1.5. Technologies of organic fuel combustion at TPPs with the lowered level of harmful emissions into atmosphere

1.5.4. Cyclone primary furnace as a tool for reduction of harmful emissions into atmosphere

1.5.4.1. Cyclone primary slag-tap furnace

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Another technology designed to minimize harmful emissions into atmosphere from coal burning is the so called TRW combustor - the original cyclone primary slag tap furnace. Special features of this technology can be found in domestic [1, 2], and American sources [3, 4]. A pilot plant shown in Fig. 1.65 was used by personnel of the American company TRW (California) to work out optimal features of the combustor.

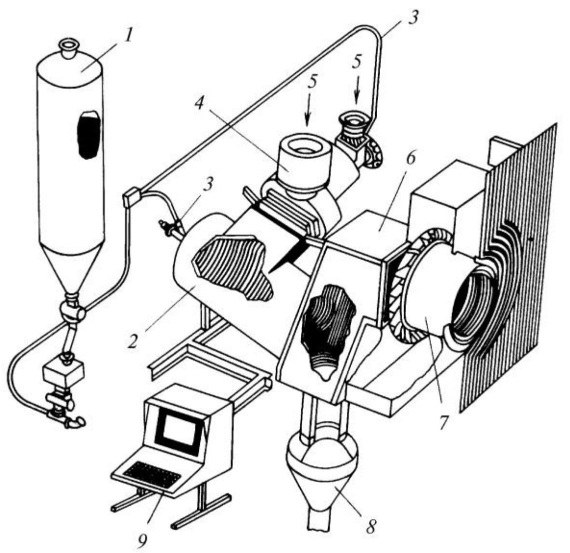

Fig. 1.65. TRW combustor: *1* — pulverized coal hopper and high-concentration supply system; *2* — cyclone chamber; *3* — coal dust inlet; *4* — precombustion chamber; *5* — air; *6* — joining case; *7* — secondary burner; *8* — slag removal hopper; *9* — controlling system

The installation consists of the pulverized-coal hopper, high-concentration dust supply system, compact cyclone slag-tap combustor, in front of which there is a precombustion chamber to warm up the air. Incomplete combustion products from TRW combustor enter the secondary burner through the short joining case and then to the main boiler furnace.

A main difference of TRW combustor from horizontal and vertical primary furnaces, applied at power plants in the CIS countries in 70-ties, is a precombustion chamber, in which a part of fuel and air with a temperature of 38° to 260°C are fed. As a result of combustion of this part of fuel a gas and air mixture with a temperature of about 1000°C is formed. These hot gases are tangentially fed into the cyclone chamber and the rest of the fuel (as coal dust with R_{74} = 30%) is fed axially. Constructive features of the chamber guarantee combustion of the most part of fuel in comparison with the domestic horizontal cyclone primary furnaces, in which the crushed coal was primarily burned at the dross.

In 1984 a combustor with capacity of 12 MW was adjusted to one of the boilers in the technological boiler-house of TRW plant in Cleveland. Before in the boiler oil was burned, therefore, in addition to the combustor, it was also needed to mount the coal grinding and transportation systems at the boiler. The core program of actual tests took 4000 hours at combustion of bituminous coal from Ohio (W^r = 4 %; A^r = 8,5 %; V^{daf} = 41 %). Then the installation, burning other types of coal, including coal-water slurry with W^r = 31,7 %, was tested. The combustor worked about 12 thousand hours.

Tests, held during hard coal combustion, showed that am efficiency of slag removal varied from 80 to 95 %, nitrogen oxide concentration in combustion products after the combustor (that worked with α = 0,7…0,9) comprised only 273 mg/m^3 (under standard conditions and at α = 1,4). Calcium, containing a sorbent agent, was supplied from a special bin into the transition case behind the combuster in order to reduce SO_2 emissions. Tests revealed that SO_2 emissions into atmosphere were lowered by 55%.

Positive experience of Cleveland combustor and extra enhancement of some units let the authors to start a full-sized installation, designed for power boilers. In December 1989 Ministry of Energy of the USA (DOE) included another project, called "Healy Clean Coal Project" into the program aimed to creation of new technologies for clean coal usage in power engineering (CCT-III). The project presupposed building of a coal Healy TPP in Alaska. Since Healy TPP is located near National Park and Denali reservation it was urgent to take all necessary measures to lower harmful emissions into atmosphere. It was decided to equip a demonstration block of the Healy TPP of 50 MW with the coal-fired boiler and two TRW combustors of 102 MW each. In addition to the first stage of desulphurization (feeding lime into combustors) it was decided to install a wet-dry absorber, spraying an active sorbent, right behind the boiler after a tubular air-heater. (Fig. 1.66). Cloth filters, on the surface of which further interaction of SO_2 and the sorbent was supposed to occur, should be the third stage of desulphurization.

The demonstration project was aimed at the effective combustion of local coal with total desulphurization to 90% and providing emissions into atmosphere less than 0,086 g/mJ (235 mg/m^3) for nitrogen oxides and 0,00645 g/mJ (16 mg/m^3) for particulate matter.

Design work started in July, 1990, but only in November, 1991 the agreement between all the participants was signed. Total costs under this agreement estimated $242,000,000 $117,300,000 of which (approximately 48 %) was invested by DOE, the rest $124,700,000 (approximately 52 %) was invested by the interested organizations: Administration of Alaska, coordinating industrial development and export; Golden Valley Electric Association cooperative; Stone and Webster engineering corporation; TRW Inc. - supplier of coal combution technologies; Babcock & Wilcox Company - desulphurization technologies supplier and Usibelli Coal Mine Inc. - coal supplier. Coal mixture was the main fuel. The mixture consisted of 35% of semi-bituminous coal from Usibeli coal mine with a sulphur content of 0,2% and 65% of residues from this coal benefication.

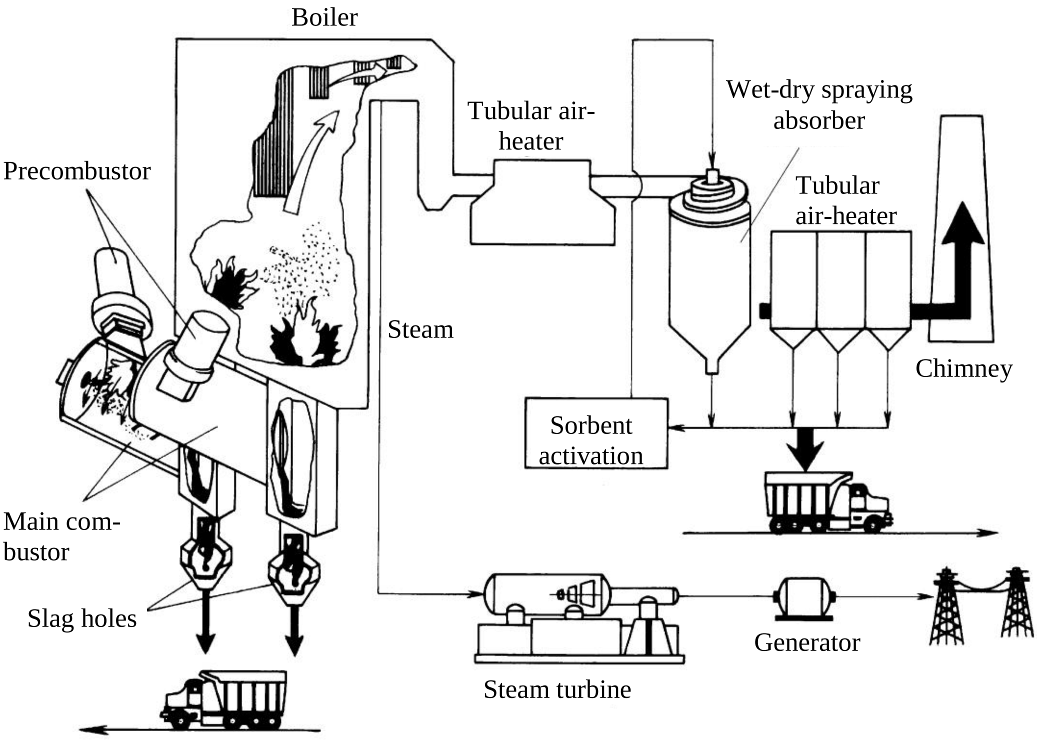

Fig. 1.66. Demonstration boiler with TRW combustors, installed near power unit #1 of Healy TPP (Alaska, USA)

Each of the combastors was rather big in size: external diameter is 2,7 m, length is about 4,7 m. Precombustor - a primary furnace, in which 25...40% of fuel was fed, made 1,6 m in diameter and had the same length. At the combustor outlet facilities for removal of liquid slag and combustion products into the bottom of the boiler furnace were arranged. Here injection of the sorbent for a partial binding of sulfur dioxides (the first stage of desulphurization) was arranged.

Technical documentation needed for Healy demonstration project was ready in November, 1993, but construction began only in May, 1995. Power unit construction was finished in November, 1997. The boiler with TRW combastors and desulphurization system was put into commercial operation in January, 1998.

Sustained studies, held during non-stop operation of the boiler during 12 days and nights showed that specific NO_x emissions comprise 0,108 g/mJ, and SO_2 emissions comprise 0,034 g/mJ, that corresponds to NO_x concentrations of about 295 mg/m^3 and SO_2 concentrations of about 93 mg/m^3 (in terms of $\alpha = 1,4$).

Maximum permissible emissions (MPEs) of sulfur dioxide according to local standards comprised 0,043 g/mJ, which is approximately 12 times lower than all-national MPEs for the U.S. Nevertheless, the accepted system of furnace gas cleaning combined with TRW combustor let meeting these extremely tough standards.

By the end of the first year of operation the boiler worked for more than 4900 hours. During this time 56 thousand tons of a mixture of semi-bituminous fuel and coal benefication wastes were burned in the combustors. As a result of this, 231 million kW·h of energy was generated. The installed capacity use factor of the unit comprised 44%.

During the scheduled outage in January, 1999 minor reconstruction of one of the combustors was made in order to minimize slag accumulation in the precombustor and combustor. Moreover, guide blades were installed before the ash collector in order to minimize wear in the cloth filter.

Personnel, involved in the project, presented a final report in 2000, but it was decided to continue an operational monitoring over the efficiency of boiler work and a level of emissions into atmosphere until November, 2001.

The studies showed that complex technology checked at Healy TPP can be used in power and industrial boilers; it can also be adapted to boilers under construction and old boilers being modernized. In the last case a problem of coal combustion at gas-oil boilers can be solved as combustor provides a high level of ash collection even before the products get into the combustion chamber.

Preliminary estimations showed that 16 combustors with capacity of 73,3 MW each are needed to transfer the unit with capacity of 410 MW from gas or oil to solid fuel. If the difference of gas and coal comprises $56 per ton then the cost of such reconstruction will pay off in three years [5].

According to recent information TRW company has already signed a licensing agreement with China for the delivery of combustors for coal-fired boilers.

References to part 1.5.4

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