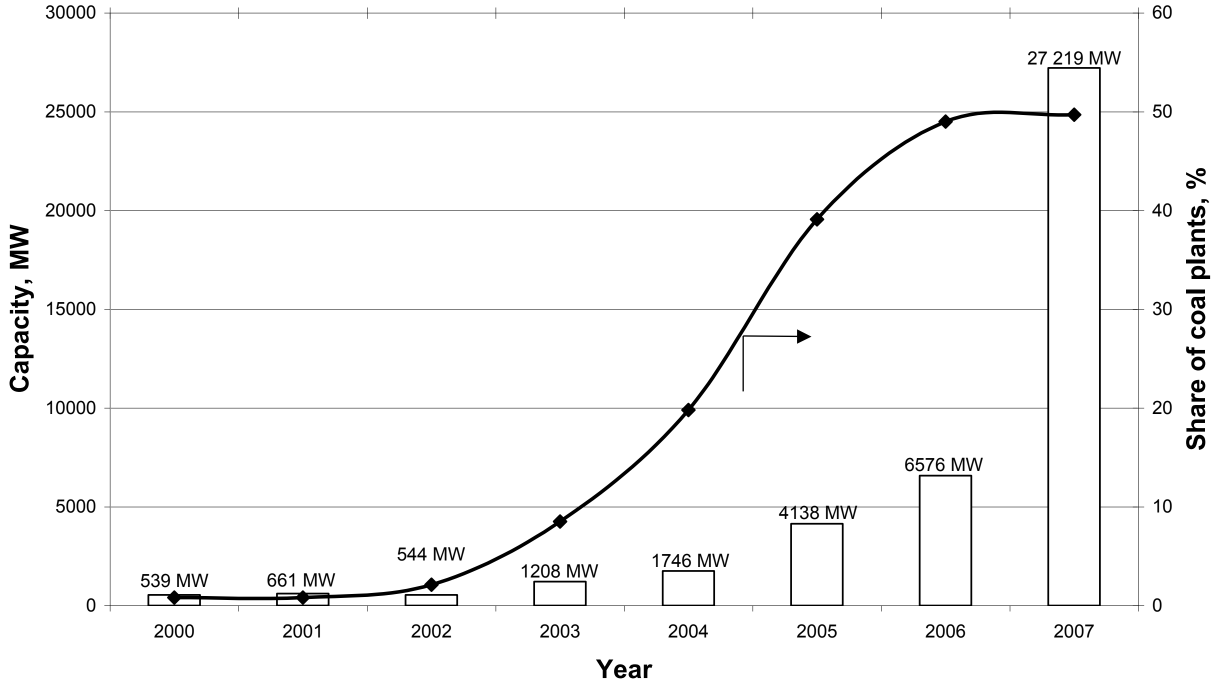

Fig. 2. Input of new coal units in USA

In 2007 another picture is observed: on coal it is supposed to install 64 units total capacity 27219 MW, and on natural gas — only 25257 MW. According to authors, hardly these plans will be realized completely, obviously part of the inputs will be stored for later terms. And nevertheless it is possible to confirm: coal again becomes fuel number 1, despite of constant toughening of atmosphere and ground ecological requirements. As to high efficiency combined-cycle installations, then for the USA experts opinion from the «Worley Parsons» international consulting company is actual: « …much of the investments that was made in the plants previous decade (1995—2005) in combined cycle (SGU) which now its relatively unused due to high gas prices… It leading many people to believe, this was a mistake which should not be repeated » [3].

The matter is that high the efficiency would not be what, efficiency of any installation finally will be defined by cost of produced electric power. And this cost substantially depends on a fuel component. In tab. 1, according to the International Power Agency (IEA) data, the calculated cost of produced electric power for three countries representing various economic regions [4] is resulted.

Table 1. **Comparing costs of electricity on coal and combined-cycle power units [4]**

Costs components	USA				Germany				Czech			
	Coal TPP		CCPP		Coal TPP		CCPP*		Coal TPP		CCPP*	
	cent/ кWt·h	%	cent/ kWt·h	%	cent/ kWt·h	%	cent/ kWt·h	%	cent/ kWt·h	%	cent/ kWt·h	%
Fuel	0,97	25,87	3,57	77,6	1,61	34,3	3,80	76,0	1,68	38,0	3,97	72,7
Operations and maintance (O&M)	0,67	17,86	0,27	5,9	1,07	22,8	0,47	9,4	0,43	9,7	0,20	3,7
Capital costs	2,11	56,27	0,76	16,5	2,01	42,9	0,73	14,6	2,31	52,3	1,29	23,6
Total costs of electricity	3,75	100	4,60	100	4,69	100	5,00	100	4,42	100	5,46	100

* CCPP – combined cycle power plant

From this table it is visible, that in the countries with a normal ratio of gas-coal prices the cost price of the electricity on coal power units on 7…24 % cheaper, than on CCPP, having higher efficiency, but burning more expensive fuel. The difference between coal units and CCPP in a fuel component appears more, than a difference in investment components even in view of additional expenses on reception and storage of solid fuel, coal crushing and pulverizing, on flue gas cleaning from ash, SO_2 and NO_x.

The additional effect in using coal as fuel is the recycling of fly ash and slag which size makes of 20 % in the USA, and in the countries of the European Union - approximately 64 %. In Russia recycling of ash and slag materials on Thermal Power Plant on different data makes from 5 up to 13 %.

2. DRY AND WET BOTTOM

The main by-product of coal burning on thermal power plants is a fly ash. But also slag makes a significant share of TPP place rests, and, hence, interest for experts on slag recycling. Unlike ashes, slags, as is known, turn out different on boilers with dry and on boilers with wet bottom. In first case the solid granules are formed differing from fly ash by size. In the second case (at evacuation of liquid slag from furnace) the glass granulated material are formed and taking place within high temperatures (1500…1700 ºC). Application of wet bottom furnaces meets rather seldom in the foreign countries. In the USA, for example, liquid slag received only on boilers with cyclonic furnaces which plenty had been built at 60-70 of the last century (now the number of such boilers is promptly reduced in connection with exhausting of a resource). Some time the significant number of boilers with two-chamber furnaces (in which the first chamber of combustion has been separated from the cooling chamber by a slag removal beam) was maintained by Germany, but last years manufacturing of such boilers is stopped. In other countries boilers with liquid slag removal system meet extremely seldom.

In Russia the first furnace with liquid slag removal system had been introduced and investigated by VTI experts in 50th years on Shterovskaya TPP designed for firing anthracite. It is necessary to note, that in firing low volatiles coal furnaces with wet bottom, undoubtedly, have some advantages before more widespread furnaces with dry bottom. Presence thicked and lined screens in a zone of active burning in wet bottom boilers reduces a heat-conducting path and increases temperature in the bottom part of coal chamber. It stabilizes process of ignition and improves burning of low volatile coals of anthracite type. For this reason in 60 and 70th years practically all the domestic boilers designed for burning anthracite, semi-anthracite and lean coals was equipped by furnaces with liquid slag removal system.

Later, trying to solve a problem of uncontrollable furnace screens slaging, wet bottom furnaces began to apply to the boilers firing high volatile coals of Kuzbas. Moreover, at lignite development of Kansk-Achinsk basin which has high humidity and volatile matter above of 40 % during first time a boilers with wet bottom were being built. Such decision appeared after researches which had show, that increasing temperature in furnaces increases linkage of separate components of the ash which was being in free condition, in more complex compounds which reduces the slaging ability of ash [5].

Considering these recommendations the Barnaul boiler factory in 70 and in the beginning of 80 produced huge number of boilers steam capacity from 210 up to 640 t/h designed for burning lignites and equipped by complex dust preparation systems and octahedral furnaces with wet bottom. Operation practice of such boilers on Krasnoyarsk, Irkutsk and some other Utility power systems had shown, that fluctuations of ash contents in coals delivered from Irsha-Borodino, Nazarovsky and Bereyozovsky basins and respective alteration melting characteristics of ashes create essential difficulties with a of liquid slag output. As to heat surfaces slaging intensity it had appeared same high, as well as on boilers with dry bottom.

Besides in the end of 80th become acute a question about toxic nitrogen oxides emissions, formed in boilers. In boilers with dry bottom, at the maximal temperature in burning core up to 1400 ºC, nitrogen oxides, as is known, are formed basically from nitrogen compounds of fuel. Then wet bottom is being used the maximal temperature in furnace can reach 1600…1700 ºC and except for fuel NO_x, are formed also thermal nitrogen oxides NO_x [6]. In such boilers NO_x concentration in flue gases reaches 1500…2000·mg/m^3 (in recalculation on NO_2), that in 2-3 times exceeds concentration of NO_x received at burning coal in dry bottom boilers.

Attempts to decrease NO_x emissions without wet bottom liquidation were undertaken as in USA, as in Germany. So, for example, on Valsum TPP, at burning high ash bituminous coal with Q^r_i = 22,2 MJ/kg cyclonic furnace had been replaced by the downward combustion chamber (with wet bottom preservation). Installation of low-NO_x Babcock burners, furnace sectioning and step input of air decreased NO_x emissions, but nevertheless its concentration was equal to 1200 mg/m^3 without recirculation and 1000 mg/m^3 with it.

In Germany, on Heilbroom TPP unit №3 , the boiler steam capacity 320 t/h had primary furnace with wet bottom. Concentration of NO_X in flue gases at nominal load was 1500 mg/m^3. The organization of OFA (at wet bottom preservation) reduced NO_x only up to 900 mg/m^3 [7].

3. TYPE OF SLAG REMOVAL SYSTEM AND NO_x

Considering it, SibVTI together with Krasnoyarsk CHP-1 decided to reconstruct boiler BKZ-320-140PT with wet-bottom furnace to dry bottom. In 1997 the project of reconstruction had been realized and had yielded positive results:

- unslaging capacity of boiler had increased from 250 up to 280 t/h;
- the boiler efficiency had raised approximately on 1 %;
- NO_x concentration had decreased more than on 40 % and has made 320 mg/m^3 (fig. 3);

- Sulfur oxides concentration at burning the Borodino coal had decreased on 20 % and had made 360…500 mg/m^3 (fig 4).

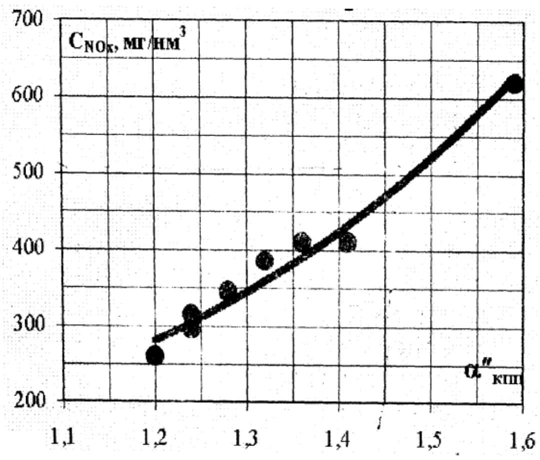

Fig.3. NO_x concentration versus air excess after convective superheater №2 (BKZ-320-140 boiler)

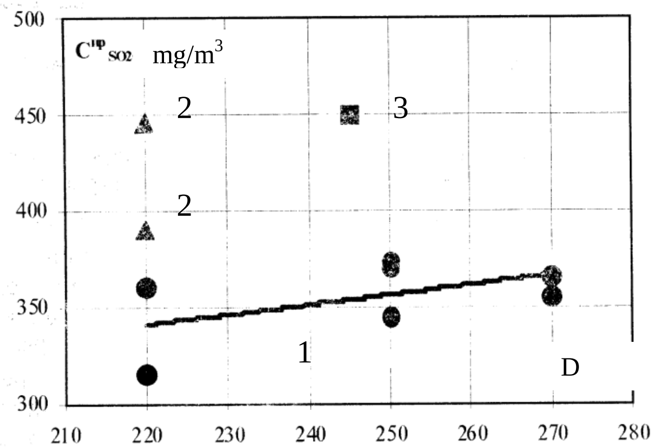

Fig.4 . NO_x Concentration versus load: 1 – Dry bottom boiler .№18; 2 – wet bottom boiler №17; 3 – wet bottom boiler.№20

The achievements connected with reduction of NO_x and SO_2 emissions, show that installation of dry bottom and transfer to dry slag removal system had lowered the maximal temperature in burning core up to 1330 ºC. As a result decreasing of thermal NO_x and increasing of SO_2 linkage by the calcium oxide, containing in initial ash of coal [8].

One more example of boilers retrofit from wet to dry bottom is a BKZ-640-140 PT boiler on the 200 MW unit (№2) on Gusinoozerskaya TPP. At this station during tests of a boiler with reconstructed furnace chamber had being burnt a mix of brown coals of Holboldga and Tugnuysk deposits of Eastern Siberia [9]. Unsuccessful technical decisions on boiler dust systems (installation of the small-sized separators, had increased aerodynamic resistance of a path etc.) had a little complicated work of a boiler, but nevertheless at loading of 170 MWt satisfactory results had been received: the efficiency of a boiler had made 90,8 %, and losses with unburnt carbon did not exceed 0,8 %. The main result of retrofit - reduction of NO_x emissions. Before reconstruction NO_x concentration in flue gas made 1600…2400 mg/m^3 (in recalculation on NO_2 at O_2 = 6 %). After reconstruction, at work of four mills and convective beam styhiometry about 1,2 NO_x concentration decreased up to 700 mg/m^3 (fig. 5). Thus heat surfaces clearing was being made, furnace slaging had local character and did not cause any restrictions in boiler work.

And still saved up experience does not convince of mass retrofit expediency already working boilers with liquid on dry slag removal system. Reconstruction costs, a boiler conclusion from operation for the period of reconstruction and almost inevitable reduction of boiler steam capacity appear too expensive for reduction of emissions and improvement of quality of slag (in case of its recycling).

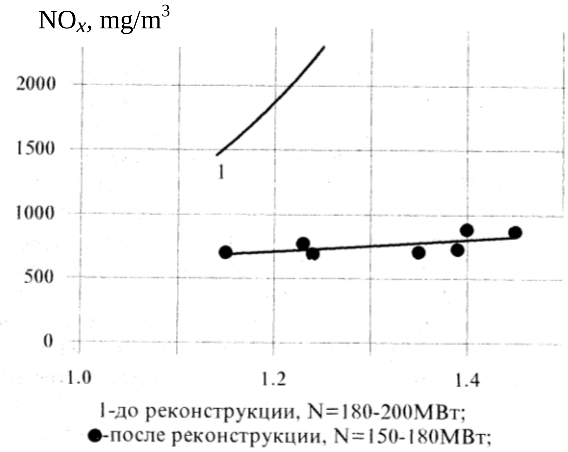

Fig. 5. NO_x concentration versus air excess on boiler BKZ-640-140

As to creation of new boiler units for coal in this case it is possible to draw the certain conclusion: furnaces with wet bottom is expedient to apply only when quality of coal does not allow to provide reliable ignition and stable coal burning without constant supplement expensive oil or natural gas to coal torch. For emissions reduction it is expedient to apply the technological methods checked up in last years which can be effective enough including boilers with wet bottom.

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