
STEAM BOILERS, POWER-GENERATING FUEL, BURNERS, AND BOILER AUXILIARY EQUIPMENT

Plasma Coal Reprocessing

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Abstract—Results of many years of investigations of plasma-chemical technologies for pyrolysis, hydrogenation, thermochemical preparation for combustion, gasification, and complex reprocessing of solid fuels and hydrocarbon gas cracking are represented. Application of these technologies for obtaining the desired products (hydrogen, industrial carbon, synthesis gas, valuable components of the mineral mass of coal) corresponds to modern ecological and economical requirements to the power engineering, metallurgy, and chemical industry. Plasma fuel utilization technologies are characterized by the short-term residence of reagents within a reactor and the high degree of the conversion of source substances into the desired products without catalyst application. The thermochemical preparation of the fuel to combustion is realized in a plasma–fuel system presenting a reaction chamber with a plasmatron; and the remaining plasma fuel utilization technologies, in a combined plasma-chemical reactor with a nominal power of 100 kW, whose zone of the heat release from an electric arc is joined with the chemical reaction zone.

Keywords: plasmatron, plasma reactor, fuel, thermochemical preparation for combustion, pyrolysis, gasification, hydrogenation

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The plasma conversion of hydrocarbon-containing raw materials (coal, petroleum coke, hydrocarbon gases) is characterized by high temperatures and, consequently, a high degree of their thermochemical transformations in desired products [1]. Figures 1a–1c represent the equilibrium composition of gas and condensed phases during the plasma complex reprocessing of low-grade coal with an ash content of 40% and a combustion heat of 16632 kJ/kg. The mixture contains 100 kg of coal and 40.25 kg of steam. The gas phase (see Fig. 1a) of products of the complex coal reprocessing generally presents synthesis gas, whose concentration attains 99 vol % at 1500 K. The total atomic and molecular hydrogen concentration varying in a range of 48–59% is higher than the CO concentration in all temperature ranges. As the temperature increases, the carbon monoxide concentration decreases from 47% at 1500 K to 34% at 4000 K. The greater part of the components of the mineral coal mass (MCM) begins to change from the condensed phase (see Fig. 1c) into gas (see Fig. 1b) at a temperature above 1500 K and completely changes into the gas phase at a temperature greater than 2600 K (see Fig. 1c). The gas phase at temperatures exceeding 3000 K generally contains Si, Al, Ca, Fe, and Na, and compounds of SiO, SiH, AlH, and SiS. The latest dissociate on corresponding elements as temperature increases. The

energy intensity monotonically increases from 1 kW/kg at a temperature of 1000 K up to 6.9 kW/kg at 4000 K. From Fig. 1d it is evident that the gasification degree during the complex coal reprocessing attains 100% at temperatures exceeding 1800 K. The rise in the gasification degree decelerates in a temperature range of 1300–1700 K. This is connected with that practically all steam induced in the system is consumed and oxygen required for the gasification of residual solid carbon does not remain in the gas phase. As temperature increases, conversion of components of the MCM begins. As a result, oxygen in the gas phase appears in a sufficient amount in order to complete the carbon gasification.

The plasma-cracking technology lies in heating the hydrocarbon gases in a combined electric-arc reactor (Fig. 2) up to their pyrolysis temperature (1900–2300 K) with the formation of finely dispersed industrial carbon and hydrogen in the united technological process. Thermodynamic calculations of pyrolysis of the propane–butane mixture by the TERRA program showed that hydrogen with a concentration close to 20 wt % dominates in practically all temperature ranges. Hydrocarbons (C₃H, C₂H₂, C₄H₂, etc.) are present in the temperature range of 2500–5000 K in the gas phase. They dissociate in hydrogen and carbon. Con-