Part 1

AIR PROTECTION FROM POWER INDUSTRY EMISSIONS

1.2. Ash collecting at TPPs

1.2.2. Fly ash collecting technologies at TPPs

1.2.3. Efficient ash collectors at TPPs

1.2.3.1. Electrostatic precipitators at TPP

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Today the main types of ash collectors, applied at coal-fired thermal power plants, are dry ones, mainly, electrostatic precipitators. At the same time, at the newly introduced foreign power units (more than 100 units in the U.S.) a share of bag filters increases. Since only in dry ash collectors the captured fly ash can be widely used as a secondary product without contamination of groundwater and soil, the use of electrostatic precipitators (ESPs) is preferred while reconstruction of the existing thermal power plants, equipped with wet scrubbers. In some countries, the use of wet technologies for particulate matter collection is prohibited at all.

Electrostatic precipitators are apparatuses, ensuring high-effective purification of large volumes of flue gases at minimal expenses for electric supply and overcoming of hydraulic resistance. At the same time tightening of regulatory requirements for purification efficiency at the simultaneous limitations of space, required for ESP location, especially, at reconstruction of the existing TPPs, requires maximum intensification of electrical cleaning and complete use of the apparatus volume.

Russia has an extensive experience in developing and industrial exploitation of ESPs at coal-fired TPPs. All coal-fired power units with capacity of 150 MW and higher are equipped with electrostatic precipitators.

Based on studies, conducted both at bench and industrial plants, a number of ESP generations has been developed, meeting the requirements existed for the period of their installation. In some cases, however, some mistakes in design of ash collecting plants were admitted. In order to save the unnecessary capital expenditures, the excessive velocities of flue gases in ESPs were accepted. This led to the fact that the operational efficiency of these devices was lower than the design one.

During 60-80-ties in the former Soviet Republics more than 700 ESPs were put into operation at coal-fired thermal power plants. The latest generation of ESPs of EGV type, developed in the late 80-ties under the task of the Ministry of Energy of the USSR, met the world level relating to effectiveness, metal and power consumption for that moment. The apparatuses were tested in industrial conditions and confirmed the design characteristics. But for the last 20 years new ESPs have not been constructed. In rare cases, imported ESPs were installed.

A park of ESPs at TPPs of RAO "UES of Russia" now consists, mostly, of the developed in 50-80-ties domestic ESPs and unique samples, developed by foreign firms after 80-ties. The average operational efficiency of ESP park at TPPs of RAO "UES of Russia" is 96,5% or even less.

More advanced ESPs, installed in the last 15 ... 20 years with the electrodes of 12 ... 13,5 m high, have the design efficiency of 98 ... 99,5%. The majority of ESPs with electrodes of more than 12 m high are apparatuses, developed by foreign companies in accordance with the requirements for ESPs, worked out abroad in the late 80-ties.

In design, ESPs, applied in heat power engineering, can be divided into two types:

- ESPs of the European construction with the hammer shaking system of electrodes. A typical example of the European construction are ESPs, produced by Lurgy and Alstom companies;
- ESPs of the English and American design with the upper suspension of electrodes, inductive shaking mechanisms and rigid discharge electrodes with the dispersed centers of the corona ignition. A typical example of the English and American construction are ESPs, produced by BHA and EEC firms.

ESPs of Semibratov factory "FINGO"

At present the JSC "FINGO" (industrial gas cleaning filters) produces horizontal dry ESPs, designed for dust removal of process gases and aspiration air in thermal engineering, production of construction materials, ferrous and nonferrous metallurgy and other industries. The most widely used is EGBM ESP (Fig. 1.33), having the following technical data:

- conditional height of electrodes, mm: 4, 6, 7.5, 9, 10.5, 12, 13.5;
- interelectrode gap, mm: 300, 350 and 400;
- a number of gas passages 8 ... 88;
- a length of electric field, m: 2.56, 3.2, 3.84, 4.48, 5.12;
- a number of electric fields: from two to six;
- performance relating to the purified gas (at conventional speed in the active zone of 1 m/s), thous. m^3/h: 50 ... 1300;
- a temperature of the purified gas, °C: less than 330;
- input dust content of gases before purification, g/m^3: 90.

Two-stage EGD ESPs (Fig. 1.34) are applied in thermal power plants in the limited size of boiler cells. EGD ESPs are one- or two-section units of rectangular shape, having three, four or five electric fields, set in each level sequentially along the gas flow. EGD ESPs have the following technical data:

- conditional height of electrodes, m: 18, 21, 24;
- interelectrode gap, mm: 300, 350, 400;
- a number of gas passages 60 ... 152;
- a length of electric field, m: 3.84;
- a number of electric fields: from two to five;
- performance relating to the purified gas at conventional speed in the active zone of 1 m/s), thous. m^3/h: 650 ... 2000;
- a temperature of the purified gas, °C: less than 160;
- input dust content of gases before purification: less than 20.

Collecting electrodes of EGBM and EGD ESPs are drawn from the S-shaped elements of 640 mm wide. As the discharge electrodes, band-needle electrodes are used. In ESPs domestic and imported supporting-feedthrough insulators, power supplies with the voltage of 80 ... 150 kV, control system "Mefis", "Sapphire", "Iskra", power units "Kraft", "ABB" and "Ador" are applied.

EGBM and EGD ESPs are used in new construction, at reconstruction of existing units, upgrading of existing facilities, as spare parts and accessories.

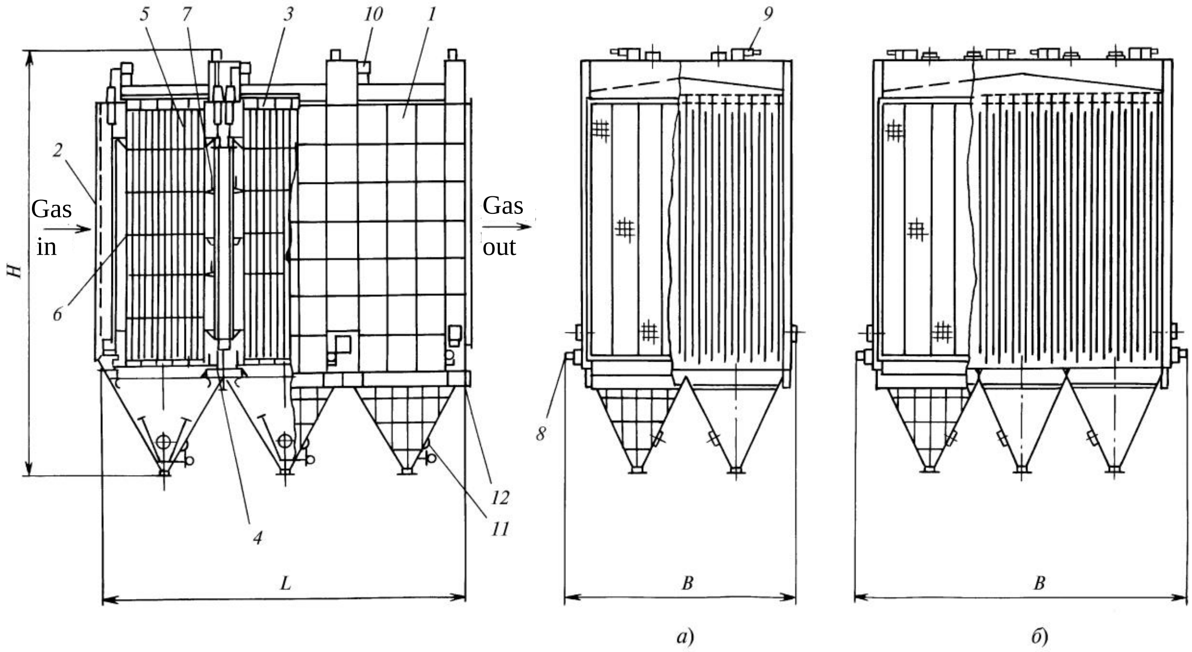

Fig. 1.33. EGBM ESPs:
а – one-section, *б* – two-section, *1* - body, *2* - gas-distributing grating, *3* - collecting electrode, *4* - shaking mechanism of collecting electrodes, 5 - discharge electrode, *6* – suspension frame of discharge electrodes; *7* - shaking mechanism of discharge electrodes, *8* - drive of collecting electrode shaking, *9* - drive of discharge electrode shaking, *10* - conductor, *11* - vibrator, *12* - support

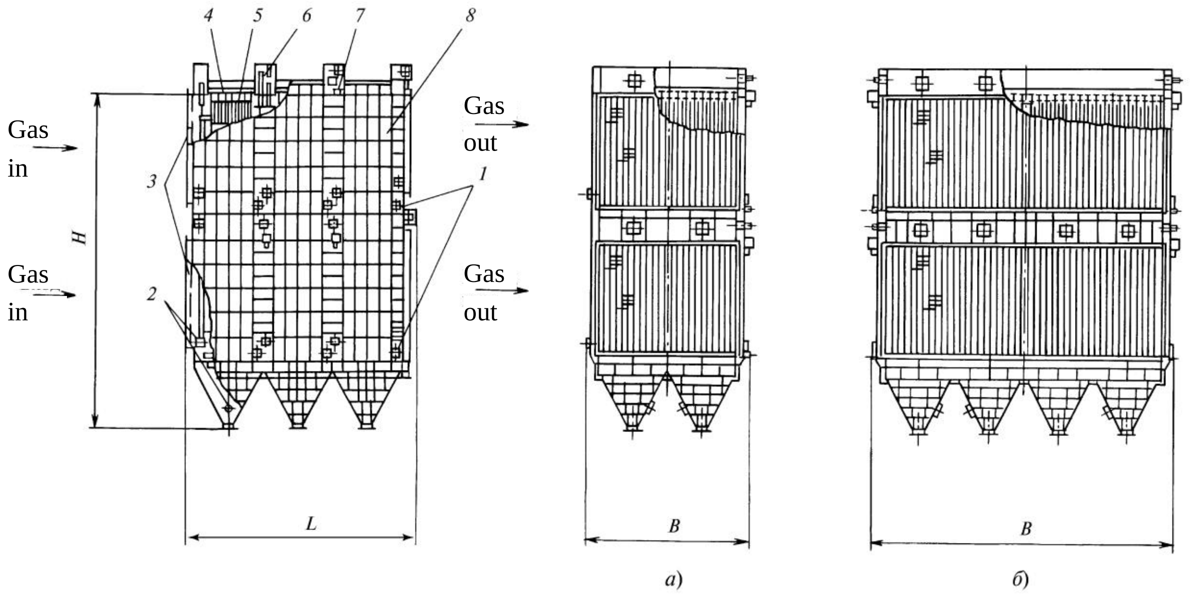

Fig. 1.34. EGD ESPs:
а – one-section, *б* – two-section, *1* - shaking mechanism of collecting electrodes, *2* – service hatch, *3* - gas-distributing grating, *4* - discharge electrode, *5* - collecting electrodes, *6* - shaking mechanism of discharge electrodes, *7* - protective box for power supply; *8* - case

ALSTOM ESPs

More than 4,000 ALSTOM ESPs are installed worldwide at power plants, waste management companies, pulp and paper mills, in the cement industry and metallurgy, including Russia. More than 800 of them are installed at TPPs.

In thermal engineering, as a rule, ESPs with spiral discharge electrodes and interelectrode distance of 400 mm are usually applied. ESPs have the following design features.

The case design ensures gas density and a minimal surface for insulation by locating the load-bearing structures in the inner part of the body. Precipitator is equipped with devices, providing the uniform gas distribution across the cross-sectional area. If necessary, a gas distributing correction is carried out by setting the additional gas-deflecting plates.

Collecting electrodes are made of a sheet steel of 1,25 or 1.5 mm at a special rolling mill. Rigidity provision is a main purpose of the special design of edges of the precipitation elements. Connected in series, the collecting elements form a series or a plane, forming an electrostatic field. These individual elements are rigidly and securely mounted on the joint upper and lower beams.

A system of collecting electrode shaking is designed to ensure the desired impact on all plates. Each plate is attached by bolts to the respective shaking beam. This connection provides a maximum transfer of impact energy when the falling hammer strikes the appropriate shaking beam. The system uses the falling hammers, mounted on a horizontal shaft like a fan, one hammer on the shaking beam. Since the shaft rotates slowly, each hammer reaches the top position and falls, striking the appropriate shaking beam. Thus, the shaking impact is distributed over the entire range of precipitation elements. Shaking mode can vary in a wide range.

All parts of the shaking units are easily accessible for inspection and are placed in a free zone over the ESP field. Acceleration at any point in the system of collecting electrodes corresponds to the values, determined during laboratory-scale tests in ALSTOM. When assessing the collecting efficiency and operation of the shaking mechanisms, a total precipitation area, shaken for a time, is to be taken into account. The greater is this area, the higher is the re-entrainment of dust from the gas stream. ALSTOM shaking system ensures a very small shaking area for one stroke. This increases the overall collecting efficiency and prevents from multiple emissions from the chimney. Filters are equipped with high-speed drives with a turnover time of 30 seconds or less, which reduces the total time of multiple emissions with shaking and allows efficiently managing the electric mode at shaking.

A *system of discharge electrodes* is suspended on four insulators. The suspension system has a boxed structure, which maintains the unchanged configuration. ALSTOM construction is designed so that each system is suspended over the upper corners outside the collecting electrodes. No part of the suspension system is jutting out of the top and bottom edges of the collecting electrodes.

In the frame cross section, suspension brackets are round or rectangular. A purpose of this design is to reduce the electric field in these areas to a minimum to prevent breakdowns. The discharge electrodes themselves are suspended completely in the interelectrode space, and are far enough from the edges or protrusions of collecting electrodes. The entire system of discharge electrodes is completely fastened and forms a rigid boxed structure. ALSTOM system of discharge electrodes is mounted and adjusted on site inside the body, which provides a high accuracy of inter-electrode distance in the assembly process. This eliminates a need for the stabilizing or guiding elements.

Discharge electrodes are shaken by the falling hammers, mounted on a horizontal shaft. These hammers strike the special shaking beams, mounted on top of the frame of discharge electrodes. Thus, all the vibrations caused by falling hammers, are transmitted to the discharge electrodes. This shaking mechanism operates in each section, fed from a single power supply unit. The drive mechanism is arranged through an insulating shaft and is located at the top of the precipitator. Work of the motor-reductor runs EPIC-III controller, which provides the optimal shaking. This mode can be adjusted during commissioning. In case of change in operational conditions, the mode can be easily changed.

Each field of electrodes is supported by four insulators, located in the insulator boxes. The boxes are equipped with hinged lids that provide an easy access to insulators for inspection and maintenance. In each box there is a device, allowing temporarily to suspend the system of discharge electrodes, in case an insulator is to be replaced.

To maintain the temperature above the dew point, an insulator heating system is set, which provides supply of warm air into each insulator box. Special pipes-screens are installed below the insulators to reduce turbulence and reverse flow of gas and they help to maintain the cleanliness of the supporting insulators.

ESPs are equipped with *microprocessor control system* EPIC-III, which provides:

- significant emission reduction;
- considerable energy savings;
- flexibility and reliability through dual means of communication;
- optimization of the shaking frequency to extend the filter life and reduce a probability of the unplanned outages;
- easy ESP modernization;
- continuous monitoring of power consumption and current-voltage characteristics.

"Condor Eko" ESPs

On the basis of personal experience of the last generation of EGV EPPs, as well as international experience, VTI and the holding group "Condor Eko" have developed a highly efficient, dry, compact EGSE ESP for technically re-equipping and for the newly built Russian thermal power plants.

The design of EGSE ESPs (Fig. 1.35) was a result of a comparative analysis of apparatuses construction of foreign and domestic producers, as well as of the joint research and development activities. A main feature of EGSE ESPs is application of the collecting electrodes up to 18 m high, the discharge electrodes with the reduced voltage of corona discharge ignition, as well as the top position of discharge electrode shaking system.

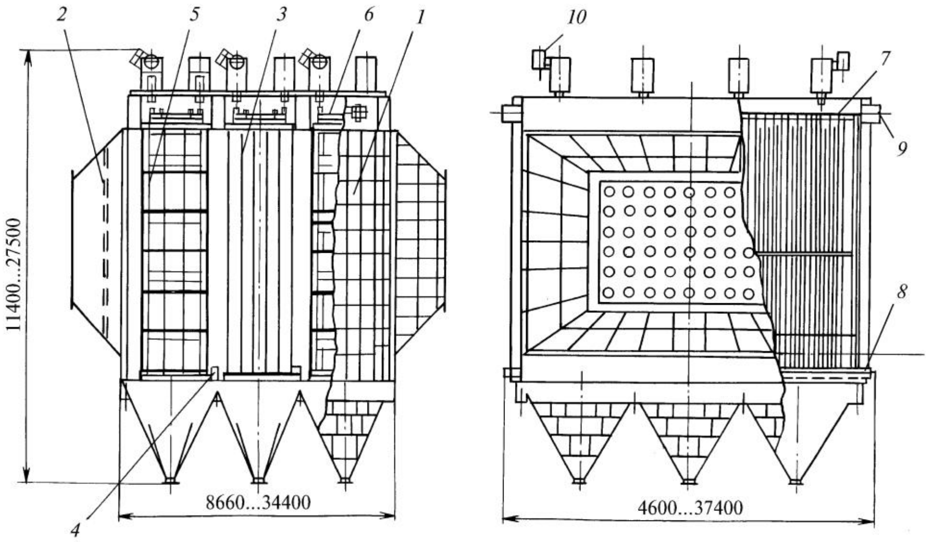

Fig. 1.35. EGSE ESP:
1 - case; *2* – gas distributing system; *3* - collecting electrodes; *4* - shaking mechanism of collecting electrodes; *5* - discharge electrodes; *6* – frame of discharge electrode suspension; *7* - shaking mechanism of discharge electrodes; *8* - drive of collecting electrode shaking mechanism; 9 - drive of discharge electrode shaking mechanism; 10 - current supply

Application of electrodes of 18 m high opens the new possibilities in developing ESPs, providing fulfillment of the European requirements for the residual dust content in flue gases up to 30 mg/m^3 and for the location of ash collectors, substituting the existing small-scale ESPs and wet scrubbers. In addition, it avoids the complicated two-tier layout of ESPs at the new, large-capacity power units such as a new one of 800 MW introduced at Berezovskaya SDPP.

As the discharge element (Fig. 1.36) in this design the element with lateral spines, reduced voltage of the corona ignition and dispersed centers of the corona discharge ignition is applied. A feature of these corona electrodes is a double reduction of the corona ignition voltage, which increases the effective drift velocity of particles as well as stability of ESP operation. This is especially important for high-ash coal and the coal, burnt in slag-tap boilers with a low content of volatiles. A new construction of shaking units and the upper placement of shaking mechanisms of the discharge electrodes reduced the inter-floor gaps and dimensions of apparatuses. A design of electrode systems and their shaking mechanisms increased the height and a number of precipitation elements in the same electric fields.

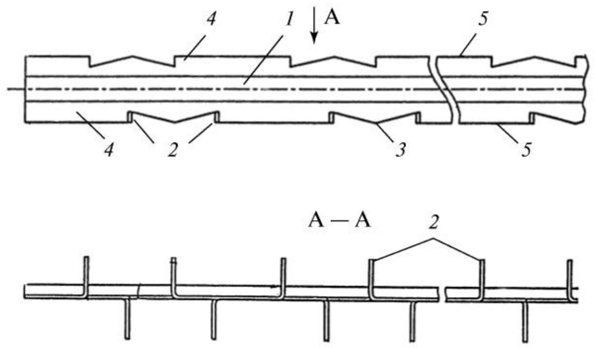

Fig. 1.36. Discharge electrode with additional points of ignition: *1* - shaped central part of the element case; *2* - corona tips, bent, *3* - corona tip in the element case plane with the greater angle at the apex compared to bent tip ; *4* - flat edge sections of the element body, 5 - end lines (planes) of flat edge sections

Quite new units in the presented EGSE ESP are drives of the corona and collecting electrodes. In the drive an Italian reductor, a domestic electric motor and a Japanese control system are used. This combination of the used components allowed to obtain the drive with the regulated rotation speed of the shaft, with adjustable start of the motor and, most importantly, realize for the first time in our practice the motor, protecting from overloading when jamming of the shaft shaking mechanism.

Upper section of the ESP body is significantly changed, which considerable improved the system maintainability and ensured a steady temperature mode in the insulator boxes.

In order to reduce the metal consumption, the increased to 400 mm interelectrode distance is used.

A system of automatic control of electric power supply greatly influences the efficiency and stability of ESP performance. Taking into account that a large part of Russian thermal power plants are coal-fired ones, fly ash from which has the increased electrical resistivity (IER), at the new ESP a microprocessor control system of power supply is installed. The system is able to optimize a power supply mode and implement the intermittent power supply, which is particularly effective when collecting the ash with high IER.

Microprocessor control system MCS II continuously automatically analyzes electrical parameters of the electric fields, optimizes the operation of supply units and controls the operation of shaking mechanisms.

The main advantages of the control system MCS II are as follows:

- operation of supply units in the mode of intermittent or continuous power supply, depending on ash resistivity. In the presence of reverse crown, the optimum cleaning is ensured by intermittent power supply mode, parameters of which are automatically selected by the controller;
- regulation of the voltage increase rate and delay time after the break to maintain the maximum level of voltage in the electrode system;
- immunity of the measuring circuits;
- a function of the controller, allowing to reduce the electrode voltage at operation of shaking mechanisms, which

is a significant reserve of ESP efficiency increase;

- ability to operate as a part of the automated process control system of the power unit to collect and save all the information on ESP operation.

ESP can be equipped with high-frequency electric power supply units, located on its roof without the need for a special room for power supply unit, which is especially important when replacing the existing ash collectors.

EGSE ESP has the following advantages compared to the existing devices:

- precipitation area (in the volume of specified body) increased by 35 ... 50%;
- residence time of particles in the active zone increased by 35 ... 40%;
- specific metal consumption (per unit area of precipitation) decreased by 20%.