

March 5, 1968

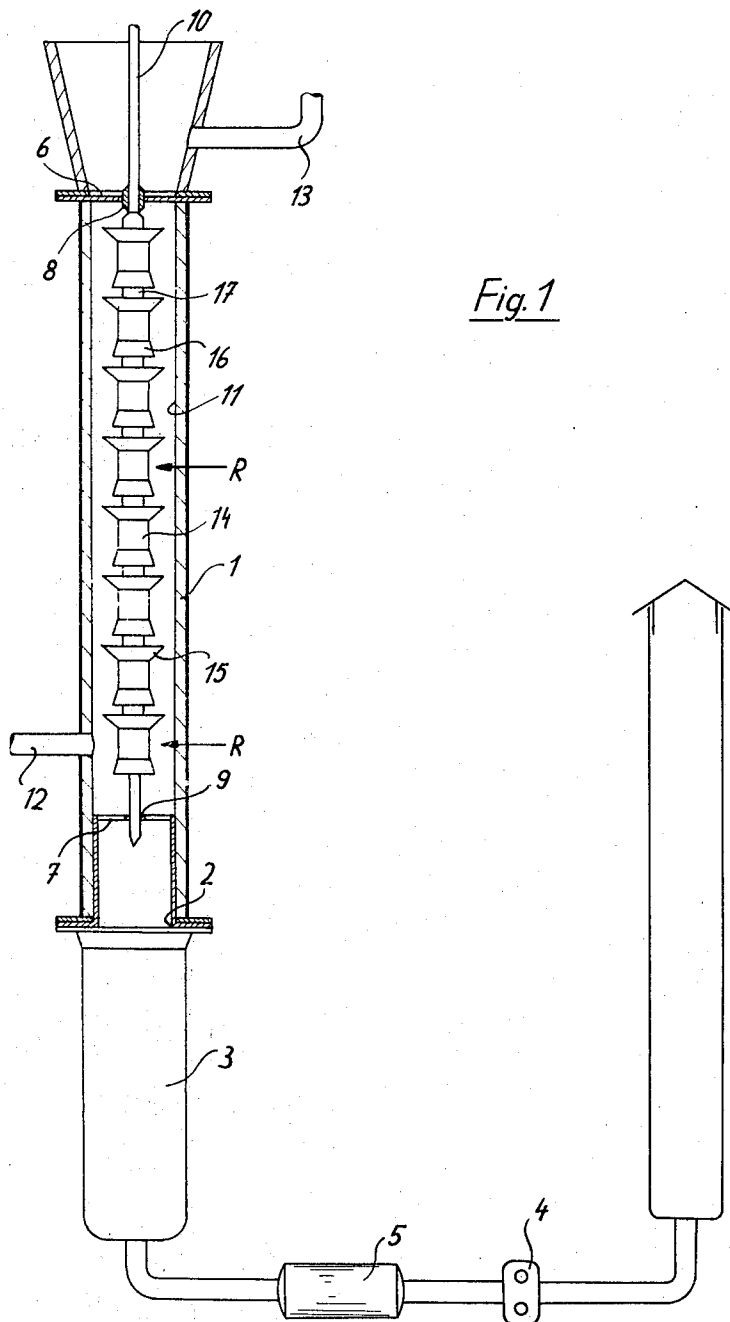
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3,371,425

APPARATUS FOR REDUCING THE SOJOURN TIMES IN FLUIDIZED BEDS

Filed June 21, 1965

5 Sheets-Sheet 1



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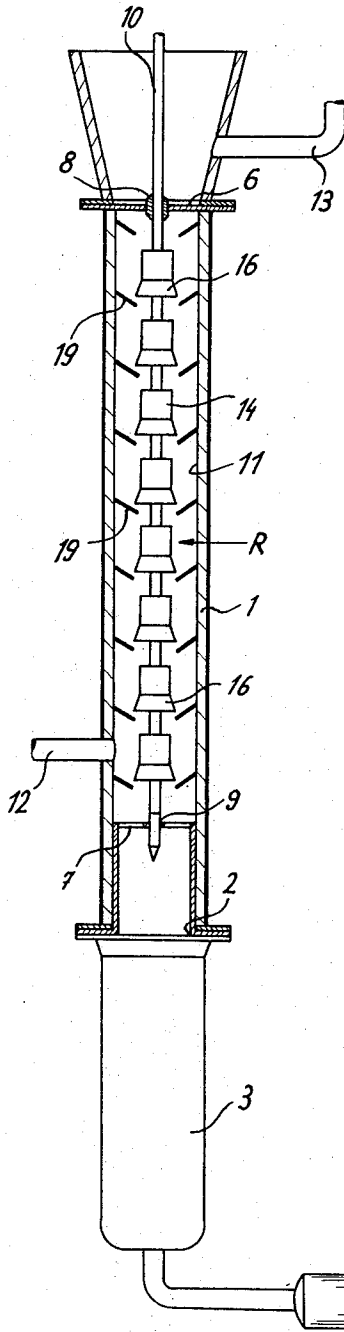


Fig. 2

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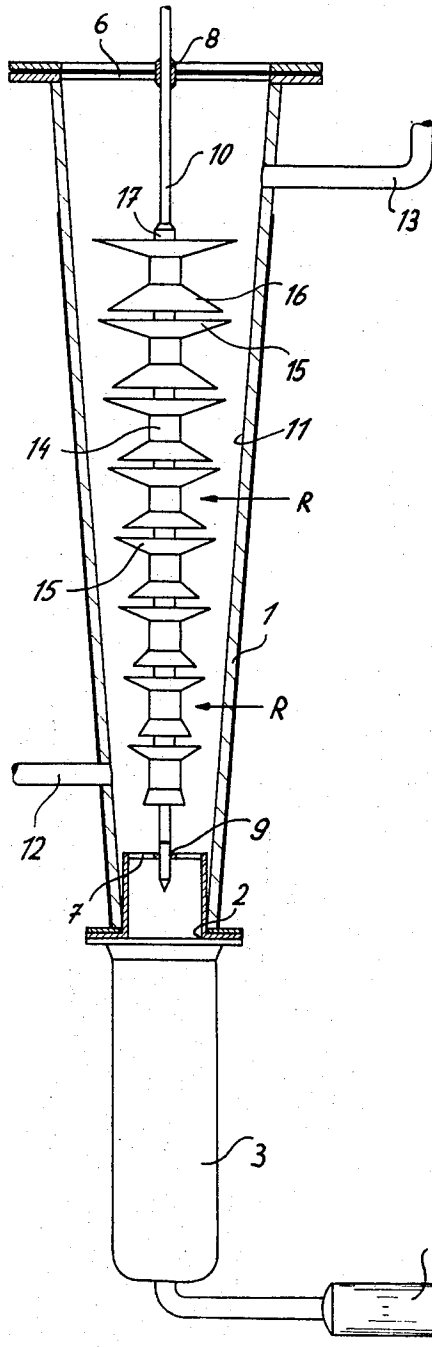
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5 Sheets-Sheet 3



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Fig. 4

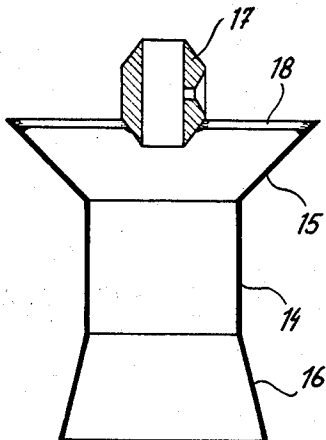


Fig. 5

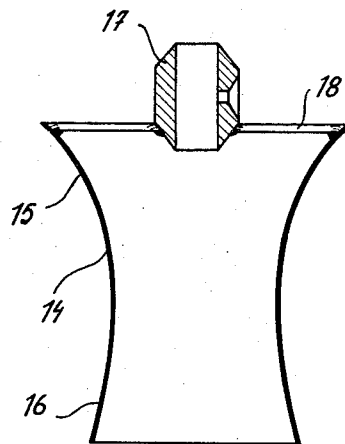
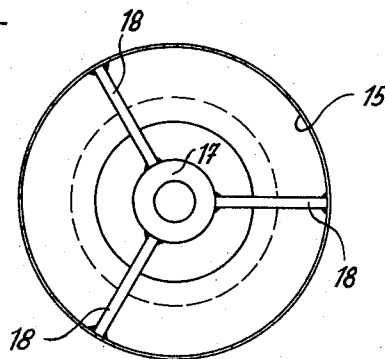


Fig. 6



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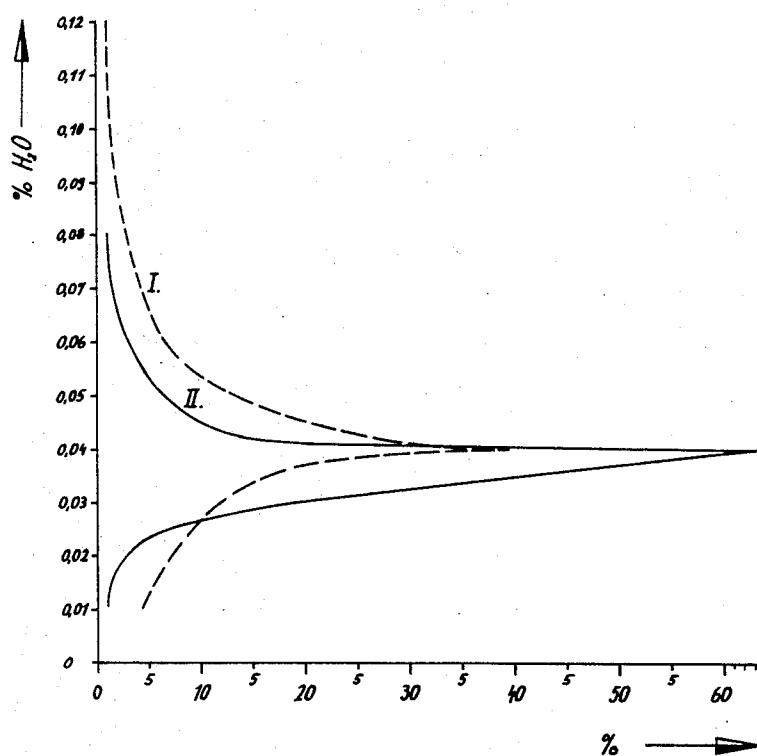
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Fig. 7



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APPARATUS FOR REDUCING THE SOJOURN TIMES IN FLUIDIZED BEDS

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ABSTRACT OF THE DISCLOSURE

An improved method and apparatus for drying particulate solids which produces a highly uniform moisture content in the particles. A drying gas is introduced through precisely arranged orifices in the base plate of an enclosed, elongated, vertical drying chamber. The chamber contains a plurality of independent, rotatable, vertically spaced hollow rotor elements. The hollow rotor elements define a vertical column in the center of the chamber. Particulate matter is continuously introduced into the chamber adjacent the base plate and is forced upwardly in the chamber through the column defined by the hollow rotor elements. Some particles which are carried escape from the column to the sides of the chamber, cascade downward in the chamber and are re-cycled upward again. Each of the rotor elements acts as an independent fluidizing bed through which particles are re-cycled.

The invention relates to improvements in a method of an apparatus for reducing the range of sojourn times in continuously operated fluidized-bed equipment.

As is well known, fluidized-bed techniques are employed for drying moist substances. The basis of these techniques is that pre-heated air or some other gas of low humidity and low dew-point is led through an entry plate into a layer of solid material having a given grain-size distribution, the velocity of the gas being so determined that motion is imparted to the layer of solids. The material that is to be dried is whirled up, as a result of which not only is the transference of heat promoted between the gas and the solid particles, but the moisture is evacuated very rapidly from the system. In the simplest case, equipment of this kind is operated periodically.

When continuous working is desired, the whirling action is caused to extend out of the drying system proper, so that material from the fluidized bed is entrained in the gas. The solids and the gas are separated in a cyclone, the gas being either allowed to escape or, after suitable preliminary treatment, recirculated. The solid material is re-circulated to the fluidized bed. As a rule, drying is initially aimed at obtaining a moisture content that lies 5% to 10% below the desired value, the solids being fed in at a controlled rate at any point in the circulation. A corresponding amount of dried material is withdrawn from another point in the "solids" circulation path, with the air or synchronized machinery. This method and others of this kind have the disadvantage, as compared to the discontinuous method, that, even if the average moisture content is identical in both methods, the moisture of the individual grains and pieces shows different values. There is thus a more or less wide range of moisture contents, directly related to the sojourn time of the individual grains or pieces of solid material in the fluidized bed.

With the present invention, however, this range of sojourn times can be extended or reduced at will. Reduc-

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ing it enables uniformity to be obtained in the moisture content of the individual particles. At the same time, the application of the method is not limited to drying processes, but is equally valuable wherever a particular sojourn time is desired, as, for instance, in the regeneration of contacts and catalysts and in many other chemical processes, e.g., in the production of electrical semi-conductors and so forth.

According to the present invention, there is provided a method of reducing the range of sojourn times in a continuously operated fluidized-bed equipment which comprises the step of mechanically swirling the solids of the fluidized bed.

The degree of swirling, which should preferably take place in a vertical plane through the longitudinal axis, can be regulated.

According to the present invention, there is also provided an apparatus for reducing the range of sojourn times of material in a continuously operated fluidized bed which comprises a reaction chamber in which the material is to be fluidized, means for fluidizing material in said chamber and means for mechanically swirling material in said chamber.

Preferably, there is provided an apparatus for reducing the range of sojourn times of material in a continuously operated fluidized bed which comprises a reaction chamber of circular cross-section, means for fluidizing material in said chamber, a plurality of rotatable members mounted one above the other for rotation about a common vertical axis coincident with the centre line of said chamber and means operable to rotate said members.

The rotatable members are conveniently hollow bodies with frusto-conical ends, fitted one above the other on a driven shaft. They should preferably be of equal dimensions, with their peripheral faces equidistant from the inner wall surface of the reaction chamber.

For preference, each of the rotary members should comprise a cylindrical middle part and adjacent frusto-conical end portions, the lower end portion, which lies towards the direction from which the gas is flowing after entry, having its sloping face at a smaller angle than the other frusto-conical part, situated at the upper end.

In a modified form, the upper frusto-conical portion of each of the rotary members may be omitted, being replaced by a corresponding diversion plate fitted to the inner wall of the chamber.

It is possible, again, for the wall of the chamber to be shaped frusto-conically and the dimensions of the rotary members to be modified in such a way that the spaces between the inner wall of the chamber and the rotary members are the same throughout. This means that the diameters of the rotary members may with advantage be increased at the frusto-conical end portions as the diameter of the space within the chamber increases.

The rotary members are fixed in some conventional manner to, and uniformly spaced along, the shaft, which can be driven at variable speed by means of an electric motor, for example.

Some embodiments of the invention will now be described by way of example, reference being made to the accompanying drawings in which:

FIGURE 1 shows an apparatus, partly in section, according to the invention,

FIGURE 2 which is similar to FIGURE 1, shows an apparatus with differently shaped rotary members,

FIGURE 3 shows a variant in which the chamber casing is itself frusto-conical in shape,

FIGURE 4 is a longitudinal section through a rotary member,

FIGURE 5 is a longitudinal section through a rotary member with a parabolic outer wall,

FIGURE 6 is a plan view of the top end of a rotary member,

FIGURE 7 is a diagram giving the percentage distribution of the relative moisture contents of fragments of plastics.

As can be seen from the drawings, an apparatus according to the invention comprises a reaction vessel 1, having a reaction chamber of circular cross-section, closed at one end by a gas entry plate 2. A container 3 defines an admission or plenum chamber for the fluidizing gas flow, which in the present case may be, for example, and is fed by a pump 4 through a heat exchanger 5.

The reaction chamber is a vertically elongate chamber of circular cross-section about a vertical axis and has disposed at its upper end a perforated or anchor plate 6. The lower end of the reaction vessel also has a corresponding anchor plate 7. Each plate 6 and 7 contains a bearing, 8 or 9 respectively, supporting a vertical shaft 10, concentric with axis of the chamber. Rotary table members R are fixed at regular intervals to the shaft 10 one above the other and equidistant from inner wall 11 of reaction vessel 1.

The reaction chamber within the reaction vessel may be cylindrical, i.e., of constant circular cross-section, or, while being circular in cross-section, it may widen conically towards the outlet or upper end of the reaction (FIG. 3), so that the interior of the reaction vessel or the vessel itself may be shaped like a truncated cone. The reaction vessel may be provided as shown with pipe connections 12 and 13, which can be used for feeding a medium for processing.

The shaft 10, which carries the rotary members R is provided with a variable speed drive by an electric motor (not shown).

FIGURES 4 and 5 show longitudinal sections through rotary members and FIGURE 6 is a plan view of such a member. The rotary member seen in FIGURE 4 is of hollow circular cross-section and has a cylindrical middle portion 14, and frusto-conical end parts 15 and 16. In the case of the rotary member shown in FIGURE 5, the middle portion 14' when seen in longitudinal section, is curved parabolically, so that frusto-conical parts 15 and 16 merge into the middle portion. In the frusto-conical part 15, which is disposed above the part 16 when the rotary member R is fitted in position, a bearing 17 is provided, being mounted, for example, on three radial arms, 18, which are welded to the inner wall of the frusto-conical casing. This produces a member through which passage is practically free from obstruction.

The rotary members R are slipped over the shaft 10 by their bearings 17 and fixed in some conventional manner to the shaft, either permanently or detachably. Where the reaction chamber is cylindrical, as in FIGURE 1, the rotary members on the shaft 10 are preferably all of the same size. Where, however, the inner wall of the reaction chamber has the shape of the sloping face of a truncated cone, as shown in FIGURE 3, the rotary members are so designed that, while they are indeed equal in diameter at the portion 14 or 14', the frusto-conical parts 15 and 16 differ in such a way that the gaps between their largest diameter and parts and the inner wall 11 of the reaction chamber are the same throughout the length of the chamber.

FIGURE 2 shows a reaction chamber and rotary members R of another kind. Here, the upper frusto-conical part 15 has been omitted and the bearing 17 is shifted either into the lower end part 16 or to the middle portion 14, which may be cylindrical, for example. The upper frusto-conical parts 15 of the rotary members R are now effectively replaced by annular diversion plates 19, fixed to the inner wall 11 of the reaction chamber and extending inwardly to present a frusto-conical surface which tapers downwardly.

The mode of operation within the fluidized-bed equipment illustrated is as follows:

As the rotary members R revolve, the material moving upwards in the middle flows away to the sides above each rotary member R. This produces two possibilities. When the rotary members revolve slowly, the particles flowing away at the top are able to fall back into the larger upper end part 15 of the rotary member below, thus finding their way back into the up-stream of particles of solid material and being carried upwards again by it. When the members R rotate more quickly, the solid particles are thrown further out, so that they return to the larger upper end parts 15 one or more steps (i.e., rotary members) lower down, before finding their way into the up-stream of particles inside the rotary members, as mentioned above.

In the variant shown in FIGURE 2, upper parts 15 of the rotary members have been replaced by diversion plates 19 fitted to the inner wall of the reaction chamber. These plates 19 may also be provided with devices for guiding and directing the solid particles. The mode of operation is similar to that of the equipment illustrated in FIGURE 1. Where, as in FIGURE 3, the reaction vessel itself is frusto-conical in shape, the sojourn time can be controlled still further. In all cases, the gas entry plate 2 is such that the number of nozzle holes per unit area decreases outwards from the inside. The mode of operation and the technical advance achieved by the devices shown in the drawings are made clear by the example given hereunder.

Fragments of plastics of identical geometrical dimensions and equal weights were introduced in equal portions into one piece of equipment as shown in FIGURE 1 and into one reaction vessel of the kind shown in FIGURE 1 but *minus* rotary members R. By fluidizing with a stream of dry air at 130° C., both quantities were dried until the moisture content was 0.04%. A stream of dry air at 130° C. was then blown through both fluidizing columns at the same rate (8 cu. m./hr.) and the rotary members in the one piece of equipment were set turning at 100 r.p.m. At the same time, both pieces of equipment were charged with undried plastics fragments and the same amounts were withdrawn within the same times. An average sample from what was withdrawn from both showed 0.037% of water for the fluidizing column that had no rotary members and 0.043% for the fluidizing column fitted with rotary members. The moisture content of the fragments withdrawn was determined, with the following results:

Test I.—Apparatus without rotary members.

Percent	Percent H ₂ O
4	0.01
7	0.02
11	0.03
38	0.04
13	0.05
6	0.06
5	0.07
4	0.08
2	0.09
2	0.10
1	0.11
1	0.12

Test II.—Apparatus with rotary members.

Percent	Percent H ₂ O
1	0.01
2	0.02
19	0.03
62	0.04
6	0.05
3	0.06
1	0.07
1	0.08

75 A comparison of frequency Curves I and II in FIG-

URE 6 shows the more uniform drying achieved by the apparatus embodying the rotary members R.

What is claimed is:

1. An apparatus for reducing the range of sojourn times in continuously operated fluidized bed equipment comprising:

a vertically elongated chamber having sidewalls, an upper portion, a lower portion and a central axis; means for continuously admitting a drying fluid at the lower portion of said chamber; means for continuously introducing particulate material at the lower portion of said chamber and above said drying fluid admitting means for drying said particulate material;

a vertical shaft rotatably mounted in said chamber substantially coextensive with said central axis;

a plurality of vertically aligned hollow members on said shaft having substantially circular horizontal cross sections such that said particulate material introduced into said chamber is carried upwardly by said drying fluid within said chamber with at least a portion of said particulate material cycled through a fluidized bed defined by each of said hollow members; and

an outlet means at the upper portion of said chamber for continuously removing dried particulate material.

2. The apparatus of claim 1 wherein each of hollow members comprise a substantially cylindrical portion connected to said shaft and having a lower portion within an enlarged lower end, and including downwardly inclined means mounted on the inner surface of said chamber side walls and having an inner periphery lying between the upper end of one hollow member and the enlarged lower end of an adjacent hollow member, said means directing at least a portion of said particulate material passing from said upper end back to said lower end of the same hollow member for re-cycling.

3. The apparatus of claim 1 wherein each of said hollow members comprise a substantially cylindrical portion connected to said shaft having a lower portion with an enlarged lower end and having an upper portion with an enlarged upper end thereby being adapted to direct at least a portion of said particulate material passing from said upper end back to the lower end of the same hollow member for re-cycling.

4. The apparatus of claim 3 wherein the enlarged upper end of the upper portion of said hollow member has a diameter greater than the lower end of the enlarged lower portion of said hollow member for facilitating the re-cycling of at least a portion of said particulate material passing from said upper end back to said lower end of the same hollow member.

5. The apparatus of claim 1 where each of said hollow members comprise a body of revolution obtained by rotating a parabola about said central axis, the smallest diameter portion of said hollow member being intermediate the end portions of said hollow member.

6. The apparatus of claim 1 wherein said reaction chamber is substantially a right circular cylinder.

7. The apparatus of claim 1 wherein said reaction chamber is substantially a frustoconical shape having its narrow end indisposed downwardly.

8. The apparatus of claim 1 wherein means for admitting a drying fluid include a plate positioned at the bottom end of said reaction chamber, said plate having gas entry orifices defined therein.

9. The apparatus of claim 8 wherein said gas entry orifices decrease in number per unit area along a line from the center to the edge of said gas entry plate.

10. The apparatus of claim 1 wherein each of said hollow members are equally spaced from said chamber side walls.

11. The apparatus of claim 1 wherein said vertical shaft is driven by variable speed means.

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