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Model Investigations of the Aerodynamics of a Direct-Flow-Vortex Flame as Applied to a TGMP-314 Boiler

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Abstract—A scheme for organizing staged combustion of gas and fuel in a direct-flow-vortex flame is proposed as applied to a TGMP-314 boiler fitted with direct-flow burners and air blast nozzles, the use of which makes it possible to obtain reduced emissions of harmful substances into the atmosphere. With the proposed scheme implemented, better efficiency of the boiler unit and lower probability of high-temperature corrosion of metal in the furnace waterwall lower radiant part should be expected.

Keywords: boiler units, furnace aerodynamics, direct-flow-vortex flame, burners, simulation, nature protection technologies, nitrogen oxides

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At present, a considerable portion of power-generating equipment in Russia needs modernization or replacement. One important problem that has to be solved under the conditions of using equipment that is becoming obsolete and physically worn is to retrofit this equipment by applying low-cost technologies. For power-generating boilers, the problem of reducing nitrogen oxide emissions to below the level prescribed by the relevant standards is a very topical one.

The TGMP-314 boilers Nos. 5 and 6 installed at Mosenergo's TETs-23 cogeneration station, which are equipped with burners manufactured by the Ekotop Company, produce flue gases the content of nitrogen oxides in which exceeds the level permitted by the relevant regulations. The concentrations of NO_x produced during the firing of natural gas exceed the standardized value equal to 125 mg/m^3 by approximately 90–100 mg/m^3 [1]. According to test data, the content of nitrogen oxides in the flue gases emitted from these boilers (recalculated for the air excess factor equal to 1.4) varies from 133 to 220 mg/m^3, respectively, in the load range from 60 to 100%.

A shift for using the direct-flow-vortex method of combustion implemented by means of direct-flow burners will make it possible to reduce the yield of nitrogen oxides to the standardized level and even below it owing to the flame core being distributed over the furnace width and depth. As a result, a lower level of maximal temperatures in the active combustion zone will be obtained; more uniform distribution of temperatures in this zone will be achieved, and high-efficient staged combustion will be organized.

The existing layout of boilers and the way in which fuel aerodynamics is organized in the TGMP-314 boilers are schematically shown in Fig. 1.

The burners are of a direct-flow-vortex type because vortex motion of jets at their outlet is set up by installing blade-type swirlers; in addition, the burner axes are directed tangentially with respect to two conditional bodies of revolution (see item *1* in Fig. 1). Large-scale vortex motion of the flame is generated in these zones.

The existing combustion scheme has the following main drawbacks:

(i) Two high-temperature vortices are set up in the furnace volume, due to which an increased yield of thermal nitrogen oxides can be generated in large-capacity boilers.

(ii) The flame exerts an increased level of dynamic pressure on the waterwall surfaces, and there are zones with local shortage of air, which in frequent occasions facilitate high-temperature corrosion of the boiler lower radiant part (LRP) during operation on fuel oil [2]. Such conditions can take place in the shaded locations shown in Fig. 1, especially on the rear waterwall in its axial zone.

(iii) The partitions between the burner channels, as well as blade swirlers, may suffer from warping and burning.

(iv) Fuel oil droplets can be thrown on the lined parts of burners.

The above-mentioned drawbacks are the main factor causing less reliable operation of the boiler unit and deterioration of its environmental characteristics. For removing these drawbacks and achieving more reliable