P a r t 4

COMPLEX TECHNOLOGIES OF ENVIRONMENTAL POLLUTION FROM THERMAL POWER PLANTS

4.1. Combustion of water-oil emulsion in steam boilers

4.1.1. Combustion of water-oil emulsion in steam boilers at CHPP-23 of the JSC "Mosenergo" in combination with the regime and technological measures

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By application of regime and technological measures in steam boilers of CHPP-23, significant results [1, 2] on increase in their ecological compatibility, reliability and economical efficiency have been achieved. Complex reconstruction of boilers of TGMP-314C type with installation of low-NOx burner and application of staged combustion and recirculation of flue gases into the zone of combustion, allowed to reduce in several times NOx emitted with flue gases into atmosphere at combustion of natural gas and oil. Positive results have been also achieved relating to benz(a)pyrene emissions (BP) from boilers of TGMP-314C type, equipped with low-NOx burners of GMVIg-50 type (TKZ–VTI). From the data shown in fig. 4.1, one can see that concentration of nitrogen oxides in flue gases was reduced to the standard values by regime methods at oil combustion without increase in BP concentration. But usually happens the opposite. Factors, reducing the intensity of BP generation (lowered local coefficients of excess air and recirculation of flue gases) increase in the intensity of nitrogen oxides generation. The gained results [1, 2] can be explained either by the features of mixing in low-NOx burner GMVIg-50, or by humidity of oil making 10 % in the tests [1]. The oil was subjected to cavitational processing; that means water-oil emulsion was combusted.

Significant decrease in BP concentration in flue gases at combustion of fuel (gas, oil) with injection of additional moisture in the combustion zone or oil in a form of water-oil emulsion, was established in MPEI tests [3,4] (fig.4.2).

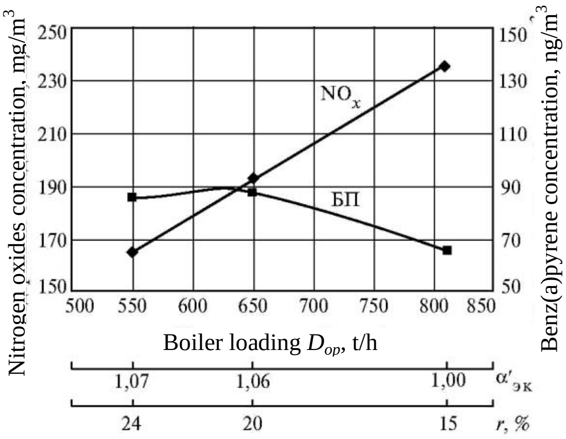

Fig. 4.1. Concentration of nitrogen oxides and benz(a)pyrene in flue gases of TGMP-314 boilers versus its loading at the staged oil combustion in combination with flue gas recirculation:
β — air share, supplied to up-burner nozzles, β = 7…8 %; q_3 — incomplete combustion, q_3 = 0

Therefore, it was shown that injection of additional moisture in the zone of fuel (gas, oil) combustion or oil in a form of water-oil emulsion is a very important factor, which influences BP concentration in flue gases from steam boilers. BP is a very toxic substance of the first class of hazard and has one of the most rigorous standards on maximum permissible concentration. In case of oil combustion, it's necessary to consider this factor.

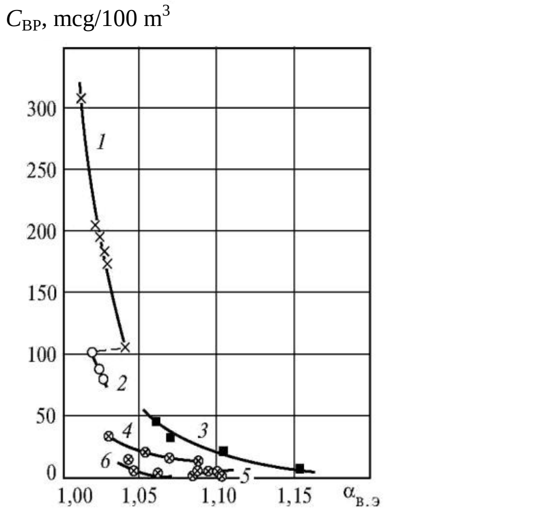

Fig. 4.2. Benz(a)pyrene concentration in flue gases at combustion of natural gas and oil in steam boilers [3, 4] versus injection of additional moisture in the combustion zone:
1 — natural gas without moisture injection, boiler TGMP-204CHL; *2* — the same as in *1*, but with injection of 0,64 t/h of water in the combustion zone; *3*, *4* — oil, steam spreading, boilers TGM-84 and TGM-84B; *5* — the same as in *4*, but combusting water-oil emulsion, W^p = 7 %; *6* — the same as in *3*, but with injection of 10 % of water (out of fuel consumption)

In the process of developing the technology of fuel combustion (especially, in case of oil combustion), there should be set a task of the complex improvement of ecological characteristics of boilers at simultaneous increase or saving of their reliability and economical efficiency. It means that it is necessary to find such a combination of regime and technological factors, at which concentrations of nitrogen oxides, BP, carbon oxides, etc. will be simultaneously decreased. Such problem is the most actual at oil combustion. This way the problem is set during conducting researches at CHPP-23. As this technology for TGMP-314C steam boilers of supercritical pressure, a combination of the above-mentioned regime measures, low-NOx burner and oil combustion in a form of water-oil emulsion (WOE) was selected. However, at present such a technology is too little investigated. In addition, during the test [2] it was established that combusting oil in a form of WOE doesn't always contribute in reduction of nitrogen oxides emissions in flue gases. But the opposite result can be gained. Due to phenomena of micro explosion of WOE drops and intensification of oil combustion process, concentration of nitrogen oxides can increase. It is rather significant during oil combustion, because it complicates the problem of reaching the standard concentrations of nitrogen oxides, being very difficult to solve. A character of impact of WOE combustion on intensity of nitrogen oxides generation can be defined by many factors: configuration of boiler and burners, aerodynamics of furnace, mode of fuel combustion. But ones of the most important factors are properties of WOE, namely its particle sizes, humidity and temperature. There are too little investigations relating to influence of

WOE characteristics and other constructive and regime factors on concentration of nitrogen oxides in flue gases from boilers. The applied apparatuses for gaining WOE do not usually allow changing its characteristics, and even more, there are very few data on WME particle sizes, humidity and temperature.

For solving the set complex problem at CHPP-23 of the JSC “Mosenergo” together with MPEI department of boiler plants and ecology in power engineering, the cavitator (apparatus for preparing WOE) of original construction was designed, produced and put into operation. The cavitator was designed on the basis of the well-known cavitator of MPEI system [4,5]. But the feature of the cavitator, introduced at CHPP-23, is an opportunity to change a cross section of the flowing channel, and hence, velocity of the oil flow. The tests showed that this allows to change particle size distribution of the obtained WOE at the certain oil (WOE) flow rate through the cavitator (table 4.1).

The mentioned feature of the cavitator configuration helps to define WOE characteristics during the test, allowing to solve the problem on nitrogen oxides and BP simultaneously for the specific boiler at certain fuel combustion mode. The suggested cavitator configuration also enables to support the optimal WOE characteristics at changing of oil flow rate through the cavitator. A new cavitator of MPEI-CHPP-23 system is installed in premises of oil pumping station of CHPP-23 after the pump of the first lifting MN1-4. The cavitator has a bypass line, which allows switching on and off the cavitator or changing its cross section without stopping the oil (WOE) supply into a main line. A principle scheme of the cavitator with oil (WOE) flow rate to 450 t/h and pressure to 1 MPa is shown in fig.4.3. In the flowing section of the cavitator there are nine flat parallel profiled channels, formed by flat plates (up and down) and profiling inserts (on sides). The channel is 10 mm high, 130 mm wide in the narrow place. In each channel there are two rows of turbulence cylinder inserts installed. Turbulence cylinders can be implemented as plain ones or with cuts at the side surface for enforcing of cavitational effect. A principle of the cavitator operation is based on the well-known phenomenon of cavitational (cavern) zone appearing behind the cylinder inserts because of sharp local pressure drop and the following “collapse” of cavern at pressure recovery along the working channel. It leads to intensive mixing of oil with water and getting the emulsion of “water in oil” type. In several working channels, installation of regulating bars is provided by the cavitator configuration. These bars allow partially or completely blocking the channel section and by this changing the total cross section of the cavitator.

Table 4.1. **Particle size distribution of WOE water drops**

Diameter of water drops, microns	Regulating bars are taken out		Two regulating bars are introduced		Three regulating bars are introduced	
	Water drops content, %					
	Before the cavitator	After the cavitator	Before the cavitator	After the cavitator	Before the cavitator	After the cavitator
To 1,27	66,7	68,8	65,8	68,5	64,9	69,2
1,27…2,5	17,0	15,4	17,5	15,9	18,3	18,2
2,5…3,8	9,8	8,7	10,9	9,9	7,8	6,1
3,8…6,3	3,3	4,8	3,3	3,5	6,2	4,9
6,3…12,7	1,2	0,9	1,5	1,4	1,7	1,0
12,7…25,0	1,2	1,0	0,5	0,4	0,6	0,4
More than 25	0,8	0,5	0,5	0,4	0,5	0,2
Totally	100	100	100	100	100	100

Note. Viscosity at temperature of 100°C made 10…10,5° FV. Results of the test conducted on March 20, 2006, are given.

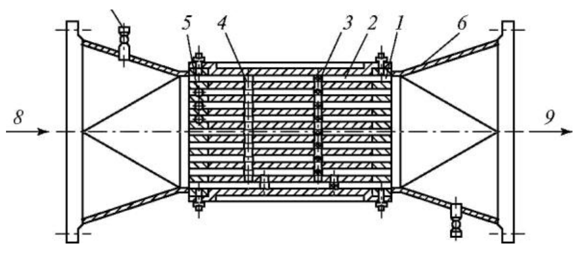

Fig. 4.3. A principle scheme of the cavitator:
1 — channel of the cavitator flowing section; *2* — plate; *3* — turbulence cylinders (of the second row); *4* — turbulence cylinders (of the first row); *5* — regulating bars; *6* — transfers; *7* — connecting pipe for additional water injecting; *8* — inlet of initial oil; *9* — outlet of WOE

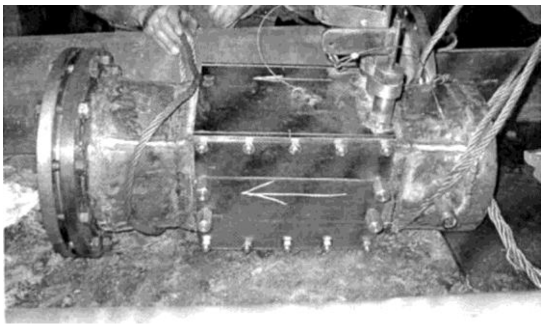

Fig. 4.4. Appearance of the cavitator

Regulating bars are introduced in the flowing section by special glands, installed on the cavitator body (fig. 4.4).

To define location of regulating bars, measuring apparatus is provided. All the details of the cavitator flowing section are fastened in the square body, having covers at the top and bottom. At the inlet and outlet of the cavitator there are transfers from square sections of the body to round section of oil pipeline. Transfers are fastened to the oil pipeline by flanges. At the inlet of the cavitator, additional water (clean water or waste waters, polluted by oil-products) can be injected into initial oil flow by the special connecting pipe. The cavitator is equipped with samplers of oil and WOE at the inlet and outlet, pressure indicators at the inlet and outlet, temperature indicators and oil flow meter. The appearance of the cavitator is shown in fig.4.4.-4.6.

On the cavitator body (fig.4.4) glands for regulating bars and regulating bars themselves are presented. One can also see that the cavitator has small overall dimensions. Without transfers and flanges it is of 340×250×226 mm.

In fig. 4.6 there is one of the channels of the cavitator flowing section. Profiling (side) plates and also two rows of turbulence cylinder inserts can be seen. The first row of inserts is implemented with the plain surface; the second one is with cutting. All the details of the flowing section of the cavitator are made of stainless steel.

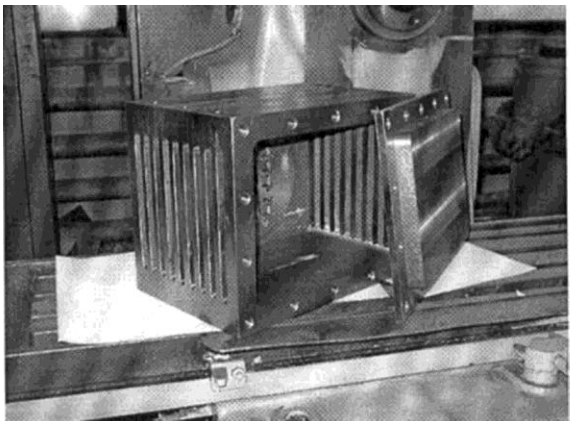

Fig. 4.5. The cavitator body

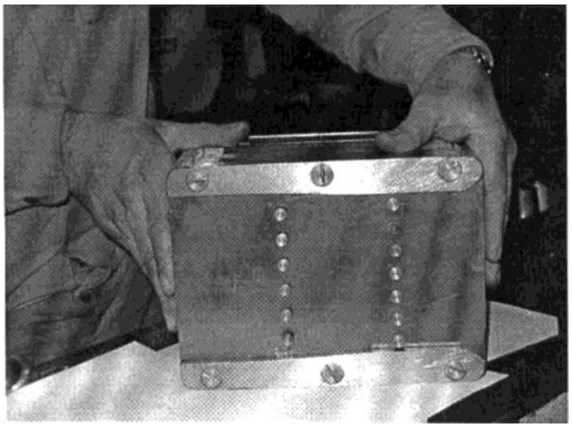

Fig. 4.6. The flowing section of the cavitator

Investigations on introduction of the suggested technology of oil combustion at CHPP-23 are planned for implementation in two phases. The first phase is testing of the cavitator with the changing flowing section (MPEI - CHPP-23 system). The first phase was conducted without combusting oil (WOE) in boilers. At this phase, operational characteristics of the cavitator, quality of the obtained WOE were investigated. The second phase – operational test of steam boilers at combustion of oil (WME) in order to find the optimal mode of fuel combustion.

The results of stand tests of the cavitator showed that the construction at working pressure after the pump MH1-4 of about 0,65 MPa is airtight. There are no any noticeable noises and vibrations. The cavitator is easy-to-use. The operational personnel has no difficulties relating to operations on changing the flowing section. Pressure drop in the cavitator at completely taken away regulating bars is 0,14…0,17 MPa, and at completely input bars it is 0,24…0,27 MPa. In case of high pressure drop, it can be decreased by partial half-opening of a slide valve at bypass line. During all the conducted tests, characteristics of the initial oil and obtained WOE were defined (humidity, heat of combustion, viscosity, particle size distribution). Particle size distribution was estimated by electronic microscope of the JSC "VTI" under SO 34.44.208 – 96, viscidity – under the state standard GOST 1929 – 87. Microphotographs of WOE were also made (with increase in 600 times).

Some results of particle size distribution of WOE are shown in table 4.1. These results show that the cavitator prepares the emulsion of a high quality. To 87 % of water drops are to 2,5 microns. Amount of large particles of 12…25 microns does not exceed 1 % and amount of particles of more than 25 microns is very small (to 0,5 %). It is necessary to mention that in the initial oil amount of large particles was not very high, because in March of 2006 to CHPP-23 fresh oil was delivered. In process of increasing of a period of oil storage, the amount of large particles of tens microns by size is considerably enlarged. From the data shown in table 4.1 one can seen that the change of the cavitator flowing section significantly effects the particle size distribution of emulsion. The greatest part of small particles it obtained at introducing three regulating bars, but at the same time a part of large particles decreases in 2,0…2,5 times. It has been already mentioned above, that the most highly dispersed emulsion doesn't always give the desired result. But by change of the flowing section and bypassing of a part of initial oil, the particle size distribution of WOE can be changed in a wide range. This helps to find the optimum combination of WOE characteristics and a mode of combustion of different fuel types in boilers.

The second phase of investigations is planned for autumn-winter of 2007-2008.

As a whole, it is necessary to mention that equipping the oil facilities of CHPP-23 with the cavitator, which helps in reliable obtaining WOE of a high quality, contributes in improving ecological, technical and economic characteristics of boiler operation. There is a number of aspects:

• The first aspect concerns the problem on BP, to which attention will be increasing over time.

Wide application of combusting oil in a form of WOE on the base of the detailed research, results in significant decrease in concentration of this extremely dangerous ingredient in flue gases. Simultaneously the content of CO and other components of incomplete combustion can be significantly decreased. Application of oil (WOE) combustion method is the well-known since long ago [3 – 7]. But there are no the detailed investigations on this method in combination with the state-of-the-art regime and constructive nature protection measures;

• The second aspect concerns the increase in oil combustion reliability at growth of its initial humidity to 20…30 %, that often happens during operation;

• The third aspect is that oiled waste waters can be used as additional moisture. One boiler of TGMP-314 type can provide fire neutralization of 15 t/h of waste waters, polluted by oil-products, even at high (to 5…10%) initial humidity of oil. Of course, such a mode can be recommended as a periodical one. But it will make a significant contribution in water protection. In addition, fuel is saved because of utilization of oil-products, containing in waste waters.

References to § 4.1

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