United States Patent

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[72] Inventor George N. Brown
Madelyn's Garden, Wilmington, Del.

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[73] Assignee E. I. du Pont de Nemours and Company
Wilmington, Del.

[54] GRAVITY-FLOW SOLIDS BLENDING
8 Claims, 10 Drawing Figs.

[52] U.S. Cl. 259/36, 259/4, 259/95
[51] Int. Cl. B01f 5/24
[50] Field of Search 259/4, 36, 95, 180, 18

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Primary Examiner—Robert W. Jenkins
Attorney—Harry J. McCauley

ABSTRACT: A gravity-flow particulate solids blender having downcomers provided with traps at their bottom ends retaining solids in static repose during blender standby provided with gas sweeps effecting controlled delivery of solids into a common collector during operation.

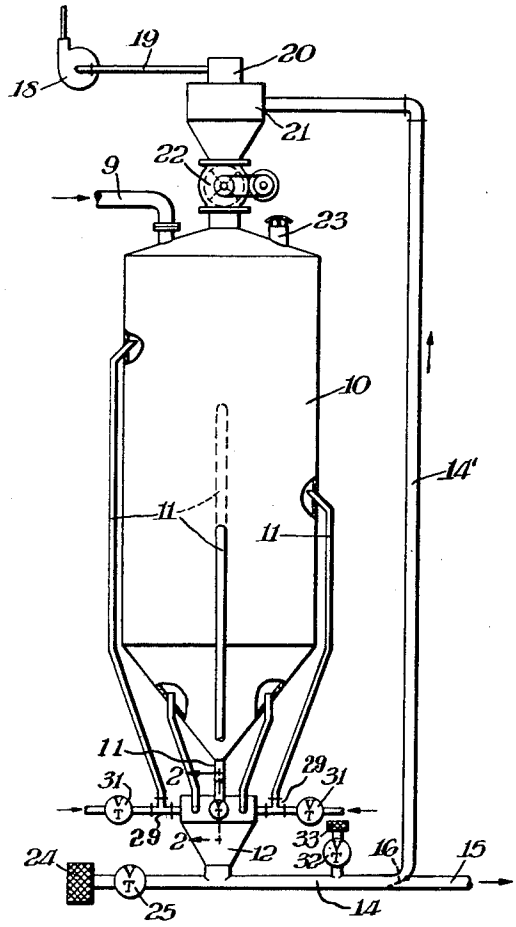
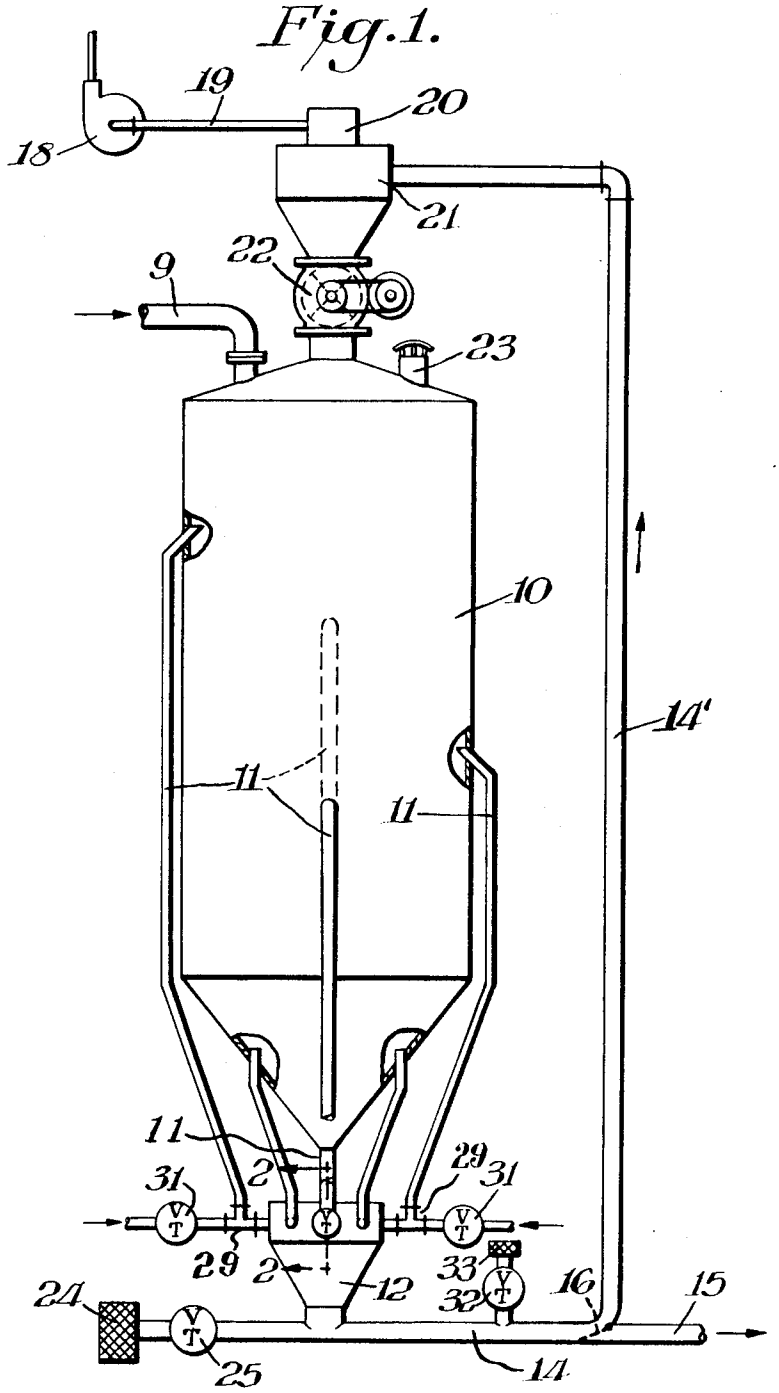


Fig. 1.



INVENTOR.

George N. Brown

BY

Harry J. McCauley

ATTORNEY

Fig. 2.

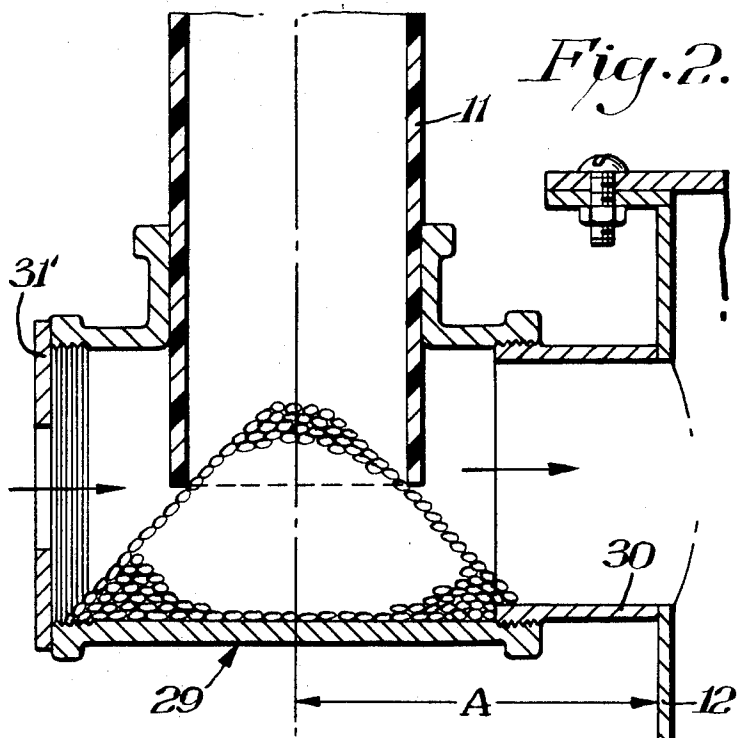


Fig. 4.

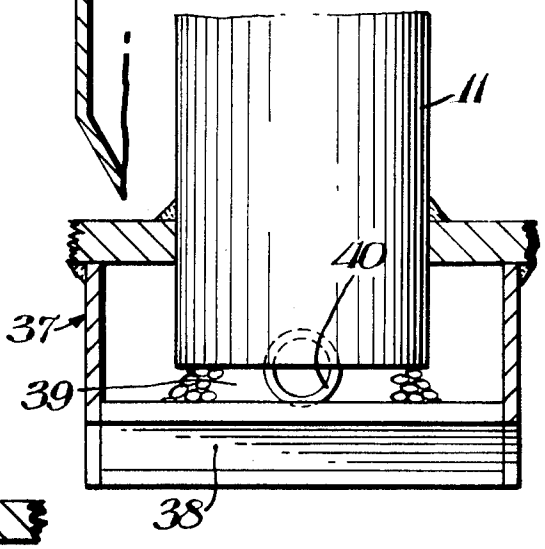
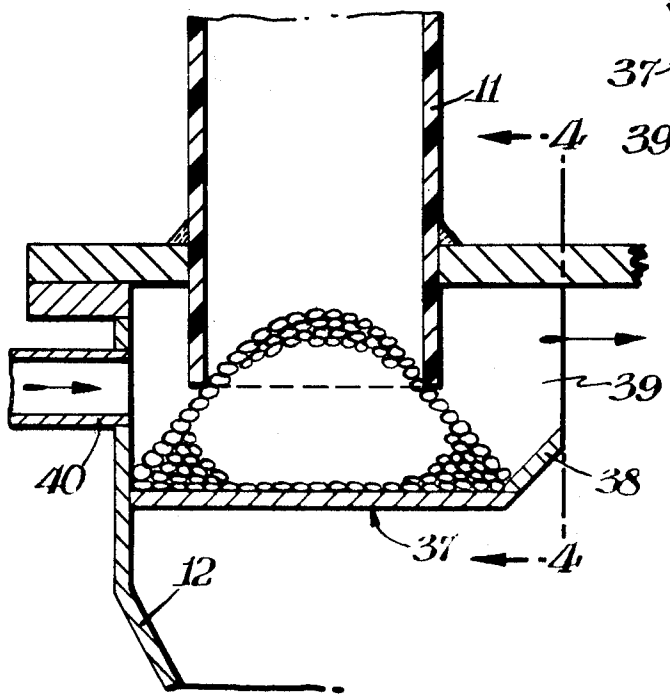
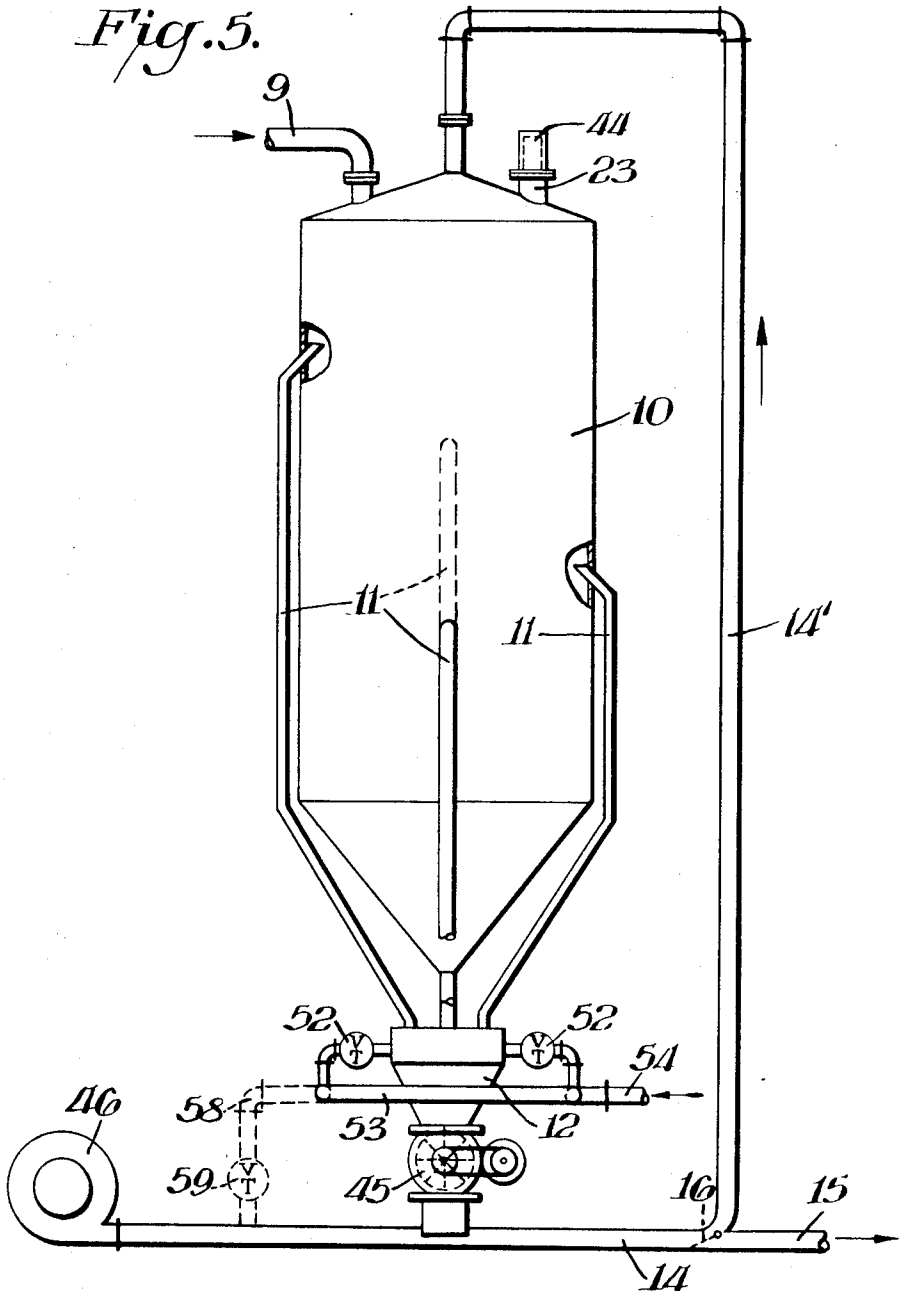


Fig. 3.



INVENTOR:
George N. Brown
BY
Harry J. McCauley
ATTORNEY

Fig. 5.



INVENTOR
George N. Brown
BY
Harry J. McCauley
ATTORNEY

Fig. 6.

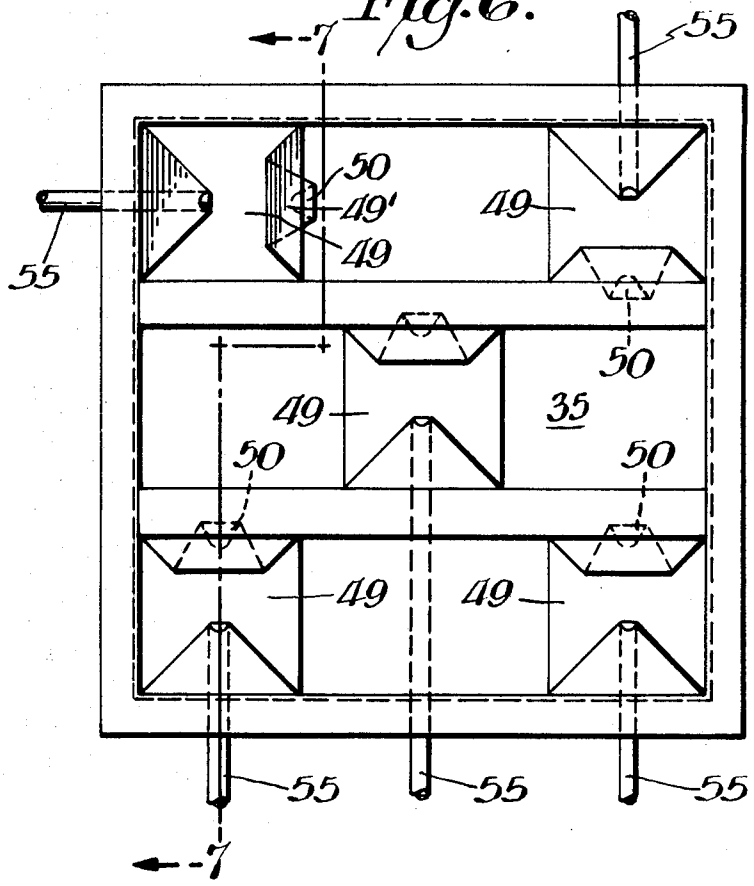
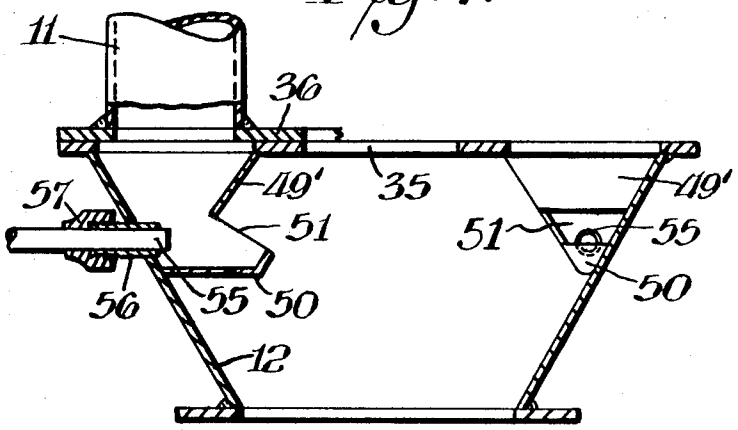


Fig. 7.



INVENTOR
George N. Brown
BY
Harry J. McCauley
ATTORNEY

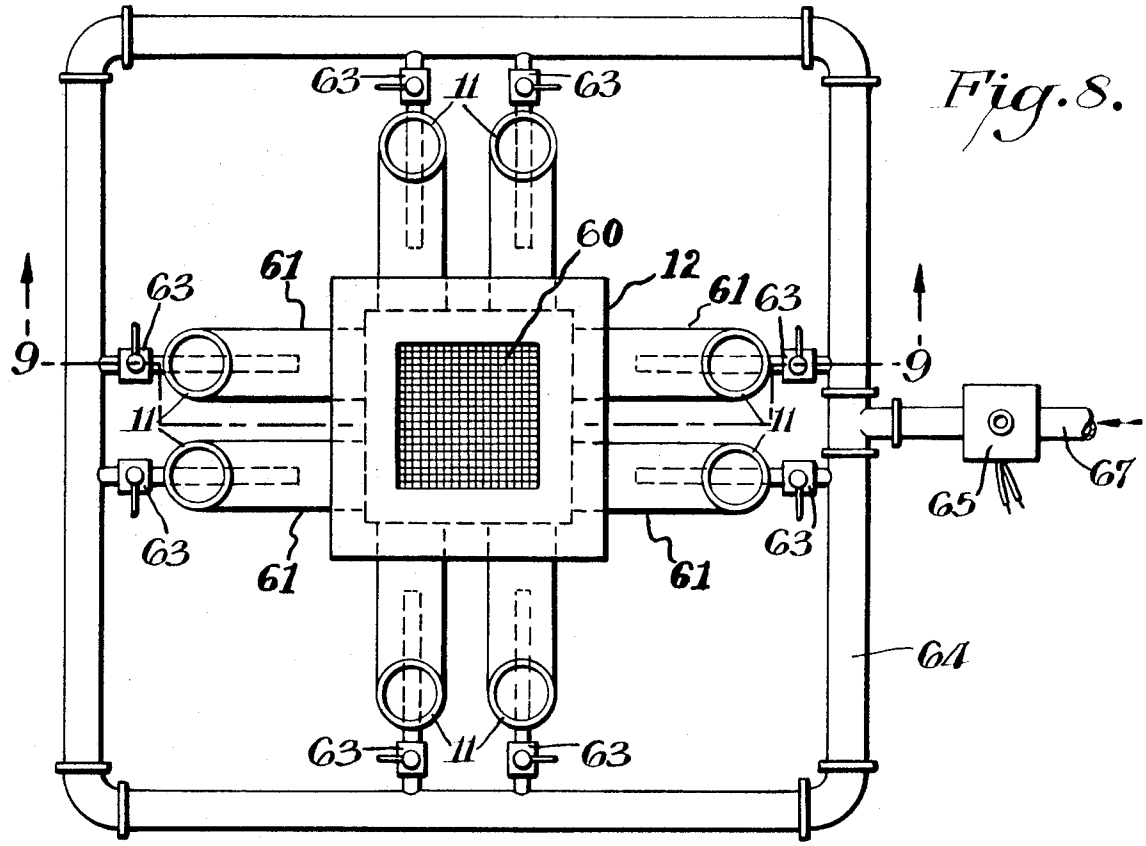


Fig. 8.

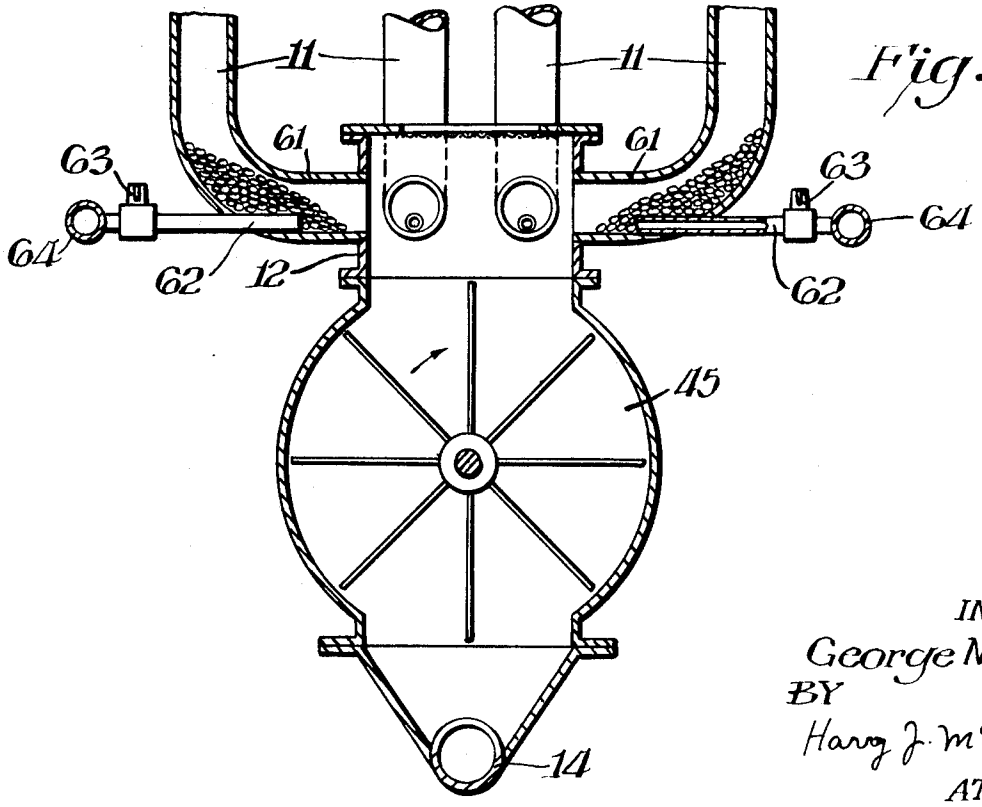


Fig. 9.

INVENTOR
George N. Brown
BY
Harry J. McCauley
ATTORNEY

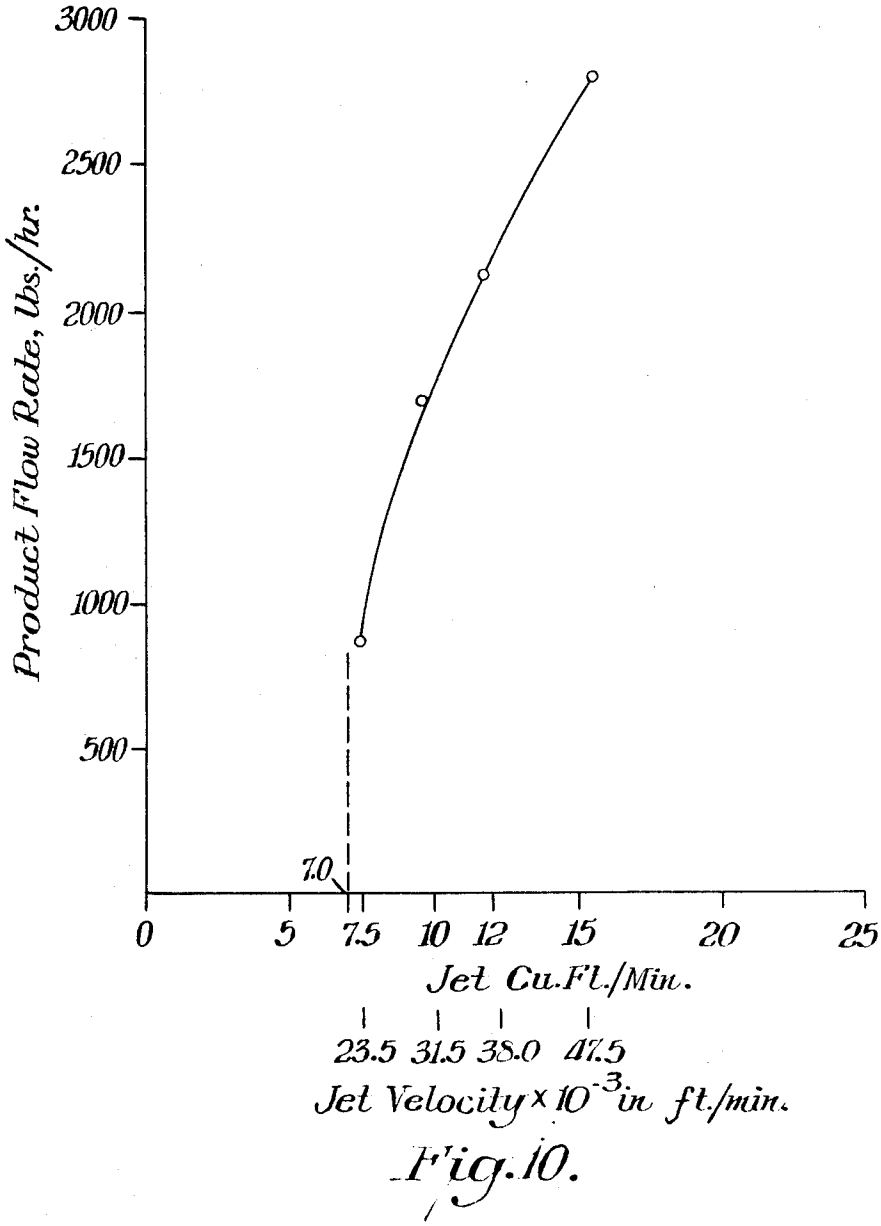


Fig. 10.

INVENTOR
George N. Brown
BY
Harry J. McCauley
ATTORNEY

GRAVITY-FLOW SOLIDS BLENDING

BRIEF SUMMARY OF THE INVENTION

Generally, this invention comprises, in a gravity-flow particulate solids blender having an elevated main storage vessel provided with a multiplicity of solids withdrawal downcomers connected at their top ends in open communication at preselected points with the storage vessel and a common collector receiving solids discharged from the bottom ends of the downcomers, individual traps interposed between the bottom ends of the downcomers and the common collector retaining solids emerging from the downcomers in static repose during blender standby, and means directing a regulated solids-conveying gas stream through solids held up in the individual traps and thence into the collector effecting controlled drawoff of solids from the downcomers during blender operation, together with the method of solids feeding from the downcomers.

DRAWINGS

FIG. 1 is a partially broken schematic side elevation view of a preferred embodiment of gravity-flow solids blender according to this invention wherein solids drawoff from the downcomers is effected by vacuum,

FIG. 2 is a side elevation section of a downcomer-collector juncture taken on line 2–2, FIG. 1, utilizing, however, an orifice for sweep gas flow control instead of the valve of FIG. 1,

FIG. 3 is a side elevation section of a second embodiment of downcomer-collector juncture which can be substituted for the FIG. 2 construction where conditions prevent lateral offsetting of the downcomer discharge ends from the collector,

FIG. 4 is an end view, partly in section, taken on line 4–4, FIG. 3,

FIG. 5 is a partially broken schematic side elevation view of a preferred embodiment of gravity-flow solids blender according to this invention wherein solids drawoff from the downcomers is effected by superatmospheric pressure,

FIG. 6 is a schematic plan view of a downcomer trap-collector subassembly adapted to use in the apparatus of FIG. 5,

FIG. 7 is a side elevation taken on line 7–7, FIG. 6, only a single associated downcomer being detailed,

FIG. 8 is a schematic plan view detailing a different design of downcomer-collector subassembly which can be substituted for that of FIGS. 6 and 7 where the downcomers are spaced apart sufficiently at their bottom ends to accommodate the collector therebetween,

FIG. 9 is a sectional view taken on line 9–9, FIG. 8, and

FIG. 10 is a plot of individual downcomer solids discharge rate in lbs./hr. versus both gas jet throughput in ft.³/min. and jet velocity in ft./min. using pressurized air as the sweeping gas.

Gravity-flow solids blending such as disclosed in Reissue Pat. No. 25,687, as to which applicant was a joint inventor, has proved to be highly effective in the quick and thorough blending of most particulate solids, quite independent of individual solids particle mobilities.

Referring to FIG. 1, such blending involves confining a mass of particulate heterogeneous solids which it is desired to blend in an elevated column, such as by retention within the upright vessel indicated generally at 10, provided with loading line 9, withdrawing from the mass in a generally vertical direction and within about one-fourth of the distance from the center of the mass to the confining wall of the column, taken at the level of withdrawal inwardly from the periphery of the solids mass, substantially equal amounts of the solids per unit time simultaneously by gravity flow from a multiplicity of regions disposed lengthwise of the mass and substantially equiangularly around the periphery of the mass, and combining these equal amounts of solids to produce a solids blend having improved homogeneity of composition.

Solids withdrawal from different regions of the solids mass is conveniently effected by a multiplicity of open (i.e., unvalved) solids delivery conduits 11 (in FIG. 1 nine in number, two serving the cone bottom lying back of the front two, so as not to be visible in the showing) hereinafter, and in the claims, referred to as "downcomers," which discharge the gravity flow of solids therethrough via their open bottom ends into a common collector 12. Although not too clearly shown in FIG. 1, the lower end of the frustoconical bottom of vessel 10 is serviced by an individual downcomer 11, so that the entire solids mass within vessel 10 is moved generally downwards during operation. From collector 12 the recombined solids can be optionally recycled back to the top of vessel 10 for additional blending through lines 14 and 14' by either vacuum (FIG. 1) or pressure pneumatic transport (FIG. 5), or withdrawn as blended product through delivery line 15 by diversional flow obtained by switching flapper valve 16 approximately 30° clockwise. This closes passage to line 14' and simultaneously opens passage through line 15, which latter must, of course, be provided with its own pneumatic transport facility (not shown) for continued transfer of product to succeeding process equipment.

The vacuum system for the apparatus of FIG. 1 comprises a blower 18 pulling a vacuum via line 19 through a conventional solids separator 20 opening into the top of a small volume solids receiver 21 into which line 14' discharges tangentially. Vessel 10 is maintained at atmospheric pressure by a top open vent connection 23, recycled solids being returned continuously thereto via conventional motor-driven rotary solids feed valve 22, which constitutes an air lock between the vacuum system and vessel 10. Conveying air for solids transport is drawn in through filter 24 disposed adjacent the discharge opening of collector 12, a regulating valve 25 being interposed therebetween.

Gravity-flow blenders of the prior art have hitherto employed direct gravity-flow solids discharge out of the downcomers 11 into the collector 12, and this has been accompanied by difficulties in flow equalization through the multiple downcomers, particularly with specific solid materials which, it will be understood, can range in gravity-flow characteristics from exceedingly mobile to actually "sticky." As a cure for this problem, flooded operation in which solids are temporarily held up within collector 12 so that they bank across the discharge ends of the downcomers to thereby throttle flow therethrough is disclosed in U.S. Pat. No. 3,158,362. Applicant, however, preferred the use of a centrally disposed frustoconical baffle internal of collector 12, as taught in his U.S. Pat. No. 3,208,737, a modification of which is also the subject of U.S. Pat. No. 3,347,534.

None of these patented approaches has proved completely satisfactory with all particulate solids which have to be blended. Specifically, discharge from downcomers 11 is affected unequally and unpredictably by the variable amount of material momentarily disposed across the downcomer outlets. Also, solids hold-up within collector 12 effectively isolates substantial process material from the blending process. In addition, variations in flow through certain downcomers sometimes drastically affects flow through neighboring downcomers, so that, in very extreme cases, as, for example, with some fluidizable materials, it has been found that some flow through a given downcomer reverse to the normal flow can actually occur during periods of unstable operation. Finally, extra valves are usually required to insure regulated withdrawal of the commingled solids from the flooded collector.

This invention solves all of the foregoing problems as well as provides positive selectability of solids flow rates through individual downcomers 11 by utilizing indirect transfer of the discharged solids from the several downcomers via traps into collector 12 through the agency of air sweeps traversing the bottom ends of the downcomers and exhausting into the collector.

Referring to FIGS. 1 and 2, a preferred construction utilizes vacuum to induce the individual downcomer solids-conveying gas sweeps.

In this embodiment the lower terminal ends of all of the downcomers 11 are offset a short distance laterally from the periphery of collector 12 at a level slightly below the top thereof. The traps in this design are inexpensive pipe tees 29, horizontally mounted so that one straight-run connection of the tee is coupled through short nipple 30 to the interior of collector 12, whereas the opposite straight-run connection is provided with an airflow restrictor such as valve 31 (FIG. 1) or orifice 31' (typically 1-inch dia.), FIG. 2, communicating with the outside, where atmospheric air is a suitable sweep gas from the process standpoint. The remaining connection of the tee is oriented upwardly to receive the bottom end of downcomer 11 in a tight slip fit, so that solids discharge occurs at a distance approximately 1 inch above the bottom wall of the tee.

It is essential that the downcomer ends be disposed well within the tees 29 in order to provide open space for the sweep gas to clear past the pile of solids gathered at the discharge openings of the downcomers 11 in order to entrain particles on the outside surfaces of the piles and deliver them to collector 12. Typically, a downcomer disposition in which the discharge end lies approximately at the horizontal axis of the tee 29 gives good performance.

It is frequently practicable to employ polymeric tubing for the downcomers 11, in which case it is relatively easy to adjust the clearance between the downcomer discharge ends and tees 29 by simply manually slipping the tubing into or out of the upwardly oriented tee connections an appropriate amount, this adjustment being facilitated by the inherent flexibility of the polymer.

It will be understood that the offset *A* from the centerline of downcomer 11 to the inside periphery of collector 12 must slightly exceed the radius of the base of the solids pile (typically, by about 1 inch for granular polyethylene) as it subsists in static repose, which is the condition depicted in FIG. 2. Then, in standby condition with no sweep gas drawn through the flow restrictors 31, 31', the solids simply accumulate at the exit ends of the downcomers, thereby blocking all downcomer solids throughput and all delivery to collector 12.

However, when sufficient vacuum (typically, 3 inch H_2O) is applied to collector 12 by blower 18 during blender operation, sweep air is drawn through all of the flow restrictors 31, 31' simultaneously at a conveying velocity through the traps of approximately 4000 ft./min. or higher, and solids are thereupon entrained from the sides of the solids piles and conveyed out of traps 29 through nipples 30 into collector 12 and immediately discharged therefrom into line 14, without any solids accumulation within the collector. Close equality of solids discharge rates from downcomers 11 is automatically attained with orifices 31', whereas regulation to equality or, if desired, preselected difference in discharge rates, is obtainable by suitable adjustment of valves 31. An overall control of vacuum applied is provided by manually operated bypass valve 32 equipped with its own filter 33, which is connected from atmosphere into line 14 downstream from collector 12. The size of valve 32 is chosen so that, when opened wide, it is effective to admit a large enough flow of bypass air to cut off all solids delivery out of traps 29.

Where space limitations prevent lateral accommodation of downcomers 11, the design of FIGS. 3 and 4 is preferred, wherein the traps 37 are boxlike structures mounted within collector 12. Here the inboard end of the trap is provided with a weir lip 38 defining a solids delivery opening 39 with the top closure of the collector. Sweep gas introduction is effected through radially disposed nipples 40, again provided with valves 31 or orifices 31' (not shown) as hereinbefore described for FIGS. 1 and 2, aligned with openings 39.

Gravity-flow solids blending with superatmospheric pressure pneumatic solids conveying is entirely practicable, a typical apparatus being shown schematically in FIG. 5. Here the number of downcomers 11 has, for simplicity of representation, been limited to five, four of which draw from the upper cylindrical section of solids storage vessel 10 whereas the fifth is connected to the vertex of the vessel's cone bottom. As in FIG. 1, vessel 10 is provided with a heterogeneous solids supply line 9 for introducing solids to be blended and a top vent 23 opening to atmosphere, which is fitted with a dust filter 44 to remove entrained dust from the exhaust.

Downcomers 11 discharge into collector 12 via traps hereinafter described, the collector outlet being connected to line 14 through conventional continuously operating motor-driven rotary solids feed valve 45, which constitutes an air lock therebetween. Rotary valve 45 is operated at a rotational speed high enough to continuously remove all solids from collector 12, so that there is no solids accumulation therein. The product removal piping system is identical with that of FIG. 1, constituting branched recycle line 14' and product delivery line 15, optionally selected by flapper valve 16. Pressurized pneumatic solids conveying air is supplied by blower 46 connected upstream from rotary valve 45.

Solids withdrawal into collector 12 is accomplished with the construction of FIGS. 6 and 7, which utilizes internally mounted traps 49 into the tops of which downcomers 11 open, as particularly detailed for the single downcomer shown at the left-hand side of FIG. 7. Vertex downcomer 11 is served by centrally disposed trap 49, thus permitting a straight-run connection for this vital downcomer. The upper closure of collector 12 is provided with a central opening 35 aligned with the opening in square frame plate 36 to which the lower ends of downcomers 11 are attached, permitting exhaust of sweep gas from the collector. Traps 49 are generally similar to traps 37 of FIGS. 3 and 4, except that they taper downwardly into V-troughs, the open ends of which are fitted with weir lips 50. The downwardly depending wall sections 49' and upwardly extending weir lips 50 define, between them, solids discharge openings 51.

Solids-entraining sweep gas is supplied through air jets 55 aligned with openings 51, the jets preferably being adjustably mounted longitudinally of traps 49 by slip-fitting through threaded nipple retainers 56 fixedly secured through openings in the collector wall into the traps. Jet pipes 55 are held fixedly in preselected longitudinal position within nipple retainers 56 by locknuts 57. In the FIG. 5 apparatus, air delivery to jets 55 is regulated by valves 52 interposed between the jets and an air supply manifold 53, hereinafter described in greater detail, which obtains its air in turn from either a high pressure plant air supply line 54 or, as is sometimes more convenient, directly from blower 46 by the cross-connection 58, indicated in broken line representation, provided with regulating valve 59.

If desired, pressurized sweep gas can, of course, be supplied to jets 55 through individual lines connected to the outboard ends; however, it is most convenient to utilize a manifold system such as that detailed for the alternate arrangement of FIGS. 8 and 9.

The latter apparatus services eight downcomers 11 which discharge into open-topped collector 12 through laterally oriented elbows 61 of sufficient horizontal run to constitute traps retaining the solids in static repose during blender standby when no sweep gas is supplied to gas jets 62, the condition depicted in FIG. 9. Collector 12 is, in this instance, a very small volume receptacle connecting to the input side of conventional motor-driven rotary solids valve 45, which is continuously operated at a high enough rate of rotation to immediately remove substantially all solids out of the discharge end of the collector, so that there is never any accumulation of solids therein. Rotary valve 45 discharges into line 14, solids delivered thereto being immediately conveyed away by pressurized gas supplied by blower 46, FIG. 5.

Gas jets 62 are preferably adjustably mounted longitudinally of the horizontal runs of elbows 61 by assemblies such as those already described for jets 55 with reference to FIG. 7.

A common pressurized gas supply (e.g., 1.5 to 2.5 lbs. operating pressure for a 1-inch dia. pipe manifold) is provided for the eight jets 62 (typically, ¼-inch dia.) by use of the square manifold 64 which symmetrically encloses collector

12, connections to individual gas jets 62 being made via manual control valves 63 interposed between the manifold and the jets. Preferably, a main electrical solenoid gas supply control valve 65 is interposed between the primary air supply line 67 and manifold 64 for control purposes hereinafter described.

When solenoid valve 65 is open, and individual valves 63 are all adjusted to desired settings, gas jets 62 discharge adjacent the solids slope disposed towards collector 12 and the solids are conveyed into the collector at a regulated rate. Jet air exhausts freely through the open top of the collector, covered with a protective screen 60, which can be further protected from ingress of foreign material, rain water or other adulterants by provision of a surmounting protective roof cap, not detailed. Simultaneous shutoff of all solids flow is obtained by closure of solenoid valve 65.

Where entraining jets 55 or 62 are employed, with their relatively high exit velocities, there is a critical position of the jet outlet with respect to the slope of the solids pile adjacent collector 12. Thus, if the jet outlet is less than about 1 inch from the face of the pile, there is a tendency to blast the particles from in front of the nozzle mouth, which reduces effectiveness as a solids feeder. Similarly, if the jet is spaced farther back than about 2 inches from the solids slope line, the jet does not positively entrain particles.

However, where the jets are disposed within the 1-inch—2-inch critical spacing, near-linearity of solids feeding is achieved, as is indicated by the operational plot of FIG. 10. The slight nonlinearity of solids feed which does exist is believed due to the varying friction of solids material in flow through downcomers 11.

The plot of FIG. 10 graphically depicts the operation of a ¼-inch dia. air jet (having its orifice spaced 1.5 inches inwards from the solids slope) passing pressurized air at essentially room temperature. The solids utilized were granular polyethylene cubes measuring approximately one-eighth inch on a side, with somewhat rounded edges, having an unpacked density of approximately (1) 35 lbs./ft.^{3} under which circumstances the following relationships existed:

Jet CMF	Jet velocity, ft./min.	⅛" square granular polyethylene product flow rate, lbs./hr.
7.0	22,000	0
7.5	23,500	810
10.0	31,500	1,680
12.0	38,000	2,100
15.00	47,500	2,800

In summary, the delivered rate of solids is a function of: (1) total gas flow from the jet, (2) exit velocity of the jet and (3) the immersion depth of the jet within the solids pile, as measured horizontally from nozzle to surface.

Solids feeding by jet as taught in FIGS. 5—10, inclusive, is independent of the level of solids maintained within vessel 10 and, thus, there is no requirement for changing the settings of valves 52 (FIG. 5) or 63 (FIG. 9) to accommodate periodic emptying or refilling of the blender.

With vacuum solids feeding in accordance with FIGS. 1—4, inclusive, however, each solids-free downcomer 11 effectively constitutes a bypass of gas which correspondingly reduces the vacuum applied to the several traps 29 (FIG. 2) or 37 (FIGS. 3 and 4). Surprisingly, solids feeding entrainment by gas continues even with one or more downcomers completely empty, but the solids feed rate, of course, decreases proportionately. This can be compensated for by providing a conventional automatic throttling control for bypass valve 32, progressively reducing its air bleed flow to a degree compensating for the progressive uncovering of the downcomers 11 during emptying of vessel 10 and, conversely, progressively increasing the air bleed flow as successive downcomers each fill in turn during loading.

An important advantage of this invention is the fact that the solids hold-up traps operate completely independent of one another and thus can discharge into collector 12 in practically any direction without interference from neighboring traps, and, also, at different vertical levels. This permits the designer wide latitude in the accommodation of a large number of downcomers, both as to relative orientation and points of introduction into the collector, which is a particular aid where the downcomers are crowded closely together, as they frequently are in manufacturing plants.

It is entirely feasible to use jets such vacuum-type those denoted 55 (FIG. 7) and 62 (FIG. 9) embedded in the piles of solids discharged from downcomers 11 as gas flow restrictors for vacuum systems instead of the valves 31 or orifices 31' taught with respect to FIGS. 1 and 2, respectively. This necessitates drawing a somewhat higher vacuum of, typically, 4 inches of Hg to obtain the requisite jet air throughput; however, this is not disadvantageous. In fact, where a large number of downcomers are involved, a smaller size blower 18 is required for vacuum-type jets than would be the case for the valve 31 orifice 31' restrictors.

In addition, it is practicable to use pressure jet feeding of solids from downcomer traps to a system which employs vacuum conveying away from the collector discharge, except that it is then necessary to interpose a rotary feeder valve such as 22 or 45 between the outlet of collector 12 and line 14 to serve as an air lock. With such a design, operation remains entirely unaffected by any air bypassing through downcomers running empty, such as occurs during filling or emptying of blender vessel 10, or the blending of relatively small lots of material which are insufficient to cover all of the downcomer inlets.

From the foregoing, it will be understood that this invention can be modified extensively without departure from its essential spirit, and it is accordingly intended to be limited only by the scope of the following claims.

I claim:

1. In a gravity-flow particulate solids blender having an elevated main storage vessel, a multiplicity of solids withdrawal downcomers connected at their top ends in open communication at preselected points with said storage vessel, and a common collector receiving solids discharged from the bottom ends of said downcomers, individual traps interposed between the bottom ends of said downcomers and said common collector retaining solids emerging from said downcomers in static repose during blender standby, and means directing a regulated solids-conveying gas stream through solids held up in said traps and thence into said collector effecting controlled drawoff of solids from said downcomers during blender operation.

2. Apparatus according to claim 1 wherein said means directing a regulated solids-conveying gas stream through solids held up in said traps is a vacuum source.

3. Apparatus according to claim 2 wherein the gas inlet sides of said means directing a regulated solids-conveying gas stream through solids held up in said traps are provided with flow restrictors such as valves or orifices.

4. Apparatus according to claim 2 provided with a regulable gas bypass valve connected to maintain a preselected level of vacuum effectively applied by said vacuum source to said means directing a regulated solids-conveying gas stream through solids held up in said traps.

5. Apparatus according to claim 1 wherein said means directing a regulated solids-conveying gas stream through solids held up in said traps is a pressure jet disposed with discharge opening in the range of about 1 inch—2 inches from the face of the slope of said solids adjacent said collector measured during repose.

6. Apparatus according to claim 5 wherein said pressure jet is mounted generally perpendicularly adjustable of said face of said solids adjacent said collector.

7. Apparatus according to claim 1 wherein said means directing a regulated solids-conveying gas stream through solids held up in said traps comprises a multiplicity of pressure jets, each individually serving a single trap, a common

manifold supplied with solids-conveying gas from a pressure source, individual gas flow regulation valves interposed between said manifold and said pressure jets, and a common gas pressure control valve interposed between said pressure source and said manifold.

8. In a process for the gravity-flow blending of solids comprising, in sequence, confining a mass of the heterogeneous solids in an elevating column, withdrawing as separate fractions from said mass in a generally vertical direction substantially equal amounts of said solids per unit time simultaneously from a multiplicity of different regions of said mass, and combining said separate fractions in a common collector to produce a solids blend having improved homogeneity of composition, the improvement consisting of entrapping said solids in said separate fractions at the discharge ends of their courses before combining in said common collector to thereby retain the solids of said fractions in static repose during blending standby and directing a regulated solids-conveying gas stream through said solids at said discharge ends of said courses effecting controlled drawoff of solids from said separate fractions into said common collector during blending operation.