

Part 4

COMPLEX TECHNOLOGIES OF ENVIRONMENTAL POLLUTION FROM THERMAL POWER PLANTS

4.5. Analytics

4.5.1. Complex technology to reduce toxic gas emissions from coal-fired boilers of TPPs

V.R. Kotler, I.A. Ryzhiy, JSC "VTI", Moscow, Russia

Coal combustion at thermal power plants and large industrial boilers usually results in a problem of ensuring the standards for permissible emissions in the atmosphere of three components: ash particles, sulfur dioxide (SO₂) and nitrogen oxides (NO_x). In the Russian Federation legislative limits of these emissions are based on sanitary standards for maximum permissible concentrations (MPCs) of the substances in the atmospheric boundary layer (1.5 m from the ground level). These rules (MPCs) are set for all pollutants, but for power engineering only maximum one-time concentrations (average for 20 minutes), given in Table 1, are of interest.

Table 1. MPC values for the main pollutants released into the air with flue gases

Contaminants	MPCs, mg/m ³		Class of hazard
	Maximum one-time	Average daily	
Carbon monoxide CO	5,0	3,0	IV
Non-toxic dust	0,5	0,15	III
Sulfur dioxide SO₂	0,5	0,05	III
Nitrogen dioxide NO₂	0,2	0,04	III
Nitrogen monoxide NO	0,40	0,06	III
Hydrogen sulfide H ₂ S	0,008	-	II
Formaldehyde HCHO	0,035	0,03	II
Benz(a)pyrene C ₂₀ H ₁₂	-	0,000001 (0,1 mcg/100 m ³)	I

Concentration of the pollutant in the ground layer is several orders lower than its concentration after the boiler, as sufficiently high chimneys provide dispersal of combustion products over long distances. The maximum surface concentration of pollutants is usually observed at a distance of 20...40 • H, where - H – is a chimney height (m).

Therefore, to ensure the environmental safety of the population living at a certain distance from the TPP chimney it is important to keep such a concentration of the pollutant in the flue gas after the boiler, which will not result in exceeding the maximum permissible concentration.

Pollutants, emitted through chimneys (NO_x, SO₂ and particulates) remain in the lower atmosphere for 4...8 days, after that they return to earth (adsorption, acid rain and dry deposition of particles). Consequently, the damage from emissions of toxic pollutants is not only local, but also regional in nature, since in a few days pollutants overcome hundreds of kilometers. There are known the disputes in 70-ies between Canada and the United States, Sweden and Germany, the Netherlands and Poland relating to sources of gas contamination of the atmosphere in some countries, which had to contend with the damage caused

by transboundary transport of SO₂ and NO_x. It is this fact has led to the need to limit not only specific emissions of pollutants (uniquely defined by their concentration in flue gases at standard excess air O₂ = 6 % or α = 1,4), but also total emissions (tons/year).

For example, in the European Union, in addition to the Directive on permissible specific emission limits of NO_x, SO₂ and particulate matter, in 27.11.2001 Directive on National Emission Ceilings - NECs was adopted. In accordance with this Directive, all EU countries, since 2010, had to limit the total emissions below the levels given in Table 2 (thous. t/year).

Both Directives are EU laws and, therefore, each EU member-state had to include both Directives into their own national legislation.

Table 2. National limits for emissions (thous. t/year), which should not be exceeded, since 2010

Country	SO ₂	NO _x	Volatile organic components	NH ₃
Austria	39	103	159	66
Belgium	99	176	139	7474
Denmark	55	127	85	69
Finland	110	170	130	31
France	375	810	1050	780
Germany	520	1051	995	550
Greece	523	344	261	73
Ireland	42	65	55	116
Italy	475	990	1159	419
Luxemburg	4	11	9	7
The Netherlands	50	260	185	128
Portugal	160	250	180	90
Spain	746	847	662	353
Switzerland	67	148	241	57
Great Britain	585	1167	1200	297
Total:	3850	6519	6510	3110

National legislation to protect the atmosphere from emissions also has two aspects:

- firstly, GOST R 50831-95 limits specific emissions of NO_x, SO₂ and particulate matter from new boilers with steam capacity of 160 t/h and up at an absolute pressure of superheated steam from 9.8 to 25.0 MPa;

-secondly, all thermal power plants, as well as other sources of air pollution, operate in accordance with MPC document, approved by local environmental bodies, fixing for a particular TPP admissible gross emission of pollutants (tons/year).

In addition to maximum permissible emissions (MPEs), temporarily-approved emissions (TAEs) are set. Their excess is associated with the appearance of "above-limit" emissions. For each category of emissions released into atmosphere significantly different payments are set. For example, if TPP fits into the norms of MPEs (regardless of the specific emissions), the payment to the Environmental

Fund for NO_x emissions makes only 52 rub/ton. MPE excess raises the fee up to 260 rub/t, and for above-limit NO₂ emissions (over TAEs) the payment is 1300 rub/ton.

All three figures are 2 orders lower than the payments made by TPP owners in the EU, USA and Southeast Asia. This led to the fact that almost all power companies in Russia would better pay relatively small fines rather than implement environmental protection measures at their power plants.

For controlling emissions of particulate matter, domestic producers have mastered the production of sufficiently effective mechanical and electrostatic dust collectors. Depending on the efficiency of flue gas cleaning, boiler capacity and characteristics of ash, different types of ash collectors are set after the boilers: dry inertia, wet scrubbers, electrostatic precipitators, fabric filters.

Battery cyclones are often used at industrial and small power pulverised coal combustion boilers. Collection efficiency at the best examples of battery cyclones reaches 90-92%, but in most cases their effectiveness remains in the range of 75-85 %.

Wet cyclonic ash collectors (with irrigation by water of cyclone or grid walls, installed in the inlet cross-section) capture up to 97% of ash particles. At the end of the 80-ies original wet ash collectors-emulsifiers appeared in the Russian Federation and Kazakhstan. Functional test of emulsifiers at certain types of coal confirmed the possibility of catching 99 % of ash particles.

Yet for large boilers ESPs are most likely used; their efficiency reaches 99.8 %. Higher rates can be likely achieved only using fabric filters or combined ash collectors (electrostatic precipitator + fabric filter).

Industrial use of fabric filters in the Russian Federation is expected in the coming years (when burning Ekibastuzsky coal at Reftinskaya TPP, ENEL company).

The feature of ash emissions (unlike NO_x, SO₂ and CO) is their "visibility", which is an important factor for public environmental organizations. As a result of the integrated pressure from environmental control authorities' and environmental non-governmental organizations all energy companies are constantly improving flue gas cleaning systems from solids at coal-fired boilers, or, if possible, are switching from solid fuel to natural gas.

It's more complicated to deal with capturing sulfur oxides and ensuring rather strict permissible emission limits of NO_x. Coal, oil and other types of fossil fuel contain sulfur (except natural gas processed from sulfur compounds at the production site). Solid fuel contains sulfur as organic sulfur and pyrite (mineral part includes Fe₂S). Combustion of coal and fuel oil results in the formation of sulfur oxides (mainly - SO₂, and 2...3 % of SO₂ is then oxidized to SO₃, but at the shortage of an oxidizer H₂S may appear).

SO₂ concentration in flue gases is usually estimated in ppm (parts per million, i.e., cm³/m³). 1 ppm = 10⁻⁴ %, or 29,3 · 10⁻⁴ g/m³. Accordingly, 1 g/m³ = 341,3 ppm. Sometimes SO₂ emissions are estimated by mass concentration (g/MJ): in this case, for recalculation it is necessary to know the heat of fuel combustion Q_i^r (MJ/kg) and specific volume of flue gases at combustion of 1 kg of fuel V_g⁰ (m³/kg). Then M_{SO2} = C_{SO2} · (V_g⁰/Q_i^r), where C_{SO2} is a mass concentration of SO₂, g/m³.

At combustion of some grades of coal, containing considerable amount of CaO in its mineral mass, SO₂ is materially bound in the furnace. But for the majority of coal

types, the initial specific emission of sulfur dioxide can be calculated by the approximate formula:

$M_{SO_2} = 20,5 \cdot S^p$, where S^p is an equivalent sulfur content of fuel, % · kg/MJ.

In accordance with national standards (GOST 50831-95), SO₂ concentration in flue gases for large capacity boilers (400 t/h and above) should not exceed 700 mg/m³ (in terms of excess air α = 1,4, i.e. 6 % O₂). For smaller boilers more soft requirements are established while taking into account the equivalent sulfur content of fuel.

Table 3. Allowable concentrations of SO₂ in flue gases according to GOST R 50831-95

Steam capacity of boilers, t/h	Allowable SO ₂ concentration, mg/m ³	
	S ^p ≤ 0,045 % · kg/MJ	S ^p > 0,045 % · kg/MJ
Up to 320	1200	1400
320-400	950	1050

It is important to note that since 2004, in the European part of Russia, all TPPs must comply with the requirements of II Protocol to the International Convention on the transboundary transport of sulfur dioxide. Comparison between the Russian GOST and this document (Fig. 1) shows that for small boilers international norms are much milder than the Russian ones (i.e. desulfurization is not required for them), and on the contrary, for large boilers (units with electric capacity over 200 MW) it's needed to provide the concentration below 400 mg/m³, which usually requires the installation of a high-efficiency desulphurization plant.

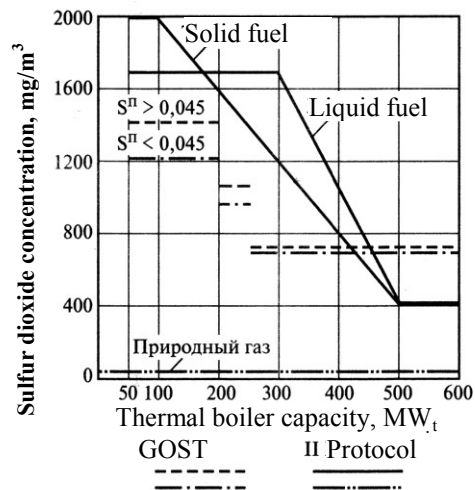


Fig.1. SO₂ concentration according to GOST R 50831-95 and II Protocol to the International Convention on the transboundary transport of sulfur dioxide.

Abroad wet desulfurization technologies are more likely used, providing high efficiency of SO₂ binding. For example, achievable efficiency of wet limestone technology is 96%. Yet higher degree of desulfurization can be obtained by using ammonium sulfate technology. This technology is proved in Russia in the industrial scale (Dorogobuzhskaya CHPP) and can be designed for any of the boiler plant. Limestone technology was tested at the pilot plants at Gubkinskaya and Severo-Donetskaya CHPPs. It is this technology was developed (but not implemented) for 300 MW lignite-fired power unit.

Absence of operating desulfurization systems at large coal-fired power units in the European part of the Russian Federation is explained, on the one hand, by their extremely high cost and, on the other hand - the availability of natural gas at the majority of coal-fired power plants. As known, the price of natural gas in Russia insignificantly exceeds the price of coal (calculating by the unit of heat), so in all cases, it is advantageous to increase the share of gas in the fuel balance of coal-fired plants than to build a highly efficient, but very expensive desulfurization system.

Capital costs for the flue gas desulphurization installation can be found in Table 4.

Tens millions of dollars spent (Table 4), and a relatively low content of sulfur in coals of the Kuznetsk Basin, Kan-Achinsk brown coal basin, and in the majority of coal fields of the Eastern Siberia and Primorye lead to the conclusion that in order to achieve the standards for SO₂ emissions at combustion of these types of coal at TPPs it is advisable to use much cheaper, although less efficient dry additive method. This technology involves feeding finely ground limestone in a top section of the furnace and the subsequent purification of flue gases from a mixture of fly ash with anhydrous gypsum and calcium oxide.

Minimum efficiency of such desulfurization is 30-35% (maximum – 50 %) that allows meeting the requirements both of the Russian GOST and European standards when burning low-sulfur coal of Siberia and the Far East (Table 5).

Probably, it is the technology to be tested in industrial scale at one of the coal-fired boilers in Siberia.

To reduce NO_x emissions, energy companies in many boilers use technological methods, which consist in improvement of the combustion process. At combustion of natural gas and oil, these methods allow to reduce specific NO_x emissions to a level that corresponds with EU BAT

(best available technologies). But in case of coal combustion, for flue gas cleaning from NO_x in the EU, USA, Japan and South Korea after large-capacity boilers, the installations for selective catalytic reduction (SCR) using ammonia or urea are set. Such facilities cost tens millions of dollars, therefore when constructing small boilers at coal-fired TPPs other methods that do not require huge investments and high operating costs are to be found.

One of these ways is a combined method of simultaneous reduction of SO₂ and NO_x emissions, tested under industrial conditions in the United States as early as the end of the last century [1]. In those years, the U.S. government partially funded a demonstration program called “Clean Coal Technology” (CCT). One of the projects, included in this program was to develop and demonstrate the combined GR-SI method (Gas Reburning-Sorbent Injection) at coal combustion at the Lakeside thermal power plant (40 MW unit) and Hennepin TPP (80 MW unit) [2].

The first of these boilers (steam capacity of 145 t/h at steam parameters of 6 MPa and 488°C) was equipped with a furnace with two cyclone pre-furnaces, therefore for the Russian energy sector this experience is of a little interest. But the second boiler (D = 238 t/h, steam parameters: 10.2 MPa, 540°C) had a conventional furnace with dry bottom ash removal, with a corner location of direct-flow burners in 3 tiers by height. Coal from Illinois deposit was used as a fuel with combustion heat of 24,9 MJ/kg (5950 kcal/kg) and a sulfur content of 2,9 %.

Fuel was ground in three mills, each fed the dust to four corner burners of one tier. Combustion chamber size was 7,88 m by the front, its volume made 1378 m³, thermal stress of the furnace volume was 146 kW/m³, or 125 thous. kcal/(m³ · h). Parameters of the boiler heating surfaces: furnace - 880 m²; superheater - 4650 m²; intermediate steam superheater - 728 m²; economizer - 832 m²; air heater (tubular) - 16042 m².

Table 4. Capital expenditures for new 500 W power units, burning coal from Appalachian deposits (with wet scrubbing facilities)

Items of expenditure	Forced limestone oxidation (Ca)				Forced magnesite oxidation (Mg)			
	High-sulfur coal		Low-sulfur coal		High-sulfur coal		Low-sulfur coal	
	Cost, US \$	\$/kW	Cost, US \$	\$/kW	Cost, US \$	\$/kW		\$/kW
The reagent feeding system	7,373,000	14,7	6,215,000	12,4	5,600,000	11,2	4,824,000	9,6
SO ₂ removal system	17,712,000	35,4	15,000,000	30,0	14,290,000	28,6	13,011,000	26,0
Flue gas removal system	7,857,000	15,7	7,250,000	14,5	7,769,000	15,5	7,150,000	14,3
Secondary product processing	7,419,000	14,8	6,018,000	12,0	7,419,000	14,8	6,018,000	12,0
Different auxiliary equipment	2,011,000	4,0	1,710,000	3,4	2,011,000	4,0	1,710,000	3,4
Capital expenditures directly for desulfurization (TPC)	42,372,000	85	36,193,000	72	37,089,000	74	32,713,000	65
Main station equipment (5 % of TPC)	2,119,000	4,2	1,810,000	3,6	1,854,000	3,7	1,636,000	3,3
Mounting of the installation	4,237,000	8,5	3,619,000	7,2	3,709,000	7,4	3,271,000	6,5
Contingencies (15 % of TPC)	7,309,000	14,6	6,243,000	12,5	6,398,000	12,8	5,643,000	11,3
Capital expenditure in view of installation work (TPLC)	56,037,000	112,1	47,865,000	95,7	49,050,000	98,1	43,263,000	86,5
Tax relief on investments (3,2% of TPLC)	1,793,000	3,6	1,532,000	3,1	1,570,000	3,1	1,384,000	2,8
Total costs of the owner (3.2 % of TPLC) (work management, bookkeeping, etc., 5 % of TPLC)	2,802,000	6,0	2,393,000	5,0	2,453,000	5,0	2,163,000	4,0
Total power plant investments (TPI)	60,632,000	121,7	51,790,000	103,8	53,073,000	106,2	46,810,000	93,3
Operating equipment (including spare, 1 % of the TPI)	606,000	1,2	518,000	1,0	531,000	1,1	468,000	0,9
Primary supply of reagents and start the installation (2 % of TPI)	1,213,000	2,4	1,036,000	2,1	1,061,000	2,1	936,000	1,9
Royalties	0	0	0	0	0	0	0	0
Total capital costs	62,451,000	125	53,344,000	107	54,665,000	109	48,214,000	96

Cost of GR-SI program implementation makes \$ 16,5 mln., Funding agencies are: the Department of Energy, Gas Institute, Department of Energy and Natural Resources of Illinois. A purpose of the program was to demonstrate the opportunity to reduce NO_x by 60% and SO_x by 50% at moderate operating costs.

The scope of the boiler reconstruction consisted of the following components:

1. Unit for reception, storage and supply of the sorbent to a boiler shop. Hopper, located outside the main building, designed for operation of the boiler for 3 days with a full flow of the sorbent.

2. The following equipment was additionally mounted at the boiler (Fig. 2):

- 4 burners for supplying gas;
- to ensure good mixing of the gas with combustion products the boiler was equipped with a flue gas recirculation

circuit, flue gases were selected after an economizer; before the gas recirculation fan a multicyclone was installed;

- above the gas burners at the furnace corners there were mounted the tertiary air nozzles, selected from the secondary air ducts on both left and right sides of the boiler (at a reduced boiler load the sorbent was fed through the same nozzles);
- even higher, at the furnace outlet there were mounted nozzles to inject the sorbent at the rated load. A special fan for spraying sorbent was set;
- another fan was installed to supply cooling air (it was used only during the boiler operation, but the sorbent feed through the top nozzles has been disabled).

Table 5. The required efficiency of flue gas desulfurization installed at the coal-fired boilers (%) according to GOST R 50831-95 and International Protocols %.

Coal grade	Specific SO_2 , emissions, g/MJ	Thermal boiler capacity, MW				II Protocol to the International convention, ≥ 500 MW (t)
		100-199	200-249	250-299	≥ 300	
Arkagalinsky D	0,18	0	0	0	0	2,8
Neryungrinsky SS	0,17	0	0	0	0	0
Kuznetsky SS	0,28	0	0	0	0	36,2
Pavlovsky B1	0,24	0	0	0	0	21,2
Nikolsky D, DG	0,31	0	0	3,2	3,2	43,5
Urgalsky G	0,35	0	0	14,3	14,3	50,0
Bikinsky B1	0,41	0	2,4	26,8	26,8	57,3
Partizansky T	0,40	0	0	25,0	25,0	56,3
Erunakovsky G	0,34	0	0	11,8	11,8	48,5
Azeysky BZ	0,44	0	9,1	35,9	35,9	60,2
Gusinoozersky BZ	0,56	10,7	28,6	46,4	46,4	68,8

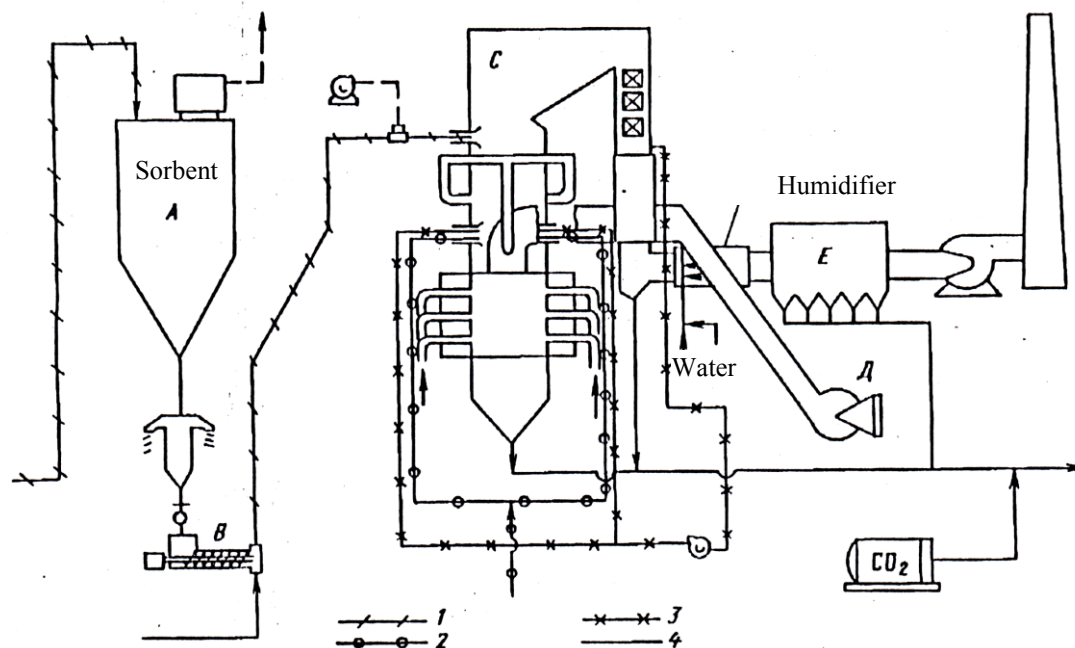


Fig. 2. GR-SI flow sheet at the Hennepin power plant (1 – sorbent; 2 – natural gas; 3 – recirculation gas; 4 – ash).

3. There were reconstructed the gas flues before and after ESP. This was due to the need for air-conditioning of the gases by water injection and ensuring the time (2 seconds)

until the moisture evaporates before coming the gases to the ESP.

4. There was mounted a device for controlling pH in the wet ash removal system as well as CO_2 injectors.

After installation of the system within 50 days the boiler was tested in the basic mode (without switching of GR-SI system). Then, experiments were conducted with the operating three-stage combustion facility, and finally – the tests using the sorbent. After determining the optimal parameters there were carried out long-term tests of the entire GR-SI system working on the main fuel; technical and economic indicators were assessed as well.

On the basis of results of the tests the following conclusions could be made.

Goals set (60% reduction of NO_x emissions and 50% reduction of SO₂ emissions) were provided during normal operation of the boiler with the following excess air factors: in the main burners - 1.08, in the reduction zone - 0.9, after the furnace 1,18. By that consumption of additional fuel (gas) made 18% (by heat), fuel gas recirculation was maximal, the sorbent was applied to the upper nozzle at the normal ratio of Ca/S = 1,75.

Before reconstruction NO_x emissions made approximately 0,31 kg/GJ (about 860 mg/m³ at α = 1,4), after reconstruction during the best tests this figure was reduced up to 0,086 kg/GJ, i.e. up to 240 mg/m³ (reduction by 72%).

Maximum binding of sulfur dioxide exceeded 60% (at Ca/S = 2,0). In this case SO₂ value at combustion of 18% of gas was taken as a base one.

Effectiveness of the three-stage combustion (by efficiency of NO_x emissions reduction) increased with a decrease of excess air (up to α_t = 1.13, when an abrupt increase in the CO concentration started). Increase in the gas share from 8 to 20% also reduced NO_x emissions (approximately from 0.12 to 0.09 kg/GJ). Boiler load (in the range of 43 to 72 MW) has practically no effect on the emissions of nitrogen oxides. A degree of binding the sulfur dioxide is also not dependent on the load, but linearly raised with increasing the molar ratio of Ca/S.

Comparing SO₂ emissions when operating the coal-fired boiler before its reconstruction and SO₂ emissions

when operating the GR-SI system, sulfur dioxide emissions reduction will be 66%.

Fig. 3 shows the performance data from January to April relating to the degree of NO_x and SO₂ emissions reduction. During this period, the boiler load varied from 40 to 70 MW, the gas share was 18% and Ca/S ratio made 1.75. Fig. 4 shows a diagram of absolute specific emissions of NO_x and SO₂ for 1 day. The boiler loads made 60 and 70 MW, additional burners were operating from 8.14 am to 18.10 pm, the sorbent was injected from 9.45 am to 17.56 pm.

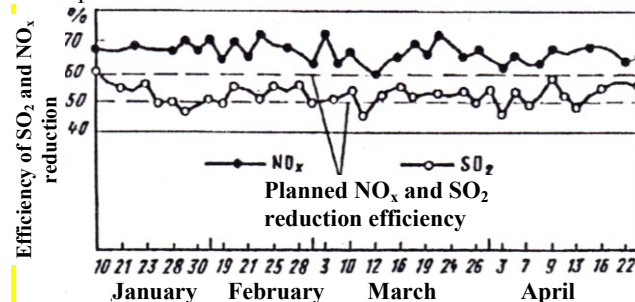


Fig.3. Long-term tests of the GR-SI system at the Hennepin power plant (load range is 40...70 MW, a gas share by heat is 18 %; Ca/S = 1,75)

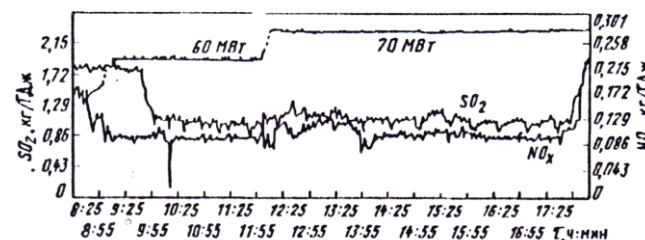


Fig. 4. Sulfur dioxide and nitrogen oxide emissions at two loadings of the boiler #1, Hennepin TPP

ESP efficiency of the 70 MW power unit is characterized by the data from table. 6.

Table 6. ESP efficiency

Mode characteristics	Emissions of particulate matter, g/s		
	At the ESP inlet	At the ESP outlet	ESP efficiency, %
Base mode without GR-SI	797	2,03	99,75
Three-stage combustion mode with the gas share of 18 %	510,7	0,676	99,87
GR-SI mode, gas share – 18 %, sorbent – Ca/S=2,06	1387,1	2,48	99,82

The table shows that conditioning of flue gases and replacement of the coal with natural gas ensured maintenance of the high ash collection efficiency. Emissions of particulate matter were considerably lower than the values permissible for TPP Hennepin (9.58 g/s).

At the boiler, equipped with cyclone pre-furnaces after introducing the GR-SI method, the maximum NO_x emissions reduction made 74%, and an average operating value was 66 % (at the gas supply of 22 % by heat). A degree of SO₂ binding, using the burnt lime (Ca/S = 1,8) made 58%.

Of course, the desulfurization efficiency at both of the boilers was not as high as when using the wet technology with absorbers. But also the costs for dry additive method were many times less. Besides, the most important is that in case of burning the majority of coal types from East Siberia and the Maritime region at Russian TPPs, as well as Kansko-Achinsky lignite and most of the coals from Kuz-

netsk Basin with sulfur content of 0,2...0,5 %, the obtained figures of sulfur binding completely allow to perform domestic rules on admissible SO₂ emissions [4].

Relatively recently, at the beginning of this century, another American company - Phenix Limited, LLC announced about the development of its own technology to reduce both NO_x and SO₂ [5]. The authors called their technology “Clean Combustion System™” (CCS), and on the basis of testing at the pilot plant they said that at coal burning it’s possible to reduce NO_x emissions up to 0,0645 g/MJ (approximately 184 mg/m³ at 6 % O₂) and SO₂ emission - up to 0.086 g/MJ (~ 245 mg/m³ at 6% O₂). In this case, the only reagent, required for the technology implementation, is limestone.

A concept of the new technology is that at the initial stage the gasification of coal dust occurs, and the air required for complete combustion is fed at the next stage.

Together with the fuel limestone is fed to a special burner. The carrying agent is air.

Fig. 5 shows a diagram of the demonstration LNS-CAP plant (Low NO_x/SO_x - Coal Applications Pilot) with a heat capacity of 7,33 MW. Coal and limestone (each from its hopper) are supplied to the coal mill 1. After crushing the ready-mix is collected in the plant with a fabric filter 2, and then, after an adjustable feeder 3 and divider 4, it is fed to the main burner of the gasifier 5. Here hot gases are also supplied that provides the required gasification temperature. It is here that the sulfur, contained in the fuel, is converted into the solid calcium sulfide, carbon in the fuel is mainly converted into CO, and organic nitrogen, bound

with the organic mass, - into harmless molecular nitrogen N₂.

Boiler slag through the slag tap hole 6 is removed from the bottom of the furnace extension-gasifier to the slag bath and hot gaseous gasification products come to the furnace 8, enclosed by the steam generating tubes. Here comes the afterburning of gasification products by the jets of heated air 9 supplied to the furnace inlet. Then flue gases pass through 1st stage of economizer 10, air heater 11, 2nd stage of economizer 12 and after the fabric filter 13 the exhauster 14 feeds them to the chimney 15. For cooling the gasifier walls a cold air fan 16 is used. Another fan (17) supplies preheated air to overfire air nozzles 9 and after additional heating - to the coal mill 1.

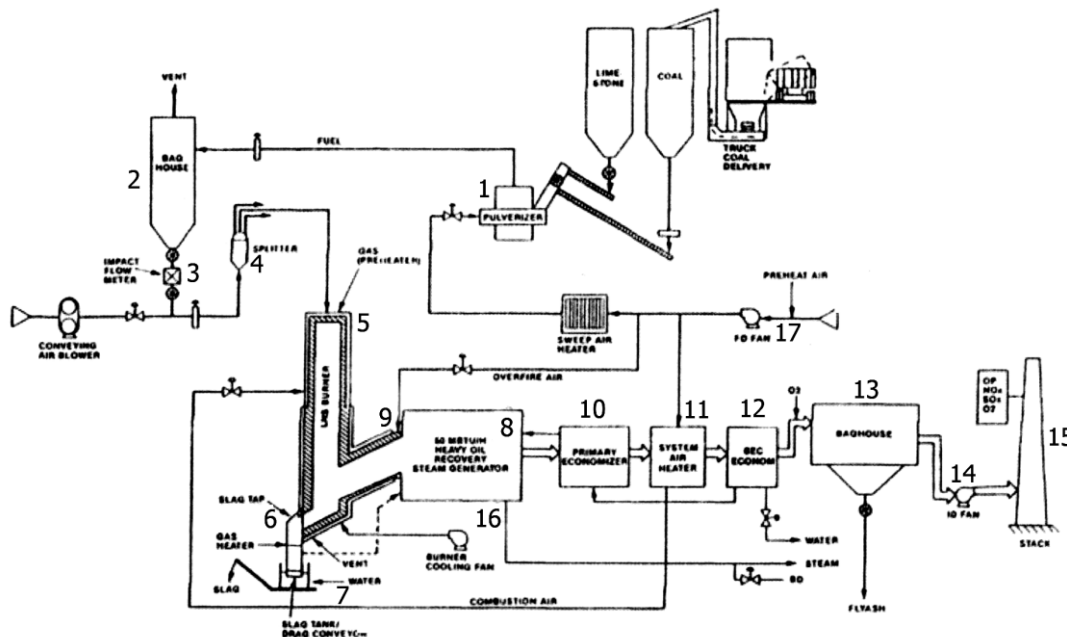


Fig.5. Process flow diagram of the LNS-CAP demonstration plant.

In addition to research on the above-described pilot plant, the company ESSO Resources Canada LTD conducted full-scale tests at the TPP Cold Lake Site in the province of Alberta (Canada). It was a small boiler with the heat capacity of 14,7 MW where low-sulfur sub-bituminous coal was burnt (coal consumption made 3 t/h). After the boiler reconstruction it was obtained even deeper emissions reductions of toxic gases than at the demonstration LNS-CAP plant.

Currently Phenix Limited is developing the technical documentation for reconstruction of coal-fired boilers, which in accordance with the American legislation should reduce NO_x and SO₂ emissions into the atmosphere. A scope of reconstruction included replacing of coal burners with new pre-furnaces with the drop flame, assembling the overfire air nozzle and apparatus for feeding ground limestone with the fuel. All accessories are assembled in the existing boiler cell.

Fig. 6 shows a general view of one of the boiler planned for reconstruction (100 MW unit #6 at TPP IPL). The boiler is equipped with mills with angular location of eight CCS burners and one gasifier on each side of the boiler. It's as dry bottom boiler with angular arrangement of four nozzles of low-dust air.

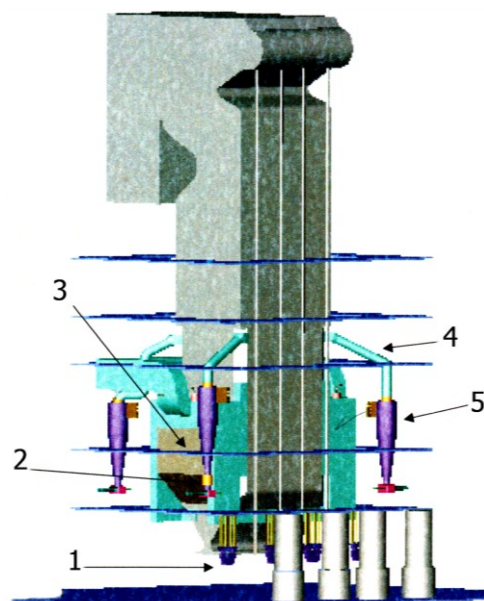


Fig. 6. The boiler of the unit 6 IPL with capacity of 100 MW with a tangentially fired furnace reconstructed under CCS-Tangential™ Technology: 1 - wet scraper conveyor; 2 - coal analyzer in real time; 3 - eight CCS burners and gasification chamber (1 per side); 4 - overfire air nozzles (in each of the four corners); 5 - fuel mixture flow separator (for each of the four corners).

It is assumed that the reconstructed boiler provides efficient burning ($q_4 < 1\%$), reduced emissions of NO_x (less than 0,0645 g/MJ) and SO_2 (0,26 g/MJ when burning midwestern high-sulfur coal and less than 0.086 g/MJ when burning low-sulfur western coal). By this, fly ash retains its commercial quality and the most important - it doesn't require any further purification of flue gases.

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