Part 1

AIR PROTECTION FROM POWER INDUSTRY EMISSIONS

1.4. Reduction of vanadium- and benzapyrene-containing emissions

1.4.1. Brief description of technologies of vanadium-containing emission reduction at liquid fuel combustion

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At liquid fuel combustion in boiler plants, in addition to gas combustion products, solid substances are generated. The last consist of mineral fuel components and organic substances - products of incomplete combustion (such as soot, coke, benzapyrene). Mineral components, mainly, include metal compounds: vanadium, nickel, iron, aluminum, cobalt, etc. An average composition of mineral part of domestic oil in oxide equivalent contains: sodium oxide — 20…40 %, silicon oxide — 5…20 %, vanadium pentoxide — 20…30 %, magnesium oxide — 3…10 %, iron trioxide — 3…20 %, sulfur trioxide —20…40 %.

About the composition of solid particles, emitted into atmosphere at oil combustion, it can be judged, at a first approximation, by the composition of deposits, removed from the tail heating surfaces of the boiler. As an example, a chemical structure of deposits from lateral streamlining pipes of boiler air heaters at oil combustion with ash content of 0,1% and sulfur of 3 % [1] is shown below:

Boiler type	Content of compounds, % (by mass)							
	CaO	MgO	Fe_20_3	Na_20	SO_3	$Si0_2$	V_2O_5	Combustibles
PK-47	3,6	0,1	4,1	14,8	37,4	1,7	16,2	21,9
TGM-84	2,2	0,2	1,2	14,4	31,2	2,6	7,6	34,1

In Russian power engineering oil-fired boilers have no installations of flue gas purification from solid particles; therefore practically all above-mentioned components are emitted into atmosphere, except for their insignificant part, which is accumulated at the boiler heating surfaces. For oil ash the vanadium is taken as the monitoring indicator and by its concentration in ash the maximum permissible level is determined. As a result in a number of cases gas- and oil-fired TPPs can't assure meeting of sanitary norms relating to emissions of solid particles. In cities the mentioned problem is sharpening because of the background pollution from other industrial sources as well as by limitations by the chimney height.

In this situation the only possible option of oil ash emission reduction is to install gas purification equipment at the boilers. First of all, as a nature protection measure, cleaning of flue gases from solid products of oil combustion allows solving another very important problem, that is, utilization and using of valuable wastes from power generation in other industries. Some domestic types of oil contain vanadium ash in the amount of 30% in V_2O_5 equivalent. This is a very high parameter for vanadium-containing raw material. Taking into consideration a concentration of other microelements in oil ash, it could be beneficially used in metallurgy in process of production of steel alloys. Besides, these measures, directed to minimizing soot emissions with oil combustion products, simultaneously solve problems relating to benzapyrene concentration reduction in atmosphere, as well as other carcinogenic, polycyclic aromatic hydrocarbons.

By now a significant experience has been gained abroad in the field of introduction and operation of different devices for collecting solid products from oil combustion. Basic apparatuses of such kind are the following:

- Electrostatic precipitators;
- Bag collectors;
- Mechanical collectors;
- Combinations of the above-mentioned devices.

Electrostatic precipitators for collecting the oil ash have a number of features in comparison with filters applied at coal-fired TPPs. Main differences are: stricter requirements for power supply units, high voltage insulators, a system of ash unloading, etc. To prevent from deposits of the collected particles, inside the insulators ventilators are installed, creating an overpressure in the insulator compartments to avoid the electric breakdown. Considering the increased adhesive capacity of solid particles, formed at liquid fuel combustion, their hygroscopic properties and the increased ability to be compacted, electrostatic precipitators are equipped with heaters usually with electric ones to raise a gas temperature above the dew-point temperature at a boiler start-up. For reliable removal of ash from hoppers, electric and steam (coil) heaters of hoppers are installed under thermal insulation.

Significant obstacles at electrostatic precipitator operation in case of combustion in oil-fired boilers are connected with pickup of solid particles. To avoid this phenomenon, ammonia is sometimes injected into the gas flue before ESP. In Japan the majority of installations are equipped with the similar devices.

To avoid accumulation of the collected particles in hoppers under ESPs, such particles are necessary to be continuously removed from hoppers pneumatically or mechanically. During the operation it is very important to provide a safe sealing of the hopper flanges because at air inflow soot can fire spontaneously.

At the pickup of particles to electrodes and other elements, when in process of shaking up it's impossible to remove the collected particles completely, a degree of their collecting reduces. Characteristics of ESPs restore as a result of water washing of electrodes, as well as gas-distributing lattice and hoppers. According to the data [1], an efficiency of collecting the solid particles by ESPS reaches 95% at oil firing. Injection of some additives into oil affects ESP operation negatively. The efficiency of its operation depends in this case on a quantity of the additive, and reduces to 65…87 %.

Application of *bag filters*, usually placed behind the smoke exhausters of boilers, is rather effective in case of oil ash collection. Flue gases enter the upper holes of hoses, they are filtered and pass out through lateral surfaces of the filtered cloth. At gas flue ducts the dampers are provided, which allow to shunt flue gases in process of gas combustion in the boiler. Before entering the gases into the filter installation, an alkaline additive is injected into them for SO_3 neutralization.

Hoses are usually purified once an hour by changing a direction of gas streams during 1 minute or so (section by section) by fans, sucking out the filtered gas back through lateral surfaces of the hoses into their open bottom butts. To protect the hoses from an excessive cloth inflexion during purification wire rings are installed along their inner surface. Back-

ward gas stream discharges a part of the collected ash, which is then removed using a hydraulic system. Filtration speed is about 0,3 m^3/min per 1 m^2 of the filtering cloth at the gas temperature of 125^0C in case all sections are in operation and about 0,34 m^3/min per 1 m^2 in case of shutting down of one section for blowing off. The collecting efficiency of solid particles can be of 95 % at application of bag filters.

In a number of countries at combustion in oil-fired boilers *mechanical collectors* are more widely applied as the cheapest ones in construction and the simplest in operation (though as for efficiency they give a place to other types). Mostly for these purposes cast and welded battery cyclones made of construction steel with the element diameters of 152 …305 mm are applied. Apparatuses with the element diameter of 254 mm are used at TPPs with chimneys of 120 m and even higher. Lower chimneys usually require the increased collecting level, and since the cyclone efficiency is connected with their sizes, elements with smaller diameters in these cases are applied.

One of essential obstacles during the cyclone operation at combustion at oil-fired boilers is deposits of the collected particles in elements which after some time leads to efficiency deterioration, as well as to growth of aerodynamic resistance of the apparatus. To prevent from such deposits, the devices are equipped with washers.

Washing the apparatus during 24 hours ensures its whole purification. For washing the water with pressure of 0,7 MPa is used.

During the cyclone operation when domestic liquid fuel is burnt, it comes about 300 mg/h of the collected particles per one element. At that aerodynamic resistance of the apparatus is about 800 MPa, the recommended temperature of flue gases before the apparatus is about 200^0C. The particle collecting efficiency varies from 70 to 90% that provides the content of solid particles in the leaving flue gases of about 50 mg/m^3. Considering the battery cyclones as one of ash collector options, it should be taken into account that the boiler load change affects their operating efficiency. Consequently the battery cyclones are not recommended to apply where great fluctuations of boiler load are supposed (for example, for urban industrial-heating boiler-houses). At the same time these apparatuses are the cheapest and don't require highly qualified personnel.

A separate and a rather complicated task is removal of solid particles from hoppers of ash collectors, generated at oil combustion. It is explained by the following features of the collected particles: their hygroscopic properties, loss of flowability at temperatures lower than 150°C as well as a high content of combustibles.

In foreign installations for this purpose pneumatic and hydraulic systems are applied. In pneumatic systems for conveying the collected particles air with the temperature not lower than 150^0C is used. In pneumatic system there is a valve with the upper rotating lock of a disc type that supports a disconnection of the collector hopper and the upper chamber, and there's also a lower lock, separating the chamber from the conveyor. A system operates as follows. First the upper lock is open and the collected particles fill the upper chamber. After some time the upper lock is closed and by a leveling valve a pressure in the upper chamber rises up to the value that slightly exceeds a pressure inside the pipeline required for conveying. After the pressure adjusting in the upper chamber the lower lock is open and its content enters the pipeline. Then the lower lock is closed and in a given period of time the whole cycle is repeated. Disadvantages of the system with locks are: a great amount of moving elements, complexity of power systems for controlling the consecutive lock operation, possible air leakage into the collector hoppers that can lead to spontaneous ignition of the collected particles.

In the most effective pneumatic systems injectors are applied. The compressed air under overpressure of 0,3…1,0 atm (30…100 kPa) passes through a nozzle and generates vacuum in the chamber that ensures supplying of the collected particles into the hopper. The advantage of this system with injectors is higher reliability because of elimination of moving parts and complete prevention from entering the conveying air into ash collector hoppers. The most essential disadvantage is the increased air flow rate (2…3 times higher than in systems with air locks).

Systems under pressure with a rotating star-shaped feeder for conveying the collected particles from hoppers into the pipeline are applied more seldom. The feeder consists of the rotating disc in a shape of the star. The feeder is connected by its upper flange with the collector hopper, and by its lower flange – with the pipeline for conveying. The collected particles under gravity enter the rotor cuts and in process of its rotation they are transported to the pipeline. Overpressure of the heated air in such systems is about 0,2 atm. Limited appliance of such schemes is explained by a risk of sticking of the feeder cuts as well as by air penetration into the collector hopper.

Other applied pneumatic systems are ones, operating under depression. A valve is needed for uniform removal of the collected particles from the hopper and for their input into the conveying line. The conveying air is fed into the system by special valves, set at both sides of the main valve. Depression is created by air blowers (or gas blowers, when the transporting agent is flue gas), located after the hoppers. The collected particles are separated from the conveying air inside the cyclones and accumulated in a special collector (hopper), from which they are discharged into autos or sacked.

Hydraulic systems for removal of the collected particles are applied rather seldom. In this case the collected material from hoppers is poured into reservoir, which is filled with water, and then the material under pressure is moved into settling reservoir. As the transporting environment, water fed by the pump, is used. The material, accumulated in the settling reservoir, is taken by the bucket elevators and loaded into autos. This method requires a great amount of water and means of its purification.

In the USA in case of small-capacity boilers (to 20 t/h), unloading of the collected particles from hoppers directly into plastic bags of high durability is practiced. The bags are separated from hoppers by the system of sliding dampers and by the chamber for material cooling to the temperature, permissible for plastic.

Because of great carbon content in the collected material in some schemes there is a return of the collected particles for their reburning.

References to 1.4.1

1. **Novoselov S.S.** Purification of flue gases from solid particles at oil burning. M.: SPO Souztechenergo, 1979.