Part 1

AIR PROTECTION FROM POWER INDUSTRY EMISSIONS

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

1.5.1. Combustion of solid fuel in fluidized bed boilers

1.5.1.3. Combustion of solid fuel in fluidized bed boilers under pressure

Kotler V.R., Ryabov G.A.; JSC "VTI"

Recently research efforts relating to fluidized bed furnaces under pressure (FBP) has grown up. The basic advantage of such furnaces is in a possibility of the combined cycle realization, when steam, generated in the boiler, is utilized in the steam turbine, and combustion products with the increased pressure are used in the gas turbine. Such a scheme increases the thermodynamic efficiency of the cycle and also allows at a greater extent reducing the overall dimensions of the furnace units and lowering pollutant emissions into atmosphere.

Manufacture of FBP-boilers allows cutting their overall dimensions almost by 60% in comparison with the traditional boilers. As a result, the capital investment economy will be of 10%, and time needed for power plant construction will be cut down by 25%. According to estimations of "Combustion engineering" and "Lurgi" personnel a power unit of 250 MW with six modules can be just fully constructed in plant conditions, that will allow minimizing the erecting work volume at the place of TPP construction.

In recent years in a number of countries technical and economic comparison of different methods of ecologically sound solid fuel processing has been conducted. It showed the prospect of development of technologies: FBP combustion and gasification in combined-cycle plant. At the moment in respect to capital investment, risk degree and dispatch of industrial implementation, a technology of solid fuel combustion in FBP is preferred. By the assessment of Western German experts, such a variety of fluidized beds has no limitations for the unit capacity of the constructed modules, appropriate to the atmospheric bed combustion technology.

The simplest and economically most efficient process of FBP fuel combustion is arranged in combined-cycle plants (CSPs) under the scheme, showed in Fig. 1.61. The required air is supplied into the bed by compressor K of the gas turbine plant (GTP) under pressure of 1,0…1,5 MPa; combustion products after ash purification are expanded in the gas turbine GT and make a yield. Heat, released in the bed, and exhaust heat from the gas turbine, are utilized in the steam cycle[2].

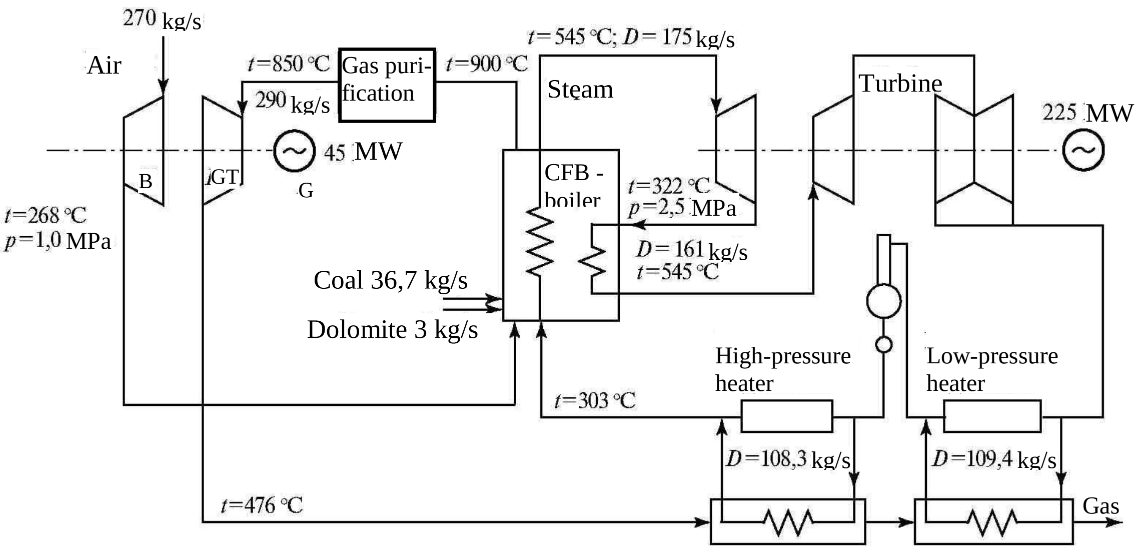

Fig.1.61. Combined-cycle plant with the fluidized bed boiler under pressure of 270 MW

Arrangement of the process under pressure, keeping all the advantages, typical for FB coal burning, results in significant increase in the unit capacity of steam generators and reduction of their overall dimensions at a greater coal combustion and sulfur binding.

Advantages of CCPs with FBP are complete combustion (with an efficiency of 99%) of any coal type, high heat transfer factors and small heating surfaces, low (750…950 in average 850^0C) burning temperatures and owing to that small NO_x emissions (less than 100 mg/MJ or 200 mg/m^3), a possibility to add sorbent into the bed and bind 90…95% of the coal sulfur, elimination of slagging and discharges as well as dry wastes, small space required (particularly, because of elimination of flue gas purification system), a possibility of unit-complete delivery (in a factory-assembled state) of the greater part of equipment and an opportunity of module construction with cutting of its cost and terms in comparison with the units installed at traditional coal-fired TPPs, equipped with pulverized coal combustion boilers.

Today in foreign countries six industrial CCPs with FBP with capacity of 70… 135 MW, burning different types of coal, are under operation. Their technical parameters are shown in Tab. 1.29. In 1999 in Japan the unit of 350 MW was put into operation. Its design efficiency is about 45%.

The results of operation of CCPs with BBP at power plants, burning different types of coal, testify that technologies and equipment applied are rather operative, principally simple, could be well-managed and repairable.

For the operating CCPs with BBP a wide range of the work load of 40 to 100% is characteristic. The required ratio of air flow rate to air pressure is provided by specially designed GTPs. Their feature as well is operation at the dusty gases, purified only in cyclones, which is ensured by some reduction of velocities in the wheel space of the turbine and application of the protection coating.

Basically CCPs with BBP of the standard construction can combust different types of fuel without any variation of power, efficiency or increase in pollutant emissions. It allows easily adopting CCPs in case of fuel type change in process of operation, especially if such an opportunity has been taken into account during design of auxiliary systems.

"Pantophagy" of CCPs with BBP is explained by the following. The burning process occurs in a deep and dense bubble FB, mainly, consisting of an inert material, in which less than 0,5 % of burning particles is contained.

Good ecological parameters were achieved at all CCPs. Binding 90…95% of sulfur was provided at the sorbent dosing at the ratio of Ca/S=1,3…2,0. Ways of the further considerable increase in efficiency of CCPs with FBP (to 52%) have been studied.

In the Russian Federation estimation studies for creation of FBP unit, are being performed, but a low price and availability of natural gas make it noncompetitive for the domestic power sector.

Table 1.29. **Industrial CCPs with FBP**

Indicator	Country, power plant					
	Sweden, "Vartan"	USA, "Tidd"	Spain, "Eskatron"	Japan, "Vakamatsu"	FRG, "Kot-bus"	Japan, "Karita"
A number and type of GTP	2×GT-35P	l×GT-35P	l×GT-35P	l×GT-35P	l×GT-35P	l×GT-140P
Total capacity of GTP, MW	33	16,5	16,6	14,8	13,7	70
Capacity, MW:						
of steam turbines	108	56,5	62,4	56,2	53,9	290
of CCP	135	71,6	76,4	71,0	62,0	350
CCP efficiency, %	34,3 (89)*	36,7	36,4	39,4	30 (71,6)*	43...44
Fresh steam pressure, MPa	13,7	9,0	9,4	10,3	14,2	25,0
Superheated steam temperature, °C	530	495	513	593/593	537/537	566/566
Steam rate, t/h	435,6	200	216,4	—	—	—
Coal	coal	coal	lignite	coal	brown coal	coal
combustion heat, MJ/kg	22,4...29,0	22,5…27,0	7...17	22,5…27,5	19,0	19,4...29,0
ash content, %	8...21	12...20	23…47	2...18	5,5	2...18
moisture content, %	6...15	5...15	14...20	8...26	18,0	8...30
sulfur content, %	0,1...1,5	3,4…4,0	2,9… 9,0	0,3… 1,2	Менее 0,8	0,3...1,2
consumption, t/h	57,6	25,9	64,8	28,4	40,7	126
Supply method	paste	paste	dry	paste	dry	paste
Sorbent	dolomite	dolomite	limestone	limestone	limestone	limestone
Sorbent consumption, t/h	5,4	8,3	25,2	1,8	3,6	8,3
Temperature in the bed, °C	860	860	860	860	840	870
Sulfur binding degree, %	85	90	90	—	90	—
Start-up year	1990	1991	1992	1993	1998	1999

* In brackets a factor of fuel heat utilization is resulted (for TPP "Vartan" at the estimated heat release of 224 MJ/s)