ATTAINING "LOW" TEMPERATURES IN A FLUIDIZATION BED BY MEANS OF NATURAL GAS

A. P. Baskakov, B. V. Berg,
E. Ya. Gimpel'man, V. V. Khoroshavtsev,
and V. P. Evseev

UDC 621.785:66.096.5

On the basis of experiments, it appears feasible to attain "low" temperatures (below 800°C) in the operating chamber of a fluidization bed by interchange of particles between this and the adjacent "high-temperature" chamber.

Certain processes in a fluidization bed (for example, heat treatment of metals: steel tempering, wire patenting, etc.) require that the temperature be maintained within the 100-800°C range. At such low temperatures it will be impossible for the hot gas to immediately burn in the fluidization bed.

One method of attaining such temperatures is by means of a bicameral apparatus with adjacent fluidization beds. In order to use hot gas as the heat source in one chamber, the temperature there is maintained at 850-1000°C or above so that complete combustion of the gas will occur. The necessary temperature in the adjacent processing chamber is attained by an interchange of fine-grain material between both chambers. This is achieved by reverse-flow devices.

Earlier studies [2, 3] at temperatures up to 100°C have shown that the temperature in one chamber can be varied over a wide range by regulating the stir rate of particles which pass through a gap in the partition between both chambers, while the temperature in the other chamber is maintained constant. Possible applications of this method have been proved out in a high-temperature test apparatus. The latter consisted of an oven with a movable steel (grade 1Kh18N9T) partition (10 mm thick) dividing it into two chambers: a "hot" one (plan dimensions 265 × 230 mm) and a "cold" one (295 × 230 mm). Lifting of the partition created a gap between its lower edge and the over bottom, through which fine-grain material flowed from one chamber to the other during fluidization. A capped grain with separate feeds of fluidizing agent for each chamber served as the gas distributor. Natural gas was burned immediately in the fluidization bed in the "hot" chamber, while the bed material in the "cold" chamber was fluidized with air at a 30°C temperature. The dense layer in both chambers was 340 mm high. A coil tube with cooling water was mounted in the "cold" chamber, for the purpose of simulating the heat removal through heat treated metallic articles. The flow rates of gas and air were measured by means of double and plain diaphragms with U-manometers. The temperatures in the chambers were measured throughout the length and the height of each by means of Chromel–Alumel thermocouples with bare junctions. Tests were performed at equal and at different fluidization rates in each chamber.

The tests have shown that, by varying the gap height and the fluidization rate, one can quite reliably regulate and maintain a constant temperature in the "cold" chamber. In our tests we attained 300-600°C temperatures under steady-state conditions. In this way, the practical feasibility of attaining low temperatures by this method has been proved to satisfaction. The temperatures remained constant along the apparatus height. The temperature variation across each chamber was insignificant and did not exceed the measurement error (5-7°C) (Fig. 1).

On structural grounds, the partition between chambers in an industrial oven must be made thick. It is then necessary to use reverse-flow devices for transferring particles from one chamber to another. One of the methods proved out earlier, namely fluidizing the fine-grain material in the gap between chambers, has been mentioned in [4]. Another method is to effect an artificial flow reversal as, for example, a

S. M. Kirov Ural Polytechnic Institute, Sverdlovsk. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 23, No. 1, pp. 5-9, July, 1972. Original article submitted September 27, 1971.

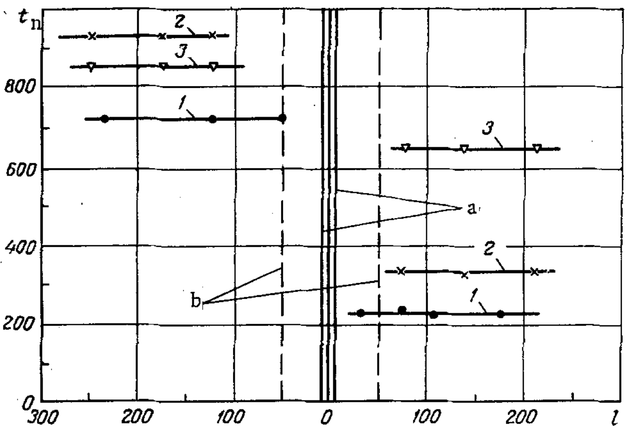

Fig. 1

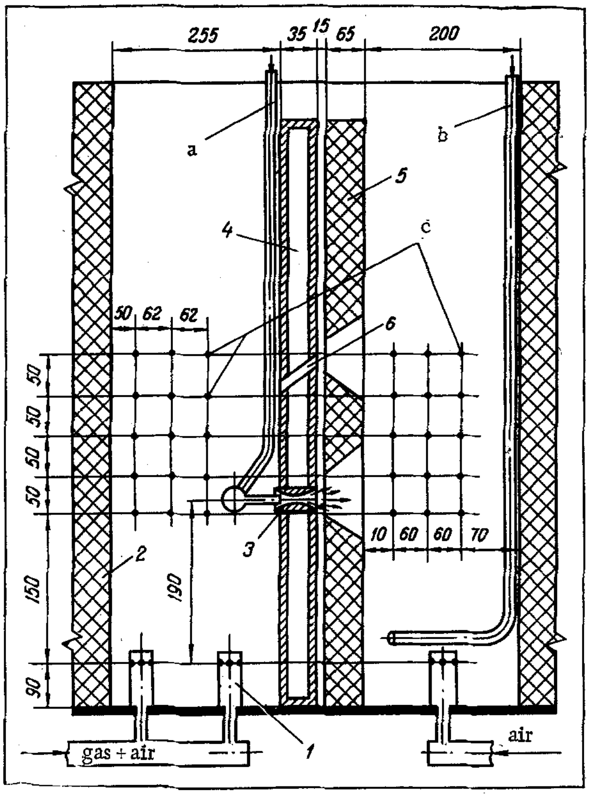

Fig. 2

Fig. 1. Temperature distribution over the length of the chambers l in the apparatus: 1) gap size regulation (dimension of corundum particles d = 320 μm); 2, 3) regulation of the change in air flow rate to the ejectors (d = 320 μm); a) contour of gap forming partition; b) contour of partition with built in ejector. Temperature t_n (°C), length l (mm).

Fig. 2. Schematic diagram of test apparatus with ejectors: 1) gas distributor caps; 2) wall lining; 3) ejector; 4) metallic partition; 5) fireclay partition; 6) reverse-flow channel (air to ejector a, water to cooler b, points of temperature measurement c).

transfer of particles from one chamber to another through a nozzle located inside the partition. This method was proved out on an apparatus shown schematically in Fig. 2. The earlier described apparatus was modified somewhat. The partition now consisted of two parts: a hollow steel box 35 mm thick with three ejector nozzles mounted inside and an insulating fireclay brick lining 65 mm thick. Air was supplied to the nozzles separately. Furthermore, three slanted channels 25 mm in diameter were provided through the partition for reverse drain of corundum. These channels ensured approximately equal bed levels in both chambers during all ejector tests. The water cooler was here made up of tubes spaced 60 mm apart parallel to the partition (only three tubes).

The purpose of the study was to prove out the feasibility of attaining a wide temperature range in the "cold" chamber, to determine the temperature field in the chamber, and to evaluate the mass transfer through the nozzle system. The tests have shown that, by varying the flow rate of the fluidizing agent and by regulating the rate of particle transfer by means of adjustments of the air velocity in the nozzles, it was possible, during stable combustion in the "hot" chamber, to attain in the adjacent chamber temperatures from 300 to 800°C. The temperature in the "hot" chamber was at that time held within the 720-1000°C range. As in the earlier experiment with reverse flow through a gap, the temperatures in the chamber (Fig. 1) remained almost uniform throughout the bed volume. Only within a narrow zone near the partition did the temperature vary by 5-7°C. Such a temperature uniformity over the bed volume prevailed while heat was carried away from the processing chamber by water circulating through the cooler coils. The water flow rates were selected so as to make the heat thus carried away equivalent to the heat which three wires of carbon steel 3 mm in diameter would carry away if they were moved at a velocity of 12 m/min.

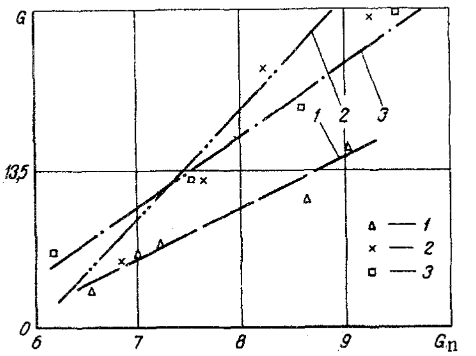

Fig. 3. Material flow rate G_M (kg/sec) as a function of air flow rate to nozzles (Nm^3/h): d = 400 μm with W_h = 0.92 m/sec and W_c = 0.84 m/sec (1), d = 400 μm with W_h = 1.3 m/sec and W_c = 1.02 m/sec (2), d = 320 μm with W_h = 0.75 m/sec and W_c = 0.68 m/sec (3).

From the equation of steady-state heat balance in the "cold" chamber

$$Q_n + Q_p + Q'_a + Q = Q''_a + Q_c + Q^{II}_l$$

(or from an analogous equation for the "hot" chamber) one can determine the quality of heat transferred by the bed material, while the flow rate of material through the nozzles can be determined from

$$G_M = \frac{Q}{c(t_1 - t_2)}.$$

Here Q_n is the heat brought in by the air from the nozzles, Q_p is the heat transferred through the partition, Q'_a and Q''_a are the heat brought in and taken out respectively by the fluidizing air in the "cold" chamber, Q''_a is the heat carried away by the cooling water, Q^{II}_l is the heat loss in the "cold" chamber, t_1 and t_2 are the temperature in the "hot" and in the "cold" chamber respectively. The values of Q^{II}_l and Q_p were determined experimentally by the method described in [3]; Q_n was calculated with the air in the nozzle assumed to heat up to the temperature of the fluidization bed in the "hot" chamber. Since Q_n calculated in this way was much smaller than Q in all the tests, it did not affect the calculated values of Q and G_M. The value of Q_c was calculated from the flow rate of cooling water in the apparatus and from the inlet as well as the outlet temperatures.

The tests for determining G_M were performed with the velocity of the fluidizing agent varied over the range W_h = 0.75-1.13 m/sec in the "hot" chamber, over the range W_c = 0.67-102 m/sec in the "cold" chamber, and with the flow rate of air to the nozzles G_n = 6.0-9.5 Nm^3/h. The bed was made up of corundum particles d = 320 μm and d = 400 μm in diameter. The dense bed was 340 mm high.

The test results are shown in Fig. 3. According to the diagram, G_M increases linearly with the rate of air flow through the nozzles. This applies to our particular test conditions, and the plotted $G_M = f(G_n)$ curve can, evidently, not be extrapolated to $G_M = 0$. The tests have also shown that G_M increases with increasing air velocities in the nozzles. According to the studies made, it is theoretically possible to apply both methods of regulating the temperatures in the chambers: by a gap and by ejector nozzles. The latter method is more flexible, the required temperatures are set here by adjustment of the ejection capacity of the nozzles (the flow rate of ejecting air). Characteristically, moderate temperature levels can be ensured with the nozzle system, if it operates in a stream of particles transported from the "cold" chamber. For particles from the adjacent chamber will flow freely into the "cold" chamber through the inclined channel.

NOTATION

Q	is the heat transferred by particles;
Q_n	is the heat brought in by air from the nozzles;
Q_p	is the heat transferred through the partition;
Q'_a, Q''_a	are the heat brought in and taken out respectively by fluidizing air in the "cold" chamber;
Q_c	is the heat carried away by water in the cooler;
Q^{II}_l	is the heat lost in the "cold" chamber;
t_1	is the temperature in the "hot" chamber;
t_2	is the temperature in the "cold" chamber;
G_M	is the material flow rate through the ejectors;

c is the specific heat, referred to mass;
d is the particle diameter;
W_h is the velocity of fluidizing agent in the "hot" chamber;
W_c is the velocity of fluidizing agent in the "cold" chamber.

LITERATURE CITED

1. A. P. Baskakov, Fast and Nonoxidizing Heating and Heat Treatment in a Fluidization Bed [in Russian], Izd. Metallurgiya, Moscow (1968).
2. A. P. Baskakov and E. Ya. Gimpel'man, Khim. Promyshl., 44, No. 6, 12 (1968).
3. A. P. Baskakov and E. Ya. Gimpel'man, Teoriya Osnov. Khim. Tekhnolog., 5, No. 1, 91 (1971).
4. E. Ya. Gimpel'man and A. P. Baskakov, Khim. Promyshl., 47, No. 9 (1971).