Part 4

COMPLEX TECHNOLOGIES OF ENVIRONMENTAL POLLUTION FROM THERMAL POWER PLANTS

4.2. Reduction of ash and sulphur dioxide emissions at TPPs

4.2.1. Reduction of ash and sulphur dioxide emissions at TPPs at ekibastuzsky coal combustion

Novik V.V., JSC "European-Asian power corporation";
Khozhatelev M.B., JSC "KazNII energetiki"; Putilov V.Y., MPEI(TU)

The problem of low efficiency of collecting ash from low-sulphur coals in electrostatic precipitators (ESPs) is well-known. It is stipulated by high specific electrical resistance of ash and presence of backward corona in layers of deposits at ESP electrodes, sharply worsening the ash collecting efficiency.

Methods and technologies of backward corona suppression are well-known. They are based on injection of SO_3 micro additives into flue gases [1 – 3]. Unfortunately, in these technologies using of element sulphur or other chemical reagents is supposed. They are enough complicated and expensive.

Electrochemical conversion of sulphur dioxide [4] is well-known. Its essence is that sulphur dioxide in favourable conditions is completely oxidized to SO_3 in the field of a special corona discharge. For this purpose the impulse unipolar corona is the most effective with the length of supplying current impulses of a microsecond range. At high enough values of holding time under such a discharge (6 sec), it was a success in laboratory tests to convert to 90 % of sulphur dioxides [4]. By this, specific power inputs for the process made about 2 W/l of the active zone.

Application of electrochemical conversion for SO_3-conditioning of flue gases in ESPs, collecting ash with adverse electric characteristics, is of a special interest. It is moreover important, that for getting the required quantity of SO_3, in flue gases from combustion even of low-sulphur coal, there is enough amount of SO_2. In addition, in case of partial conversion, needed for ESP, less power inputs are required.

In 90-ties KazNIIE and SFNIIOGAS conducted the works on application of impulse supply of ESP fields for electrochemical SO_3-conditioning of high-ohm ash from ekibastuzsky coal at the industrial ESP of the JSC "EEK". The tests were successful. An opportunity of backward corona elimination inside the filter was shown, but the conversion level of initial sulphur dioxide reached 30…40% out of flue gas composition. Absence of a skip of the obtained SO_3 through ESP meant a real opportunity of the associated partial gas desulphurization.

Afterwards, instead of impulse supply with expensive impulse attachments, KazNIIE offered a system of additional corona-forming electrodes to standard ESP fields. In this system it was suggested to apply a bipolar corona of DC, firing in the natural discrete-focal mode, which represents a quasi-impulse mode by the character of current. This solution promised simplicity and a relative cheapness of the construction.

On this way selection of type and electrodes supply mode was necessary. These electrodes should provide sufficient efficiency of SO_2 and SO_3 conversion, and also the following pilot testing of the method.

4.2.1. Research phase

A task of experiments was testing of efficiency and power inputs for conversion in bipolar corona with different types of electrodes at variation of the initial concentration of sulphur dioxide and holding time of a mix in the active zone.

The tests were conducted at the laboratory desk-size plant. It is intended for passing of air and sulphur dioxide mix through the screen of corona discharge, formed by one corona-forming couple.

It included the chamber with specially oriented corona-forming electrodes, the system of dozing and supply of SO_2 mix with air at normal conditions, the system of collecting reaction products in a skip and reliable infrastructure, providing the controlled conditions of tests and measuring of results.

The plant provided SO_2 concentration in the mix of 0,5 … 10 g/m^3, holding time of a mix in the active zone of 0,5…6 sec; electric characteristics of corona - to 50 kV and 900 mA of DC and AC. Chemical analysis of the gas mix provided measuring of sulphur di– and trioxide separately with permissible SO_2 limit of 0,030 g/m^3 and by SO_3 limit of 0,013 g/m^3.

The following electrode couples were investigated: "spiral-spiral" and "spiral-acicular wire". Similarity with future natural electrodes was not passed.

The size of conversion was defined using gas analysis by decrease in the initial sulphur dioxide in the active zone considering SO_3 in a skip:

$$K_{\text{conv}} = \frac{c^{\text{in}}_{SO_2} - c^{\text{out}}_{SO_2} + c^{\text{out}}_{SO_3}}{c^{\text{in}}_{SO_2}}, \qquad (4.1)$$

In numeral value of K_{conv} a correction on complete filling of the chamber cross section by midsection of the corona zone, was introduced and the conversion efficiency in the chamber was defined, %,

$$\eta = \frac{K_{\text{conv}}}{K_{\text{filling}}} 100. \qquad (4.2)$$

Power inputs were calculated by the discharge parameters of the mixed flow and the corona mode. Tests were conducted in the pre-breakdown corona mode. Power inputs were not optimized.

Some results of the tests conducted for the electrode system "spiral – spiral" at DC are shown in fig. 4.7 (curves *1* and *2*).

One can see that the conversion efficiency can reach of about 25%. By this, its dependence of the inlet SO_2 concentration is increasing. The more sulphur dioxide in the active zone at permanent holding time is, the higher dependence is.

The conversion dependence of holding time τ_n at the same concentration is also obviously increasing.

Minimum power inputs characteristic for the mentioned curves and calculated by the discharge capacity, made 2W/l of the processed gas.

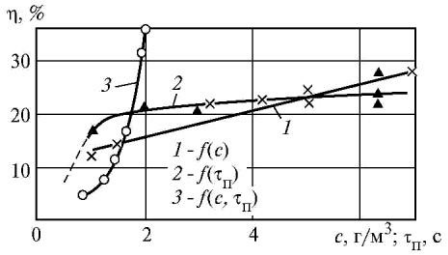

Fig. 4.7. Efficiency of sulphur dioxide conversion versus its initial concentration and holding time in the bipolar corona:
1, 2 — in laboratory plant; *3* — in industrial ESP; с – sec; г/м^3 – g/m^3

4.2.2. Industrial test

The test data were considered at development and creation of a system of additional electrodes for the industrial ESP of Aksusskaya power plant of the JSC "EEK". Administration of the power plant gave ESP №8B, operating more than 20 years. The system was preventively prepared and mounted by employees of the power plant during complete overhaul of ESP at the beginning of 1998.

The system of additional electrodes consisted of electrode sections, forming the screen from bipolar corona at the inlet and outlet of each of four ESP fields of LUK type with 12-meter electrodes. Power to electrodes was supplied from the standard ESP fields. Arrangement of the system of additional electrodes in ESP is shown in fig. 4.8.

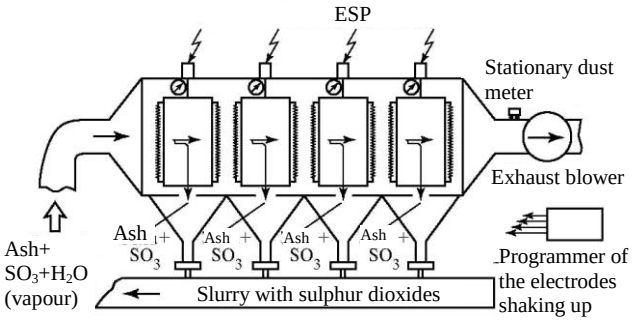

Fig. 4.8. Arrangement of the system of additional electrodes at industrial ESP at Aksusskaya power plant

Such a system of additional electrodes was intended to reduce ash and sulphur dioxides emissions in the industrial ESP. The set purpose is realized by electrochemical conversion of sulphur dioxides from flue gases to sulphur trioxides with their following application for chemical conditioning of deposit layers of the collected in ESP ash. Trioxides (in a form of sulfuric acid), precipitated on ash particles, are bound with alkaline components of ash and evacuated in the standard system of wet ash removal.

In the structure of the system of additional electrodes the total holding time in the active zone of 0,5…0,7 sec was included. The initial concentration of sulphur dioxides was about 2 g/m^3 at sufficient content of oxygen and moisture in flue gases.

The operational efficiency of the system was estimated by decrease in sulphur dioxide and ash content in emissions. The work was conducted in frames of testing the modernized ESP, carried out jointly with the Ministry of Ecology of Kazakhstan Republic.

Comparative tests were conducted. However, direct comparisons of efficiency indicators of the same ESP, switching off the system, are impossible because of constructive points, therefore comparisons were made indirectly.

Relating to sulphur dioxides, measurements of concentration of sulphur di- and trioxides in gas phase were made at the ESP outlet in its two operational modes: with turned-on supply of fields and with dead fields. In case of dead fields the data were considered as the inlet concentration. Besides, in a number of tests, series switching off ESP fields supply with the progressive total of a number of fields, were carried out. The gained data allowed to estimate the joint effect of the initial concentration of sulphur dioxide and holding time in the active zone of the system on the total indicators of conversion. In fig. 4.7 the curve *3* shows these data.

Gas analysis was made according to the certified methodology of KazNIIE.

Relating to ash, concentration at ESP outlet was measured in comparison with the inlet one, calculated by coal composition and boiler loading. Outlet concentration was measured using dust-selected pipes and calibrated and certified optical dust meter of IONG type manufactured by KazNIIE.

In addition to gas phase analysis on sulphur dioxide concentration, pH-factor of ash collected in the fields (from hoppers) and ash supplied to the ESP inlet, were compared during the tests. In separate tests a balance on all the streams of sulphur was made. The total sulphur content was measured in ash samples at ESP inlet and outlet, in ash samples from hoppers, ash scrapes from ESP electrodes. Sulphur content in coal and slag was analyzed. Balance residual did not exceed 10 %.

Based on test materials, interdepartmental commission has fixed the following:

- steady decrease in sulphur dioxide emissions to 32 %;
- achieved level of ash content in emissions of 0,5 … 1,0 g/m^3 depending from the boiler loading in comparison with 1,5 …1,8 g/m^3 before modernization;
- no indications of backward corona in fields (by volt-ampere characteristic);
- conditional decrease in pH-factor of the collected ash approximately by one unit in comparison with ash at ESP inlet (with the following recovery to background standard in wet ash removal system in several minutes).

By test results, the regional agency of the Ministry of Ecology of Kazakhstan reduced the payments for sulphur dioxide emissions for the tested power unit.

At present one more ESP, equipped with the system of additional electrodes, of the same type was put into operation at the power plant. The following system replication is planned.

To this it should be added the following:

- power inputs for the system make about 10 % of standard costs for ESP field supply. In specific expression power inputs for bipolar corona in the system was about 0,2 W/l;
- sulphur content in ash, scrapped from precipitating electrodes in ESP with the system of additional electrodes, in comparison with ash at ESP inlet and scrapes from another ESP without the system of additional electrodes, approximately increased by 50 % and reached 3 g/kg of ash. Such sulphur concentration is not dangerous for ESP electrodes.

Experience of creation and industrial testing of operation of the modernized ESP showed the following:

- a task to improve ash collection with high electric resistance is successfully combined with the associated desulphurization of gases in ESPs, equipped with the system of additional electrodes, in conditions when the initial concentration of dioxide is 1,2 …2,0 g/m^3, and ash composition provides binding of the conversion products;
- the system of additional electrodes in tested type and

conditions, can provide the maximum level of conversion to 35…40%. There is a constructive opportunity to regulate (reduce) this level;

- the system of additional electrodes in tested type, can be applied for replication in other ESPs, which operate in the similar conditions. Nothing prevents from equipping the new ESPs with the similar system at compatibility of conditions and purposes;
- at less concentration of sulphur dioxides in gases, it is possible to use the system only for eliminating backward corona in ESP. Desulphurization will be insufficient in this case. Determination of the lowest limit of dioxide concentration, sufficient for conditioning, is a task of the future investigations;
- at sulphur dioxide concentration in gases of more than 2 g/m^3 and keeping of maximum stage of conversion in the system of additional electrodes, total amount of SO_3 grows and increasing of a probability of ESP electrodes corrosion can be expected. In order to reduce it, there should be applied the supply mode of the system, which decreases the level of conversion to the safety level, or chemical additives can be used, binding the sulphur dioxide excess.

Along with application of electrochemical conversion in ESP, an opportunity of its application only for desulphurization is under consideration. For that, creation of a special unit-converter, conversion products from which should be collected and connected in a wet absorber, is planned in the future.

It should be mentioned that it is possible to construct targeted technological schemes and structures of the system of additional electrodes and the converter.

In process of designing of the system for ESP, development of electrode location scheme seems to be very important, especially their type, length of the discharge period and corona discharge mode. It is obvious, that such issues should be linked with the certain ESP configuration and ash features to bind sulphur trioxides.

During creation of electrochemical conversion unit, the initial parameters of flue gases should be also considered. And configuration of the electrode system is to be targeted to such a level of initial dioxide conversion, at which its products can be assuredly bound either by elements from ash composition, or additives of special reagents. Therefore, even at this phase of introducing the method of electrochemical conversion of sulphur dioxides, its different applications can be seen. Apparently, an area of using the method can be widened and should not be limited by power industry.

References to § 4.2

1. **Conditioning** plants with SO_3 application. Brochures of the firm “Lurgi-Lentjes”, 2000.
2. **Technologies** of SO_3-conditioning. Brochures of the firm “WAHLCO”, USA, 1996.
3. **Technology** of SO_3-conditioning. Brochures of the firm “Research-Cottrell” — EPRICON, 1997.
4. **Mizuno A., Clements I.S., Davis R.H.** A Method for the Removal of Sulfur Dioxide from Exhaust Gas Utilising Dulsed Streamer Corona for Electron Energization // IEEE Trans. on IAS. 1986. Vol. 22. № 3. P. 516—522.