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

Pneumatic Transportation of Dispersed Medium through a Vertical Tube Immersed into a Fluidized Bed

V. Yu. Krasnykh[a], V. N. Korolev[a], A. V. Ostrovskaya[a], and S. A. Nagornov[b]

[a] *Ural Federal University, ul. Mira 19, Yekaterinburg, 620002 Russia*

[b] *VNIITiN, Russian Academy of Agriculture, Novo-Rubezhnyi per. 28, Tambov, 392022 Russia*

Abstract—We discuss the technical problem of how to transport granular material in a vertical direction from the underlying section of a multistage apparatus containing a fluidized bed to an upper section through tubes immersed into the fluidized bed without additional expenditures of energy. The intensity with which the dispersed medium (a mixture of gas and fuel particles) moves through the tube and the mass flowrate of particles are determined by the ratio between the hydraulic resistances of dispersed medium inside the tube and of the fluidized bed outside of it. In turn, this ratio depends on the fluidization number W ($W = w_s/w_0$, where w_s is the seepage velocity and w_0 is the fluidization commencement velocity) and on the tube immersing depth into the bed.

Keywords: dispersed medium, fluidized bed, pneumatic transportation, solid particles, fluidizing agent, bed porosity, hollow cylinder (tube)

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Overflow devices serving to transport solid particles from upper sections of a multistage apparatus to its underlying or neighboring sections are an important structural element of such equipment. The task the authors of this article set forth was the inverse one: to reveal whether it is possible to transport solid particles in the opposite direction, i.e., from an underlying section of the apparatus to its upper section without additional expenditures of energy. Such a task is stemming from the following experimentally established fact [1]: if a hollow cylinder is immersed into a fluidized bed, the height to which dispersed medium ascends inside this hollow cylinder is larger than the height of fluidized bed in the apparatus.

In [2], a pattern in which gastight vertical cylinders immersed in a fluidized bed are streamlined was described. However, the way in which a fluidized bed flows over a hollow vertical cylinder differs from the way in which it flows over a gastight cylinder. With a gastight cylinder, the bed porosity and gas velocity tend to increase near the cylinder's outer surface, whereas in a hollow vertical cylinder conditions are created for intense pneumatic transportation of the solid phase inside of the cylinder itself.

The purpose of this work is to describe the transportation of dispersed medium through a tube immersed vertically into a fluidized bed, to explain this phenomenon, and to elucidate the factors influencing the flowrate of solid particles flowing out through the tube top section.

EXPERIMENTAL RESULTS

A fluidized bed was created in an apparatus with rectangular cross section 0.15 × 0.15 m. Particles of spherical and irregular shape with equivalent diameter d_p from 0.13 to 1.15 mm were used as a solid phase, and air was used as a fluidizing agent. A perforated grate with a live section (i.e., a free section for air flow) equal to 9.82% served as a gas distribution device. This value is optimal in terms of power expenditures for fluidizing the bed of dispersed material [3]. A 1.5-m-long glass tube with the inner diameter D was secured in a vertical position at the apparatus center by means of two clamps allowing the tube to be moved along the bed height. A few different tubes with the inner diameter D varying from 1.5 to 24 mm were used in the experiments. The poured bed height H_0 was varied from 20 to 120 mm. To obtain a visual idea of how dispersed medium ascends in the tube, the process was recorded by means of a digital video camera at a frequency of 25 frames per second and by means of a camera with an exposure time from 1 to 10^{-3} s. The mass flowrate G of particles flowing out through the tube upper edge was determined using the weight method (the mass of particles flowing out through the tube for a preset period of time was determined by weighting them on electronic scales).

When a dense layer transfers into fluidized state ($W \geq 1.05$), fluidizing agent rushes at high velocity to inside the tube due to low hydraulic resistance of the tube inner cavity, and solid particles are intensely sucked from the space adjacent to the tube lower edge as a result of ejection. Dispersed medium moves