Nov. 15, 1955 W. C. LAPPLE 2,723,883

HANDLING PULVERULENT MATERIALS

Filed May 21, 1951 2 Sheets-Sheet 1

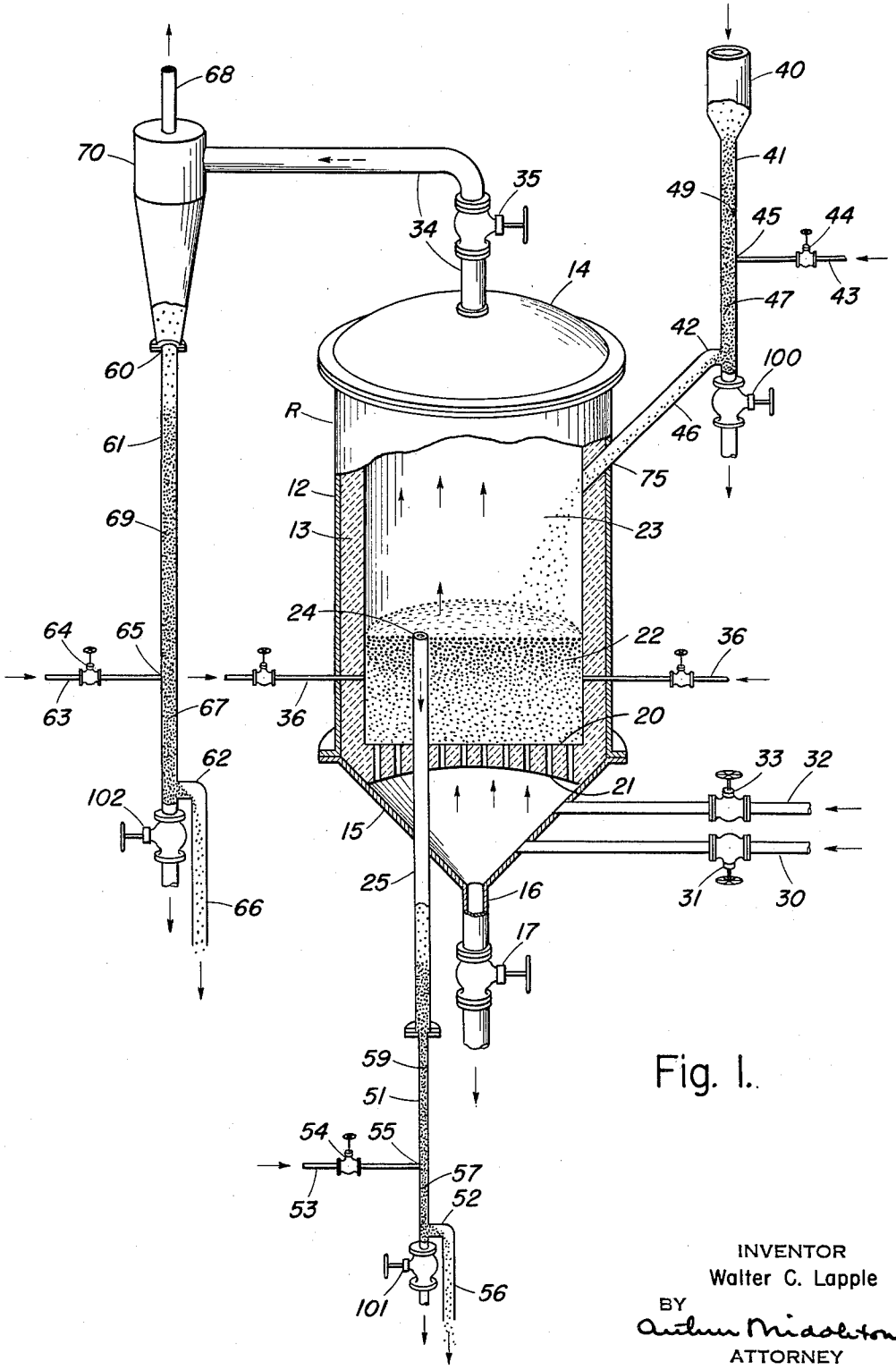


Fig. I.

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Filed May 21, 1951 2 Sheets-Sheet 2

Fig. 2.

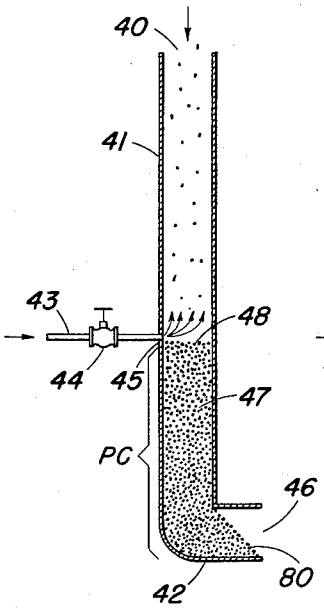


Fig. 3.

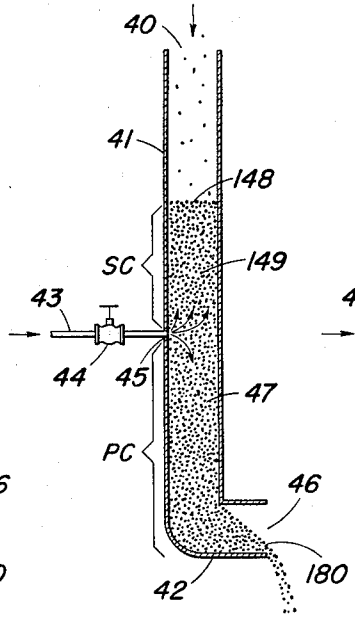
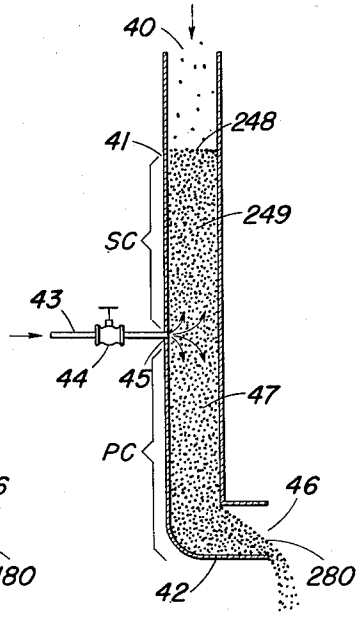


Fig. 4.



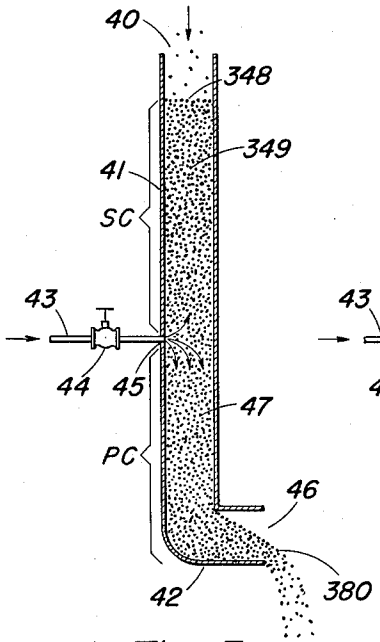


Fig. 5.

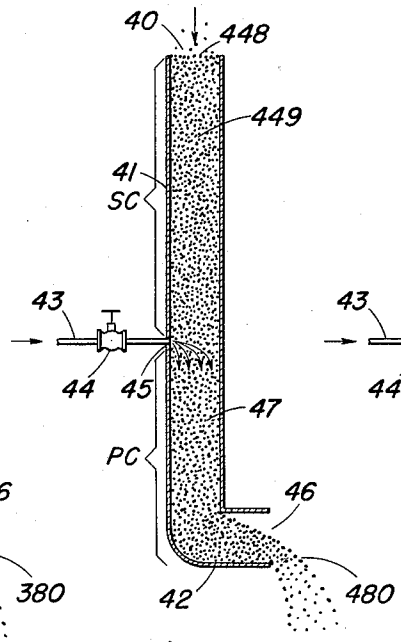


Fig. 6.

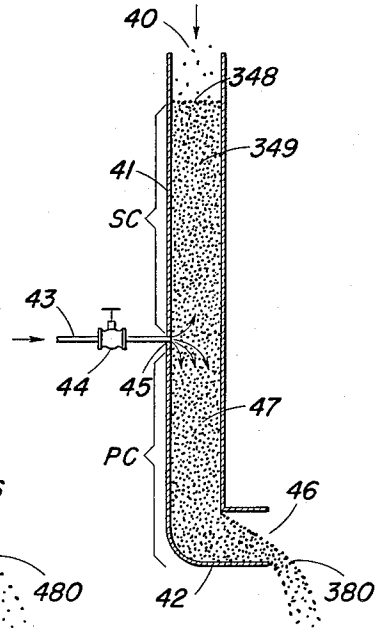


Fig. 7.

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2,723,883

HANDLING PULVERULENT MATERIALS

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Application May 21, 1951, Serial No. 227,434

1 Claim. (Cl. 302—17)

This invention relates generally to the art of handling finely divided solids, particularly to ways and means for controllably flowing such solids from an upper to a lower level and if desired into or out of the confined space in vessels of any sort such as enclosed reactors, storage containers, solids transport conduits and the like.

In moving finely divided solids from an upper to a lower level, use is commonly made of an ordinary standpipe or vertical chamber which serves as a solids conduction or flow-line. In such devices the rate of solids flow-like movement is controlled by the use of restrictive devices such as cone valves, screw conveyors, and the like in or attached to the flow-line. However, such devices are not particularly efficient due to high first cost and maintenance expense; also, such devices have a pronounced tendency to plug and are only difficultly accessible for clean out. Moreover, such devices do not provide adequate safeguards against gas leakage and blow-backs through the line; hence they are unsatisfactory for use in feeding or discharging solids from sealed or pressurized vessels because they permit gas leakage and allow undesirable irregular or intermittent solids flow; this gas leakage also contributes to dust losses due to the constant agitation and entrainment of solids. Further, such devices are incapable of handling varying loads of solids without constant attention. That is, if the rate at which solids enter the flow-line should suddenly increase or decrease, then manual manipulation of controls is necessary in order to compensate for this change. If the flow of high temperature solids is contemplated then mechanical devices such as screw conveyors cannot be used because they are unsatisfactory for high temperature operation.

A principal object of this invention is to provide ways and means for controllably flowing finely divided solids from an upper to a lower level while minimizing dust losses during such operation and leaving non-solids conditions such as temperature, pressure and the like on both such levels substantially unchanged.

Another important object of this invention is to provide inexpensive and reliable ways and means for the automatic control of solids flow into or from a confined space without regard to the temperature of such solids and without changing substantially the non-solids conditions such as temperature, pressure and the like within that space, whereby the rate at which solids pass through a flow-line is automatically maintained to be substantially equal to the rate at which solids are supplied to such flow-line even though the rate of supply itself may vary.

Still another object of this invention is to provide an ever present gas-seal within the flow-line whether or not solids are being supplied thereto, thus minimizing the escape of obnoxious gases and preventing blow-backs from sealed or pressurized vessels while at the same time preventing undesirable irregular or intermittent solids flow.

A still further object of this invention is to provide ways and means for handling finely divided solids whereby dust losses are minimized or avoided so that such solids may be safely and economically discharged from pressurized vessels.

Broadly stated, this invention contemplates controllably descending finely divided solids through a conduit while maintaining a gas-seal therein and proposes to accomplish this by feeding such solids to a columnar solids-conducting zone, such as a tube, to establish and maintain therein a dense gas-sealing column of such solids, supplying gas at a predetermined rate to such column at a point intermediate its upper and lower extremities, diverting a quantity of such gas from its point of entry downwardly through the column to expedite the gravity-flow of solids therethrough at a rate proportioned to the quantity of gas so diverted, and controlling the quantity of gas so diverted and thus the rate at which solids pass through the column by controlling the rate at which solids are fed to the column, whereby the quantity of gas so diverted is directly proportioned to the rate at which solids are fed to the column and the rate at which solids pass through the column is equal to the rate at which solids are fed thereto.

In its briefest form the apparatus invention hereof comprises a generally vertical unobstructed tube connecting an upper zone from which the tube receives solids with a lower zone to which solids are to be transferred, the conductor terminates at its lower end in an offset solids discharge adapted to contain the angle of repose of solids admitted from the upper zone. A gas inlet is provided in the conductor intermediate its ends and spaced above the discharge opening a sufficient distance to provide a seal against the pressure differential between the upper and lower zones when a portion of the conductor below the gas inlet is filled with solids admitted from the upper zone.

In somewhat more detail, this invention contemplates establishing and maintaining in a hollow unobstructed columnar space a gas-sealing subjacent primary column of finely divided solids of substantially constant height and having a lower discharge opening through which such solids are prevented from flowing by their resistance to flow as defined by the angle of repose that the solids normally assume at the discharge, supplying gas at a fixed rate to the zone at a gas-entry point located intermediate the upper and lower extremities thereof, and causing solids to descend through the columnar zone and spill from the discharge by supplying such solids to an upper section of the zone to establish therein a superjacent column of solids of a variable height extending above the gas-entry point which column restricts gas-upflow and diverts a quantity of such supplied gas in proportion to whatever height the column of solids assumes, whereby the gas so diverted descends through the chamber to exert a force on the solids overcoming their resistance to flow so that they pass through the zone and discharge therefrom at a rate that varies in accordance with the rate of feed, whereby the rate of movement of solids from the discharge is controlled by regulating the rate at which solids are fed to the zone.

Summarizing, this invention proposes to control the flow of finely-divided solids from an upper to a lower level by feeding such solids to a generally vertical unobstructed tube having an upper feed inlet and a bottom discharge outlet to establish in the lower end portion thereof a primary column of such solids adapted to assume an angle of repose at the outlet, supplying gas to the tube at a gas-inlet substantially at the upper level of the primary column, restricting the upflow of such gas in the tube so that solids are discharged from the outlet by establishing in the tube a secondary column of such solids above the gas inlet, and controlling the height of the secondary column and the consequent rate at which

solids are discharged from the outlet by regulating the rate of feed of such solids to the inlet.

Very briefly, the rate at which solids descend through the zone is controlled by the quantity of injected gas that is diverted to pass through the discharge; and the quantity of gas so diverted is regulated by the rate at which solids enter the zone.

Thus this invention provides an inexpensive and reliable methd of controlling solids-flow without the use of manually operated obstructive devices in the solids-conducting line whereby the movement of solids therethrough is regulated to coincide with the rate at which solids enter such line while at the same time a gas-seal is provided in the line by the column of solids residual therein even though the feed has stopped. This constantly maintained gas-seal is insured by the fact that the flow impelling force is exerted by downwardly diverted supplied gas that will only descend through the columnar zone when there exists above the gas-entry point therein a sufficient column of solids to divert a quantity of such gas downwardly by proportionately resisting or at least restricting its upward escape.

This invention has its chief application when employed in association with confined spaces, however, it has application in any case where it is desired to controllably flow finely-divided solids from any upper to any lower level especially when it is desired to minimize dust loss during such operation.

An important feature of this invention resides in the fact that there are no manual manipulations required once the system is put in operation. The gas is supplied to the columnar zone at a fixed rate and the rate at which solids flow through the zone is varied according to the proportion of supplied gas diverted downwardly from its point of entry; the proportion of downwardly diverted gas is dependent upon the height of the secondary column above the gas-entry point, and this height is regulated by the rate at which solids are fed into the zone so that the rate at which solids flow through the zone and are discharged therefrom is automatically controlled to coincide with the rate at which solids are fed to the zone.

Another important feature of this invention resides in the fact that the solids gravity-flow through the standpipe under the proper conditions rather than being carried or forced therethough. That is, the gas supply merely overcomes the resistance of the solids and permits them to flow.

Other objects and features of advantages of this invention will become apparent as this specification proceeds.

In connection with the gas-sealing column of solids residually in the chamber: It is to be noted that, when a constantly maintained although everchanging gas-seal is desired, the gas-entry point must be located a sufficient distance above the discharge end of the zone so that the primary column of solids that will remain residually in the zone is of sufficient height to prevent undesirable gas leakage through the line. By primary column of solids residually in the zone is meant those solids remaining in the zone after the feed of solids thereto and discharge therefrom has ceased. These solids remain in the zone because, when the feed is stopped, the discharge gradually diminishes until the column height becomes insufficient to divert gas-flow downwardly; and the discharge ceases. At this point there will always remain residually in the zone a primary column of solids extending at least to the gas-entry point.

In operation, a vertical standpipe or tube can serve as the columnar zone. Subtended to such standpipe is a short offset lateral or horizontal section, such as an elbow and nipple, the nipple being open to provide a discharge opening. This short section serves as a lower support for the column of solids and is of sufficient lateral length to prevent the solids from flowing out of its end; the angle of repose that the solids assume at this point being the controlling factor in determining the minimum length of such section. When no gas is being diverted downwardly through this section no solids will flow therefrom. A relatively small fixed rate of air or other gas is injected into the standpipe at a predetermined point located between its upper and lower extremities. This point is located by reference to the gas-sealing requirement previously mentioned.

Finely-divided solids are fed into the standpipe and cause a dense column of solids to build up in the lower section therein. As feeding continues this column of solids increases in height and eventually becomes of sufficient height to extend above the gas-entry point thus establishing variable height secondary column. The variable height secondary column above the gas-entry point creates a pressure head which restricts or opposes the normal tendency of the supplied gas to escape upwardly.

As the height of the secondary column increases due to solids being fed thereto so does the pressure exerted by it, and when this pressure becomes great enough it will oppose or at least restrict the upflow of gas and divert a quantity thereof from its point of entry downwardly through the standpipe and out through the discharge. This diverted gas will exert a motivating force on the solids overcoming their normal resistance and causing them to spill from the discharge.

The quantity of gas so diverted controls the rate at which solids spill from the discharge, and the quantity of gas diverted is in turn controlled by the height of the column of solids which is itself controlled by the rate at which solids are fed to the standpipe. Thus, the quantity of supplied gas that is diverted downwardly is proportioned to the rate at which solids are fed to the standpipe while the rate at which solids are spillingly discharged from the standpipe is proportioned to the quantity of gas so diverted. The result is that the rate of discharge is proportioned to the rate of feed.

According to this invention, the proportion between rate of feed and rate of discharge is substantially 1 to 1 so that solids will discharge from the standpipe at the same rate they are fed thereto. This proportion is automatically maintained irrespective of the rate of feed and is accomplished by the action of the secondary column of solids in downwardly diverting a quantity of supplied gas by opposing its upward escape. Since the rate of discharge is substantially equal to the rate of feed, it is seen that when the system is an equilibrium (i. e. constant feed rate) the height of the secondary column of solids will remain substantially constant. This height will vary with the feed rate, rising if such rate increases and lowering if it decreases, remaining constant, however, at any constant feed rate.

The total quantity of gas supplied to the chamber is a chosen fixed amount and the limiting range of solids-discharge rates over which the automatic feature is operable is defined by this quantity of gas. The lower limit is zero rate of solids-discharge and is established whenever the downwardly diverted quantity of supplied gas is insufficient to overcome the resistance of the solids and cause them to flow from the discharge. That is, no solids will flow except under influence of the motivating gas. The upper limit is defined by the maximum rate of solids flow whereby all of the supplied gas is downwardly diverted from its point of entry. Within these limits the rate of solids discharge is made to automatically coincide with variations in the rate of feed.

The upper limit of solids flow may be varied either upwardly or downwardly by increasing or decreasing the quantity of motivating gas supplied to the chamber. If a larger amount is supplied, then the upper limit is raised because if all of this increased quantity is downwardly diverted, it will exert a correspondingly increased motivating force on the solids and consequently cause them to be discharged at an increased rate. If the amount of

gas supplied is decreased then the upper limit is correspondingly lowered because less gas is available for exerting a motivating force.

There is also an extreme upper limit of operation for the automatic control feature of this invention. This limit is defined by the maximum rate at which solids would flow downwardly through an unobstructed column tube being impelled therethrough by gravitational force alone or by gravitational force in combination with other forces. That is to say, the rate at which such solids can be made available to the influence of the motivating gas defines the extreme upper limit of operation.

It is to be noted that the solids in the standpipe or flow line are in a dense phase. That is, they are resting compactly within the standpipe and are not turbulently mobilized therein. It is also noteworthy that the quantity of motivating gas admitted to the lower end of the standpipe is just sufficient to effect the desired rate of gravity flow discharge, and this quantity of gas will give a gas velocity through the discharge nipple that is normally on the order of 1 to 2 feet per second (although it may go as high as 10 feet per second depending upon the materials being flowed) and is therefore to be contrasted with the higher quantities of gas commonly used in solids transport lines wherein the solids are transported through conduits as entrained solids and the velocity of the entraining gas is normally on the order of 50 to 150 feet per second.

As this invention may be embodied in several forms without departing from the spirit or essential characteristics thereof, the present embodiment is therefore illustrative and not restrictive, since the scope of the invention is defined by the appended claim rather than by the description preceding it, and all changes that fall within the metes and bounds of the claim, or equivalents of such metes and bounds, are therefore intended to be embraced by this claim.

In the drawings,

Figure 1 shows a preferred embodiment of this invention in association with a confined space represented here by a fluidized solids reactor and an associated dust-diminishing station. Figures 2 through 7 inclusive are detailed drawings of an embodiment of this invention showing its operation under varying conditions.

In Figure 1, the invention is shown in association with a fluidized solids reactor system and the drawing depicts the invention in use as a feeding device as well as a discharging device.

Since Figure 1 shows an embodiment involving a fluidized solids reactor it will be advisable to discuss briefly the general nature and operation of such reactors in solids fluidizing operations.

In general, in the fluidized solids technique for treating ores, a bed of finely divided ore particles is maintained as a dense mobilized homogeneous suspension behaving like a turbulent liquid and exhibiting a fluid level. This is accomplished by passing through the bed an uprising stream of gas at a velocity sufficient to considerably expand the depth of the bed as well as to maintain its particles in turbulent suspension in the uprising gas stream, but at a velocity insufficient to cause the gas to entrain and carry out of the reactor any substantial quantity of solid particles. Under such conditions the bed is called a fluidized bed. The fluid level of this fluidized bed is maintained by the use of a spill-pipe or overflow arrangement so that as more solid particles are introduced into the bed the resulting increased depth causes the particles to overflow down through the spill-pipe just as a fluid does.

Due to the turbulence of the fluidized beds, heat exchange by and among the particles thereof is almost instantaneous so that if two portions of particles, each at a different temperature from the other, are commingled in a fluidized bed the resulting mixture will almost instantly assume a temperature intermediate the temperatures of the portions commingled. Further, this rapid heat exchange creates a substantially uniform temperature throughout the bed.

In Figure 1 the total reactor assembly called a reactor R is preferably a vertical cylinder having a metal outer wall **12** and lined with insulation and fire brick **13**. The reactor has a top **14** and a coned bottom **15** provided with an outlet **16** valved as at **17**. The reactor is provided with a constriction plate **20** having a plurality of orifices such as that one shown at **21**. This plate extends across the reactor throughout its cross-sectional area and is adapted to hold thereon a fluidized bed **22** of finely divided solids undergoing treatment, above which is a freeboard space **23**. The fluidized bed **22** has its fluid level controlled by the entrance **24** to conduit or spillpipe **25** through which the treated solids pass to discharge.

Fluidizing gas is supplied to the reactor through an inlet pipe **30** suitably valved as at **31** at a velocity sufficient to fluidize solids in the bed. Exhaust gases pass upwardly through conduit **34** suitably valved as at **35** and enter a confined spaced here represented by a dust-diminishing station or cyclone **70**. Solids to be treated in the reactor are supplied to the reactor via conduit **46** which enters the reactor at **75** and through which solids flow into freeboard space **23** through which they drop onto the bed.

Heat for initially heating the reactor can be furnished by supplying fuel to the reactor via conduit **32** suitably valved as at **33** and provided with a burner (not shown). Additional fuel if needed can be supplied into the fluidized bed for combustion therein through suitably valved conduits **36**.

In dust-diminishing station **70** entrained solids are separated from the exhaust gases, the dust-free gas is discharged through conduit **68** and the separated solids are discharged from the bottom **60** of the dust-diminishing station into columnar zone standpipe or tube **61** where they form a primary column of solids **67** and a secondary column of solids **69**. A gas-supply line **63** enters standpipe **61** at gas-entry or gas-injection point **65** and this gas supply line is provided with a control valve **64** in order to controllably fix the quantity of gas supplied through conduit **63**. At the bottom of standpipe **61** is a short angled or offset horizontal section **62** which serves as a support for the solids in standpipe **61**, and which prevents such solids from flowing into conduit **66**. The angled solids-supporting section **62** is of sufficient length so that the solids resting thereon will not overflow into conduit **66**; the flow of such solids being prevented by their resistance to flow as defined by the angle of repose which they assume in section **62**.

When the system is in operation solids are discharged from dust-diminishing station **70** into standpipe **61**. These solids form constant height subjacent column **67** and a variable height secondary column **69**. A small fixed quantity of air or other gas enters standpipe **61** at point **65**. The superjacent or secondary column of solids **69** restricts the upflow of the gas and diverts a quantity of the supplied gas from point **65** downwardly through standpipe **61**. This downwardly moving gas acts as a solids-impelling force overcoming the resistance of the solids and causing them to flow from section **62** into standpipe **66** where they gravity-flow or spill freely to storage or other use. If the quantity of solids entering standpipe **61** should decrease the discharge of solids from section **62** will continue at a diminishing rate until secondary column **69** is just high enough to divert sufficient gas downwardly from point **65** so that the rate of solids flow from section **62** is substantially equal to the diminished rate at which solids are entering standpipe **61**. When this point is reached the rate of solids flow from section **62** becomes constant once more and coincides with the rate at which solids enter standpipe **61**.

Conversely, if the rate at which solids enter standpipe **61** should increase, then the rate of flow from section **62** will continue at an increasing rate until such time as

secondary column 69 is of sufficient height to divert enough gas downwardly from point 65 so that the rate of solids flow from section 62 coincides with the increased rate at which solids enter standpipe 61, whereupon the solids flow from section 62 again becomes constant.

If the feed of solids to standpipe 61 ceases then solids will flow from section 62 at a diminishing rate until secondary column 69 has completely moved downwardly to become primary column 67. When this occurs secondary column 69 ceases to exist and, there being no secondary column to divert solids-impelling gas downwardly, solids flow from section 62 will cease.

Normally the upper level of primary column 67 will be above gas-entry point 65 and in no case will the column level be below point 65. In this way a constant gas seal is provided within standpipe 61 even though no solids are supplied thereto. In operation, the presence of this gas seal insures that the gas entering station 70 will be discharged via conduit 68 rather than through standpipe 61. Moreover, the dust is allowed to settle in the standpipe rather than being forcibly ejected from station 70.

Referring now to the mechanism for feeding the reactor: Solids to be treated in the reactor are fed by any suitable means into receiver 40, thence into columnar zone standpipe or tube 41 where they form a primary column of solids 47 and secondary column of solids 49. At the bottom of standpipe 41 is a short angled or offset solids-supporting substantially horizontal or lateral section 42 which supports the column of solids and which would normally prevent them from discharging out of standpipe 41 due to the fact that section 42 is of sufficient length to contain the angle of repose which the solids normally assume when resting thereon thus preventing such solids from flowing into line 46 and thence into the reactor. A motivating-gas supply line 43 is provided for introducing gas into standpipe 41 at gas-entry or gas-injection point 45. This line is suitably valved as at 44 in order to fix the quantity of gas being supplied.

In operation, the finely divided solids to be treated are fed into feed receiver 40 and then into the reactor R by means of standpipe 41, gas supply entering at gas-entry or gas-injection point 45, section 42, and conduit 46. These elements cooperate in the same manner as similar elements previously described in connection with the discharge of solids from station 60. In the case of feeding into a freeboard section 23 as here, the gas-seal provided by column 47 insures that all exhaust gases from the freeboard 23 will exit through conduit 34 rather than having a portion of them escape through conduit 46 and feed receiver 40. Moreover, fluctuations of pressure within freeboard 23 will not affect the rate of feed since the feed is essentially a gravity-flow feed.

Referring now to overflow conduit 25 by means of which solids are discharged from the fluidized bed 22: Conduit or standpipe 25 has attached to its lower end a columnar zone, standpipe, or tube 51; solids discharging from the bed to standpipe 25 gravitate downwardly into standpipe 51 to form primary column of solids 57 and secondary column of solids 59. Primary column 57 reduces the leakage of gas from the reactor down through the standpipe to a minimum which will not initiate solids-flow. At the bottom of standpipe 51 is a short offset solids-supporting, substantially horizontal section 52, and attached to this horizontal section is a spill-pipe 56. Section 52 is of sufficient length so that the column of solids in standpipe 51 is prevented from flowing into standpipe 56 due to the fact that the angle of repose of the solids prevents them from flowing unless an additional motivating force is exerted on such solids. Conduit 53 suitably valved as at 54 is provided in order to supply gas to standpipe 51 at point 55 for the purpose of exerting a motivating force on the solids therein to cause them to flow.

The operation of the elements controlling the bed solids discharge, such as standpipe 51, gas supply line 53, section 52 and primary and secondary solids columns 57 and 59, is the same as for similar elements previously described in connection with the discharge of solids from dust-diminishing station 70 and the feeding of solids into the reactor from feed receiver 40.

Clean-out valves 100, 101 and 102 are provided at the bottom of horizontal sections 42, 52 and 62 respectively. These valves permit ready access to standpipes 41, 51 and 61 for cleaning them out should they become plugged or obstructed. The valves also allow for complete drainage of all solids from the standpipes should that be necessary or desirable for any reason.

Figures 2 through 7 are detailed drawings showing an embodiment of this invention in varying phases of operation. In Figures 2 through 7 the same numbers are used to identify similar elements and a detailed description of one such figure will suffice to describe them all, after which the varying phases of operation shown by the figures will be described.

In Figures 2 through 7 standpipe 41 corresponds to standpipe 41, 51 and 61 in Figure 1 while horizontal section 42 of Figure 2 corresponds to horizontal sections 42, 52 and 62 of Figure 1 and air supply pipe 43 of Figure 2 corresponds to air supply pipes 43, 53 and 63 of Figure 1.

Referring to Figure 2, a columnar or generally vertical standpipe 41 with a solids receiving end 40 and a lower angled or offset solids-supporting section 42 is provided to receive solids. Lower section 42 has a laterally facing open end 46 through which solids discharge when the proper conditions exist within standpipe 41. Leading into standpipe 41 at point 45 is a gas-supply line 43 suitably valved at 44. This line is for the purpose of supplying a fixed quantity of gas of a predetermined amount into standpipe 41. This supplied gas is the motivating or solids impelling force that controllably causes movement of solids through standpipe 41 and out discharge end 46 of section 42. Standpipe 41, section 42, and suitably valved conduit 43 can be constructed of any suitable material such as ordinary steel pipe or tubing and the like; or construction can be of heat or erosion resistant material. Generally speaking, any material that will stand up well is suitable material and its selection may well depend upon economic factors as well as the type of materials being handled. Further, the shape of the standpipe and discharge opening is immaterial; it can be round, oval, square, etc.

Solids are fed into standpipe 41 through end 40 and a dense primary column of solids 47 is established within the standpipe. This primary column is also designated as PC. The upper level of solids in standpipe 41 is designated 48. The solids assume an angle of repose in lower section 42. This angle is the acute angle included between solids surface 80 and the bottom of section 42 and may be said to define the resistance of the solids to flow. A fixed quantity of air is supplied to standpipe 41 via conduit 43. The quantity of air supplied is a fixed amount, the amount being predetermined in accordance with the type of material to be handled and the desired range of flow rates. In Figures 2 to 7 inclusive, the total quantity of air entering standpipe 41 at point 45 is designated by four arrows, with the direction of flow of such gas being represented by the direction of the arrows. The total amount of air supplied is fixed and is assumed to be equal in all the Figures 2 through 7.

Figures 3 to 7 are similar to Figure 2 except that Figures 3 to 7 show a secondary column SC. The significance of variations in secondary column height 149, 249, etc., the upper solids level 48, 148, etc., and the surface 80, 180, etc. of solids in section 42 will be apparent as this description proceeds.

When the device is functioning, operation is as follows:

Referring to Figure 2, a fixed quantity of air is continuously supplied to standpipe 41 via conduit 43. This air enters standpipe 41 at point 45. Solids are fed to the

reactor and a column of solids **47** is established therein. In Figure 2 the upper level **48** of column **47** is below gas-entry point **45** and consequently all supplied gas escapes upwardly through standpipe **41**. Under these conditions there is no motivating force exerted on the solids and they remain static within the chamber.

In Figure 3 with the feed continuing and the same fixed continuous supply of air as in Figure 2, the upper solids level **148** within standpipe **41** has risen thus establishing a superjacent secondary column **149** (SC) that has reached a sufficient height above gas-entry point **45** so that the secondary column offers opposition to the upward escape of gas. When this opposition becomes great enough a quantity of the gas is diverted downwardly from point **45**. When the quantity of gas so diverted becomes great enough, the reposal surface **180** is disturbed and the resistance of the solids is overcome causing them to flow out of discharge opening **46**. Thus, in Figure 3 the upper level **148** of column **149** has reached such a height that about one quarter of the supplied gas (represented by one arrow) is now diverted downwardly thus exerting a motivating force on the solids and causing them to move from section **42** through discharge opening **46**.

In Figure 4, under the same conditions as Figures 2 and 3, as to continuing feed and amount of supplied air, the column **249** is seen to be of increased height. As this height increase continues so does the proportion of diverted gas and consequently the rate of solids discharge through **46**. In Figure 4 approximately ½ of the supplied gas (represented by two downwardly pointing arrows) is diverted downwardly and the rate of discharge through opening **46** is proportionately increased.

In Figure 5, under the same conditions of feed rate and quantity of supplied gas as those existing in the preceding description of Figures 2, 3 and 4, upper level **348** of secondary column **349** has now reached a point where approximately ¾ of the supplied gas is diverted downwardly (represented by three downwardly pointing arrows) and the discharge rate is proportionately increased.

When the discharge rate is equal to the feed rate, level **348** will remain constant so that if, in Figure 5 (or any other figure), solids emit from **46** at the same rate they enter at **40** then the system is in equilibrium and a constant discharge rate is attained.

Figure 6 illustrates what happens when the feed rate suddenly increases while the air supply remains constant. The upper level **448** of column **449** rises to such a height that substantially all supplied gas is restricted or opposed from rising and thus is diverted downwardly, this causes a proportionate increase in the discharge rate and the system establishes a new equilibrium level.

Figure 7 shows the return to normal equilibrium as represented by Figure 5 when the feed rate returns to that described as existing in Figures 2, 3, 4 and 5. The discharge continues at a diminishing rate until the discharge rate coincides with the feed rate; at this point the system is again in equilibrium. Thus, in Figure 7 the system has returned to the same equilibrium level as that shown in Figure 5.

Should the feeding of solids to the chamber cease altogether then the discharge of solids will continue at a diminishing rate until there are insufficient solids in standpipe **41** to divert motivating gas downwardly for impelling solids flow. When solids flow has ceased there will always remain residually in the standpipe primary solids column **47** (PC). Thus it is insured that there will always exist a column of solids that is of a height at least equal to the distance between gas-entry point **45** and lower section **42**. If a constant gas seal is desired, gas-entry point **45** should be so located that the space between such point and lower section **42**, when filled with solids, will provide a gas-seal against the highest expected gas pressures.

Referring to Figure 6, this figure shows the invention operating at maximum capacity for function of the automatic feature whereby equilibrium between feed rate and discharge rate is automatically attained. Assuming that the feed rate equals the discharge rate in Figure 6; if the feed rate increases beyond the assumed rate then it will result in the piling up of solids in the chamber above the standpipe. In other words, the upper limit for the fixed gas supply will be exceeded. However, this greatly increased feed rate can be handled merely by increasing the quantity of air being supplied. This will raise the upper limit of operation because it will provide more air to be diverted downwardly. At a new rate of air supply then, the upper operating limit is varied and the invention operates automatically within the new limits.

If, for any reason, immediate cessation of solids discharge is desired then the supply of air should be cut off. Shutting off the air supply allows the solids to immediately assume their angle of repose in lower section **42** and solids flow ceases.

Whereas I have shown only embodiments wherein the inside diameter of the discharge nipple is the same as that of the standpipe, it is to be understood that this is not a necessary size relationship. The size of the discharge nipple will vary according to the expected discharge rates, the size of the solids to be handled and so forth.

Example I

The operation of an embodiment of this invention will be described in connection with the discharge of finely divided lime dust from a dust-diminishing cyclone in which entrained solids carried out of a fluidized solids reactor are separated from the entraining gases.

The reactor can be a commercial size fluidized solids reactor in which finely divided limestone is calcined. Dust carried out of the reactor entrained in the exhaust gases passes through a cyclone where the dust is separated from the entraining gas and the dust-free gas is discharged to other uses while the separated solids are discharged to storage or further treatment.

The cyclone may be of a commercial size with a solids discharge end 4″ in diameter. Attached to this discharge end is an adapter and a 30″ length of standard 2″ steel pipe which serves as the vertical solids flow line. At the bottom of this pipe is attached a clean-out valve for providing easy access to the line in case of plugging. Located just above the clean-out valve is a ½″ hole in the 2″ vertical pipe. A short nipple is inserted in the ½″ hole in such a manner that it extends outwardly at right angles from the outer edge of the pipe and of sufficient length so that it extends approximately 34 mm. from the inner periphery of the vertical standpipe. This serves as the lower discharge. A motivating gas-entry point ⅛″ in diameter is provided in the wall of the vertical pipe at a point 10″ above the lower discharge for the purpose of supplying motivating gas to the pipe. Air is supplied to the vertical pipe through the gas-entry point at a rate of 0.050 C. F. M. (measured at 20° C. and one atmosphere of pressure). When the reactor is in continuous operation solids are discharged from the discharge end of the pipe at an average rate of 131 pounds per hour. When feed to the reactor is cut off the rate of discharge from the pipe diminishes to zero pounds per hour. During the time the discharge rate is zero pounds per hour, the residual column of solids in the pipe prevents any gas from the cyclone from leaking through the pipe thus forcing all gas out of the top of the cyclone. When feed to the reactor is resumed solids resume discharging and the average rate of discharge is again reached. Throughout the operation the flow of solids is smooth rather than spotty and dust losses are at a minimum due to the fact that the column of solids prevents the violent discharge of solids from the cyclone and gives the dust an opportunity to become quiescent.

Example II

In laboratory tests a 2″ inside diameter standpipe was employed. Subtended to the standpipe was a standard

2" elbow equipped with a reducer and a ½" inside diameter nipple 1" long; thus establishing a 2" inside diameter standpipe having a ½" inside diameter lower offset discharge. A gas-entry point was located 9" above the discharge opening. Air input was .045 C. F. M. (20° C. and 1 atmosphere).

Fine lime solids (100 micron average size) were introduced into the top of the standpipe and a primary column 9" established therein. As feed continued a secondary column was established and solids commenced to flow from the lower discharge.

At a solids feed rate of 213.5 pounds per hours a secondary column height of 1.3 feet was established and solids flowed from the lower discharge at a rate of 213.5 pounds per hour.

When the rate of solids feed was increased to 480 pounds per hour the secondary column reached a height of 2.15 feet and the solids discharge rate was 480 pounds per hour.

A further increase in the feed rate to 539 pounds per hour resulted in a new secondary column height of 3.1 feet being established and the solids discharge rate increased to 539 pounds per hour.

In every case, when equilibrium was reached wherein feed rate equaled discharge rate, the secondary column assumed a constant level. Variations in the feed rate resulted in automatic adjustment of the secondary column height to a new equilibrium level.

Dust losses were minmized due to the fact that solids were given a chance to settle while passing through the dense column phase.

I claim:

Apparatus for transferring finely divided solids from an upper zone in which there exists one pressure to a lower zone in which there exists a different pressure while maintaining a seal against the pressure differential between said zones, comprising a generally vertical open-ended unobstructed solids conductor connecting said upper and lower zones and adapted to receive solids from the upper zone said conductor terminating at its lower end in an offset solids discharge adapted to contain the angle of repose of solids admitted from the upper zone; and a gas inlet in the conductor intermediate its ends said inlet being spaced above the solids discharge a distance sufficient to provide a seal against the pressure differential between the upper and lower zones when that portion of the solids conductor below the gas inlet is filled with solids admitted from the upper zone.

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