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DESIGN OF SPRAY DRIERS WITH MIXING

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Spray drying is widely used in industry. Tests have shown that spray driers are indispensable for drying materials where lengthy contact with the heating stream is not possible, in particular for drying polymer materials.

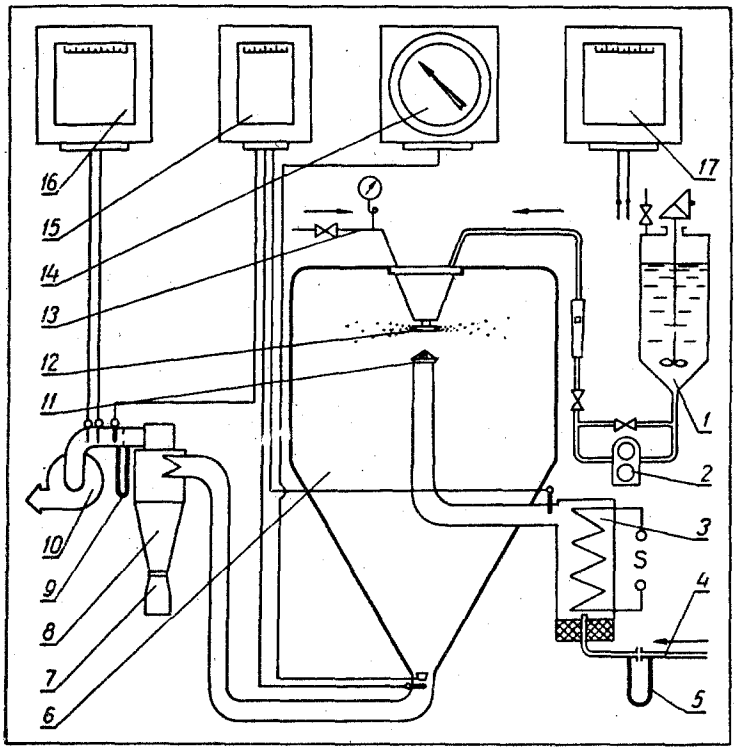

Fig. 1. Diagram of test apparatus. 1 – product to be dried; 2 – gear pump; 3 – electric heater; 4 – tube for adding helium; 5 – differential manometer; 6 – drying chamber; 7 – receiver for dried product; 8 – cyclone; 9 – differential manometer; 10 – blower; 11 – top-cap; 12 – spraying disc; 13 – compressed air line; 14 – gas analyzer; 15 – electronic potentiometer; 16 and 17 – electronic psychrometers.

In spite of the existence of published data [1-3], an accurate and reliable method of designing spray driers has not as yet been developed, due to lack of reliable heat and mass transfer relations. The concentration, in particular, is not known. In engineering calculations the motive power of the process is still computed as for equipment with ideal mixing or displacement, although actually real equipment only approximates to one or other of these ideal cases. Reduction of the harmful effect of mixing in spray driers can be achieved by logical control of the motion of the heating stream and sprayed material.

In designing real equipment, it is necessary to know the nature of the mixing of the flows, which determine the concentration field. Apart from other methods of calculating longitudinal mixing [4, 5], the concentration field may be expressed in terms of the effective motive power, or the ratio of the motive power in the actual equipment to that in equipment with ideal displacement: $E = \Delta P_i / \Delta P_d$. The effective motive power may conveniently be designated by the number of pseudo-sections n, which depends on the hydrodynamic conditions; for ideal displacement $n = \infty$, and for ideal mixing $n = 1$. This paper is devoted to an experimental determination of the number of pseudo-sections for a once-through spray drier.

To clarify longitudinal mixing in the gas phase in a once-through drying chamber, tests were carried out on the washing out of a labeled gas. Fig. 1 shows the test arrangement. The solution being dried is fed by the gear pump through the supply tube onto a rapidly rotating disc driven by an air turbine. Air is drawn over the electric heater by the blower, entering the drying chamber through a tube located in the center. The tube ends in a top-cap with vanes so arranged as to impart a rotary motion to the air. Technical details of the equipment are as follows: rate of vaporization of water – 1.5 to 5 *l*/hr; diam of cylindrical part of chamber – 800 mm; height of cylindrical part of chamber – 700 mm; height of conical part of chamber – 600 mm; angle of cone – 60 degrees.

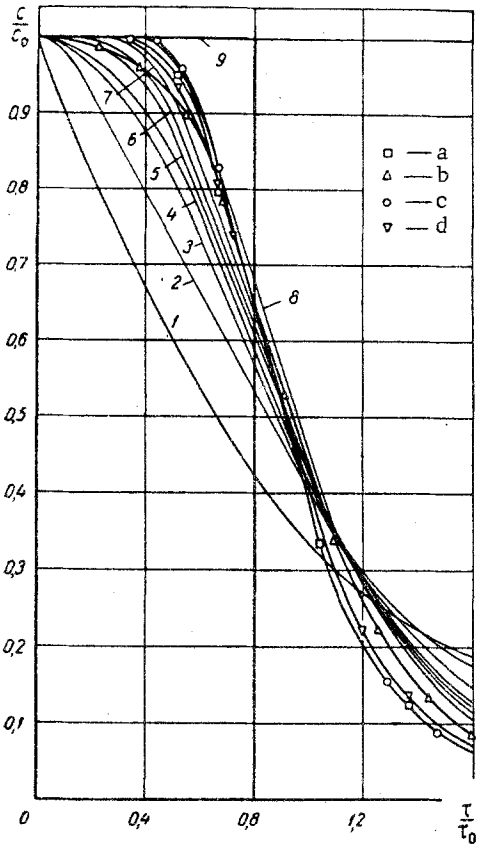

Fig. 2. Wash-out curves: theoretical: 1 – n = 1; 2 – 2; 3 – 3; 4 – 4; 5 – 5; 6 – 6; 7 – 7; 8 – 10; 9 – ∞; experimental: a – top-cap but no spray; b – no top-cap, no spray; c – with spray, 3 *l*/hr of solution at 155°C; d – same at 300°C.

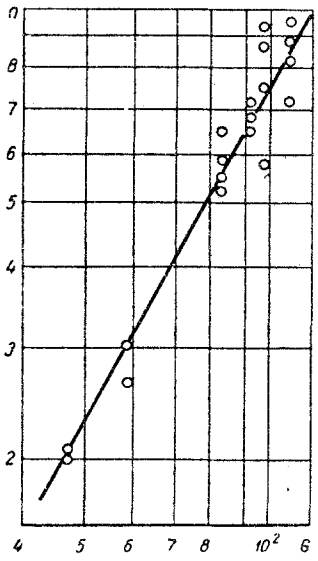

Fig. 3. Dependence of number of pseudo-sections n on flow rate of heat-transfer agent per unit cross-sectional area of drying chamber.

A certain proportion of helium was mixed in with the incoming heat-transfer agent. After steady conditions had been established, the helium was cut off, and its removal from the chamber began, while the concentration of the outlet gas-air mixture was analyzed and continuously recorded by a gas analyzer. The flow rate of heat-transfer agent was varied from 20 to 45 m^3/hr, while that of the sprayed solution was varied up to 4 *l*/hr. The data obtained by this method and the corresponding curves for the labeled gas are given in Fig. 2 for a flow rate of 45 m^3/hr; also given are the curves for ideal displacement and ideal mixing, and for intermediate equipment, derived theoretically in [6].

Comparison of the measured curves with theory shows that the once-through equipment is close to the ideal displacement equipment, while the flow rate of sprayed liquid and the temperature of the heat-transfer agent show practically no influence on longitudinal mixing in the gas phase. Only the flow rate of the heat-transfer agent affects the concentration field. Fig. 3 shows the experimental data for computation of the number of pseudo-sections as a function of the flow rate G of the heat-transfer agent. The straight line satisfies the equation $n = 2 \cdot 10^{-3} G^{1.8}$. Since the flow rate of heat-transfer agent in spray driers is usually not less than 100 kg/m^2 · hr, the number of pseudo-sections will be about 8-10, so that the motive power of the process can be calculated as for ideal displacement equipment. For special conditions characterized by reduced load, the number of pseudo-sections can be calculated using the equation given above. As for other kinds of driers, the effective motive power must be determined accurately, after which the actual power can be determined accurately, after which the actual power can be determined.

NOTATION

E – effective motive power; P_i – motive power in equipment of ideal intermediate type; P_d – motive power in equipment of ideal displacement type; n – number of pseudo-sections; G – flow rate of heat-transfer agent per unit cross-sectional area of drying chamber; c – concentration of helium ("labeled" substance) at time τ; c_0 – initial concentration of helium; τ – time; τ_0 – calculated displacement time = ratio of volume of equipment (m^3) to flow rate of heat-transfer (m^3/hr).

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RATE OF BURNING OF PEAT AND PEATY COKE PARTICLES IN AN AIRSTREAM

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In actual furnace conditions – in chambers, and especially in cyclone furnaces – fuel particles of various sizes acquire different relative velocities, and thus burn while exposed to a gas and air stream. Then the stream velocity has a great influence on rate of burning of the fuel particles.

Tests have been performed with spherical peat particles [1], pressed from peat dust using a special mold, and also with spherical particles of peaty coke, obtained by prolonged coking of pressed peat particles of diameter 5, 10, and 15 mm in a steel hermetic retort at a heating temperature of up to 800°C; the coke contained residual volatiles equal to 6.01% of the combustible mass.

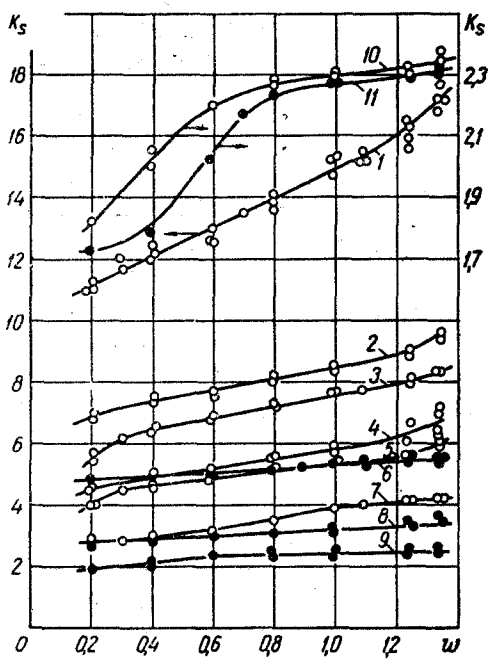
For comparison, spherical particles of electrode carbon obtained by machining were also used.

The particles were suspended on non-combustible threads, and burned in a vertical tubular electric furnace of diameter 40 mm in an airstream at various flow velocities from 0.2 to 1.35 m/sec and at a furnace temperature of 1270°K. The specific rates of burning of these and other particles were compared.

During burning the peat and coke particles were continuously weighed by means of a specially developed self-balancing photoelectronic recording analytical balance [1].

The burning process for each particle was recorded, using an MPO-2 type oscillograph, on photographic film in the form of a certain curve (oscillogram), analysis of which gave a value of the mass burn-up of the particle; also a time marker was included on the film every second, from which total time of burning of the particle could be determined.

After the test the residue of the burned particle was weighed on an analytical balance, to check the burn-up value recorded on the oscillogram.



From the experimental results, the specific rate of burning was determined as an average curve of the overall burn-up. The specific rate of burning is the mass of fuel burning per unit time per unit area of external surface of the particle, and was calculated with the aid of the expression

$$K_s = \frac{w - w_r}{S_p \tau_b} = \frac{\Delta w}{\pi d^2 \tau_b}$$

Fig. Dependence of specific burning rate $K_s \cdot 10^3$(kg/m^2 · sec) on flow velocity ω (m/sec) for spherical peat particles of diameter 5.0 mm – 1; 8.0 – 2; 10.0 – 3; 12.0 – 4; 15.0 – 5; for particles of electrode carbon of diameter 5.0 mm – 6; for spherical particles of peaty coke of diameter 4.5 mm – 7; 8.0 – 8; 12.0 – 9, and for particles of peaty coke of diameter 12.0 mm with residual volatiles 6.01% of combustible mass – 10, and 2.55% – 11.