Thermal drying of coals is a necessary, although energy-intensive and explosive (for coals with a volatile matter content above 35% and dust fraction) industrial process for improving the performance characteristics of coal products; at the same time, the process has a negative impact on the environment. At Russian coal preparation plants, gas dryers of the following three types are used for coal drying: flue-gas tube (40%), drum-type gas (50%), and fluidized-bed gas (10%) dryers [1].

In the case of steam coals, on-site drying significantly reduces the cost of their transportation to consumption places and precludes freeze-clumping. Reducing by 1% the total moisture of coal used to fire steam generators increases their thermal efficiency by 0.1%. In the manufacture of binder-free, thermally agglomerated coal briquettes, preheating and drying form the necessary step that determines to a great extent the quality of the product. For semicoking processes in a multizone shaft furnace, each zone has a drying chamber. Drying is especially needed in the case of coal hydrogenation in which coal with a moisture content of at most 1–3% is used for slurry making [2].

A certain drying mode, including an allowed drying rate, a coal temperature, the temperature and relative humidity of the drying agent, its moving speed, and a change in these parameters at different steps of the drying process, is specified for each process.

The most important aspect of thermal drying of coal is explosion safety of all thermal units operating under a reduced pressure. The explosion safety is enhanced through the retrofitting of dryers to operate under elevated pressure, improvement in the tightness of sealing the devices, and recycling used to lower the oxygen content of the drying gas.

To increase the productivity and efficiency of coal thermal drying processes, fast heating methods with a heat-transfer gas are used, but this requires a high initial temperature and a high relative velocity of the heat-transfer agent. Flash drying can be conducted in an ascending or descending drying-gas stream, a curvilinear vortex flow, or a fluidized-bed pressure reactor [1].

An example of coal heating in an ascending flow of a heat-transfer agent is drying in tube dryers. Their mode of operation is close to the plug-flow mode; the contact time of disperse solid materials does not exceed a few seconds. Coal drying is due to convective heat transfer during cocurrent flow of gases and materials.

The performance of the devices depends upon the gas flow rate, drying-gas temperature, and the size of the unit. A drawback of such dryers is uncontrollable air leak, a high temperature of the heat-transfer gas, rather large dimensions, and a high capital cost for construction. The problems of size and capital expenditure are removed in part by using Venturi tube-type countercurrent/cocurrent air nozzle devices, but they also operate at a high drying-gas temperature (about 1000–1200°C).

Abroad (United States, Germany), vacuum drying and modified drying in a fluidized bed with recycle and a special heat-transfer-medium supply system are considered the most promising processes for both intensification of thermal drying during coal preparation and tackling environmental problems. Contact (screw and disc) dryers with a throughput of 10–20 t/h have been designed. Microwave flash drying of lignite and sub-bituminous coals is also considered promising, as well as the use of high-power electron beams in the future [3].
At the Institute for Fossil Fuels (IGI) in the mid-1950s, the use of flash heating in a curvilinear vortex flow of a hot gas with a low oxygen content in cyclone-type devices was proposed for drying and thermal preparation of coals [4, 5]. For the first time, the vortex chamber as an apparatus for heating and drying of bulk materials was proposed for heating poorly caking coals upon the manufacture of agglomerated fuel [6].

**GENERAL CHARACTERIZATION OF THE DRYING PROCESS IN A HIGH-SPEED VORTEX FLOW OF DRYING GAS**

At a relatively low temperature of the drying gas (up to 600°C), a high gas velocity (up to 50–100 m/s) in conjunction with flow hydrodynamics results in a substantial effect of the aerodynamic factor on the removal of moisture, thereby determining a high specific rate of moisture evaporation (up to 4000 kg/(m³ h)), a low heat consumption for evaporation of moisture (up to 4 MJ/kg of water), and a high particle heating rate (up to 10⁴ °C/min). The residence time of particles in the chamber ranges from 0.2 to 2.0 s, depending on the size.

The cyclone (vortex) chamber is simple in design, has a small size and a low metal content, is characterized by high efficiency, and (most importantly) is explosion-proof owing to its operation with a pressurized drying gas having a low oxygen content (1–3%).

Structurally, the vortex chamber (Fig. 1) consists of two tubes inserted into one another, the outer (housing) tube (1) and the inner tube (2) with tangential nozzles cut in two or three rows. The front face of the chamber (with respect to coal supply line) accommodates a coal feeder (usually, auger-type) ended with a baffle plate (3), which prevents the coal from heaping near the entrance and provides for its entrainment by the drying gas. The blind (nozzleless) part (4) of the chamber slightly increases the residence time of coal in the chamber, thereby facilitating more uniform heating of coal and the redistribution of heat in the heated mass. The hot drying gas is forced by pressure from the heat source to the annulus. Owing to the gas pressure and the tangentially cut nozzles in the front part of the apparatus inner tube, the heat-transfer gas at a high speed gets into the inner tube. Coal with a particle size up to 2–5 mm is entrained by the gas stream, creating a swirling vortex gas—coal flow, wherein the main portion of the flow is concentrated in the peripheral zone because of centrifugal forces. The peripheral and central streams are withdrawn from the chamber via volutes 5 and 6.

Owing to certain inertia of coal particles, the gas stream moves ahead of these particles in velocity, thereby creating favorable conditions for effective heat and mass transfer. Vortex chambers are superior to drum dryers in both metal content per structure and size and are comparable with tube dryers and fluidized-bed dryers in both the velocity of motion of the material and the gas velocity. However, vortex chambers are more compact as compared to the latter two types of dryers. Tangential gas supply to a vortex chamber is useful for creating high-capacity devices with easily controlled coal-heating conditions. High relative velocities of coal and gas and considerable turbulence of the gas flow make it possible to obtain in these chambers such specific thermal loads that are unattainable in devices of other types [6, 7]. The features of gas—coal flow movement in the case of diffused gas supply create favorable conditions for the uniform and fast heating of coal particles of different classes and make it possible to minimize the temperature difference between the heated coal and effluent drying gas.

![Fig. 1. Schematic of the vortex chamber: (1) housing; (2) nozzle; (3) baffle; (4) tube; (5, 6) peripheral and central outgoing flow volutes, respectively; (7) flange; and (8) splitter.](image-url)