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G. N. BROWN
SOLIDS FLOW EQUALIZER

3,208,737

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3 Sheets-Sheet 1

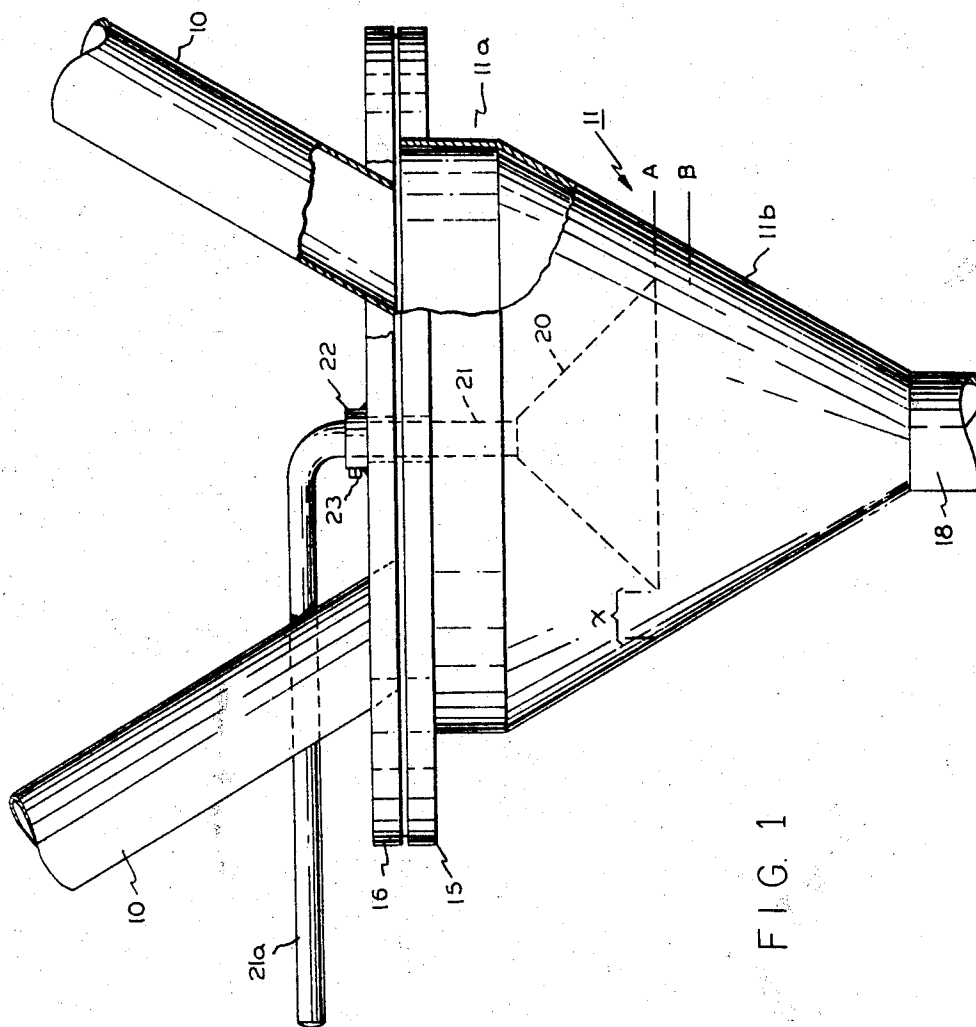


FIG. 1

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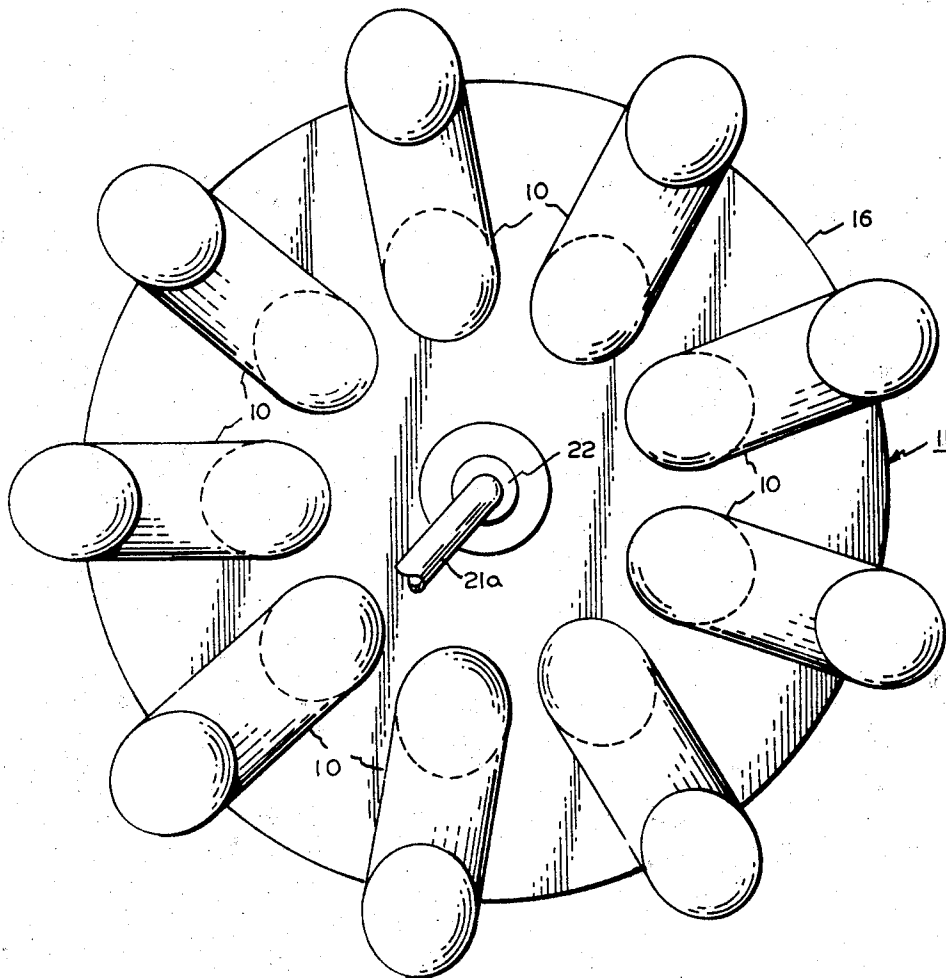


FIG. 2

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3 Sheets-Sheet 3

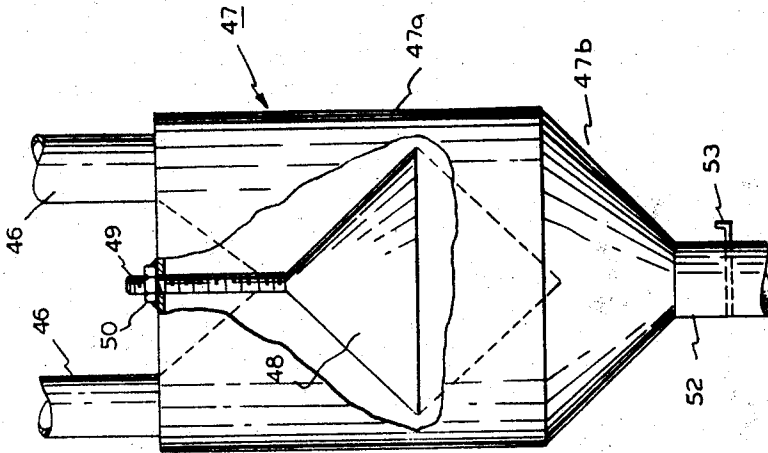


FIG. 4

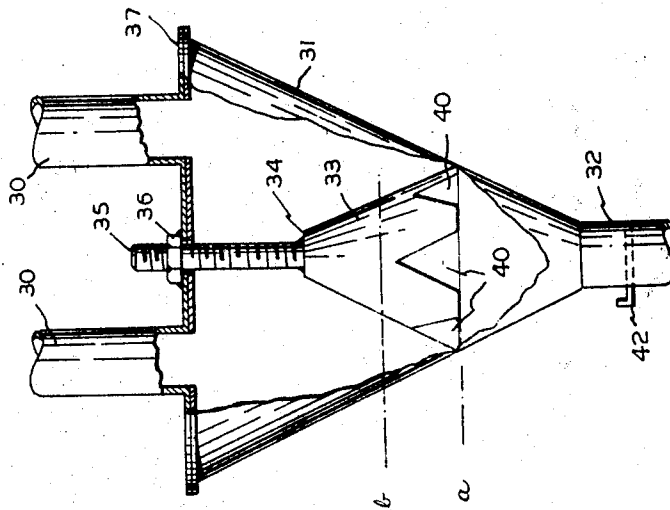


FIG. 3

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SOLIDS FLOW EQUALIZER

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2 Claims. (Cl. 259—180)

This invention relates to apparatus for particulate solids flow equalization, and particularly to a gravimetric solids flow equalizer for balancing the flow of particulate solids discharged into a common collector from a plurality of pipes filled with solids in gravimetric flow.

There are circumstances, such as in solids blending, wherein it is essential that solids flow equalization out of a multiplicity of solids-carrying pipes be achieved to relatively close precision, a typical situation being the solids blending taught by U. S. Patent 3,106,385. Here blending is accomplished by the withdrawal of solids in gravimetric flow via individual pipes with inlets located at a plurality of points spaced in a regular peripheral and longitudinal pattern around the exterior of a large capacity, elevated solids reservoir. The flows of the pipes are thereafter recombined, so that the solids are reunited into a common bulk which is then either recycled, for more intimate blending, or drawn off as product, if the degree of blending achieved in a single pass is adequate for the purposes.

The close regulation of the flow of solids through individually valved pipes, especially within a completely closed system, is a tedious and time-consuming task, and it is a principal object of this invention to simplify this operation. Another object of this invention is to provide a solids flow equalizer of improved economy, in that it eliminates the necessity for the provision of all of the valves hitherto required, one which is adapted to the simultaneous regulation of multiple flows for materials of widely varying flow characteristics and a design which is compact and conveniently incorporated into existing installations as well as those to be built in the future. The manner in which these and other objects of this invention are attained will become apparent from the detailed description and the following drawings, in which:

FIG. 1 is a partially broken away side elevation view of a preferred embodiment of the solids flow equalizer of this invention, wherein only a single pair of diametrically opposed solids introduction pipes is shown for purposes of simplicity,

FIG. 2 is a plan view of the apparatus of FIG. 1,

FIG. 3 is a partially broken away side elevation view of a variation in the design of FIGS. 1 and 2 wherein the flow restricter is scalloped peripherally by the provision of solids passages in the form of V-notches, and

FIG. 4 is a partially broken away side elevation view of another embodiment of solids flow equalizer wherein the solids collector chamber confronting the flow restricter is cylindrical in form.

Generally, this invention is a gravimetric solids flow equalizer comprising, in combination, a substantially vertically disposed solids collector circular in horizontal cross-section with side walls of vertical inclination in excess of the angle of repose of solids processed through the flow equalizer, a plurality of equi-sized solids introduction pipes discharging into the top of the collector, the solids introduction pipes being sloped at substantially equal angles of inclination with respect to the horizontal in excess of the angle of repose of solids processed through the flow equalizer over straight lengths upstream of the collector exceeding a distance of about three pipe diameters with discharge ends spaced radially from the center of the collector at locations disposed symmetrically both peripherally and longitudinally of the collector, a con-

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centrically disposed common solids discharge opening in the bottom of the collector, and a flow restricter mounted concentrically inside the collector intermediate the discharge ends of the solids introduction pipes and the common solids discharge opening defining, with the side walls of the collector, a uniformly distributed open peripheral area having a minimum radial dimension greater than the self-bridging dimensional limit for solids processed through the flow equalizer, a maximum radial dimension less than 50% of the minimum radius of the collector within the region in which the flow restricter is disposed and a total extent aggregating greater than the area of the common solids discharge opening but less than the collective inside area of the solids introduction pipes, the flow restricter being disposed within a region spaced lengthwise from the discharge ends of the solids introduction pipes a minimum vertical distance equal to about said three pipe diameters magnitude and from the common solids discharge opening a minimum vertical distance equal to about three times the maximum radial dimension of said open peripheral area magnitude.

Referring to FIGS. 1 and 2, there is shown a preferred embodiment of apparatus according to this invention intended for use in an installation in which it was desired to equalize the gravimetric flow of solids through nine pipes 10 of equal inside diameters (typically 3") which led from different levels and peripheral locations of an elevated solids blending apparatus of the design taught in U.S. Patent 3,106,385. The material which was to be processed by the apparatus was somewhat irregularly-shaped polyethylene cubes measuring approximately 1/8" length on a side, which material had an angle of repose of about 38°. Accordingly, to guarantee continuance of gravimetric solids flow, pipes 10 were pitched at a common angle of 60° with the horizontal, and formed to minimum straight runs upstream of the discharge openings into the solids collector, denoted generally at 11, of no less than about three pipe diameters' length (in this instance 12"). Under these circumstances, the discharge of solids in gravimetric flow out of a pipe is substantially independent of the head of solids maintained within the pipe, apparently as a result of side wall friction, interlocking of solids particles one with another in a mutually flow-obstructing fashion, and perhaps other considerations.

It is essential to flow equalization according to this invention that the discharge ends of solids introduction pipes 10 be spaced radially from the center of collector 11 at locations disposed symmetrically both peripherally and longitudinally of the collector, by which is meant that corresponding points of adjacent solids introduction pipes must be spaced at equiangular intervals measured peripherally and at equal distances measured radially, referred to the center of solids collector 11. As an example, the centers of pipes 10 were located at equiangular spacings around a circle 6" in radius, referred to the axis of collector 11 as center. Moreover, the inclinations of all pipes 10 with reference to the longitudinal axis of the collector should have the same orientation, i.e., either all towards or all away from this axis, at substantially equal angles of inclination. Finally, the disposition of corresponding points of the pipe 10 discharge ends should be symmetrically located longitudinally of collector 11, it being understood that pipes 10 can enter through the collector side wall equally well as through the top, although the latter arrangement is preferred in the interests of conserving head room.

There is considerable design freedom as regards collector 11, that shown in FIGS. 1 and 2 having a short-length cylindrical coping 11a (typically 18" outside diameter by 4" high), provided with an integral bolting flange 15 adapted to engage with a mating flange 16 through which the discharge ends of pipes 10 open, surmounting

a main body of inverted frusto-conical shape 11b (typically 13" long) terminating in the concentrically disposed common solids discharge outlet opening 18 at the lower end. For self-cleaning solids through-put, it is desirable that the walls of the conical frustum section 11b be sloped at an angle greater than the angle of repose of the solids in process, the design of FIGS. 1 and 2 having a bottom included angle of 60°. It is essential that a proportionate solids passage area relationship be preserved as hereinafter detailed, and solids discharge 18 can, for the design described, be 3" inside diameter.

The flow equalizer of FIGS. 1 and 2 is provided with a solids flow restricter 20 which, in this instance, is constructed so as to actually abut the inside wall of the collector at lowermost setting, thereby permitting complete closure of the solids flow path through the collector should this ever become necessary in order to effect repairs or alterations to the downstream piping system. Since different materials display widely different flow characteristics, it is desirable to mount the restricter for adjustable vertical movement axially of collector 11, to thereby permit selection of the optimum peripheral restricter-collector clearance for any given solid material in process, and this provision is incorporated in the design detailed.

The restricter 20 detailed has the general form of an upright frustum of a 10" base diameter cone, pitched at a base angle of 45°, and is readily fabricated from a strip of imperforate sheet metal bent into the shape shown. The restricter is mounted concentrically inside collector 11 within a region wherein the uppermost solids flow equalization positional limit, measured from the restricter periphery, is no less than three diameters of pipe 10 below the discharge ends of pipes 10 and wherein the lowermost solids flow equalization positional limit is no less than three times the maximum radial clearance between the periphery of restricter 20 and the inside wall of section 11b above discharge opening 18. In the specific design shown, the upper flow equalization positional limit A of restricter 20 is 9" measured from the underside of flange 16, whereas the lower flow equalization positional limit B is 6.5" above the opening 18, defining approximately 1.5" as the range of flow equalization vertical adjustment of restricter 20 axially of collector 11. In fact, the restricter can be moved axially over a considerably greater distance of about 5", measured from its lower limit in abutment against the inside wall of conical section 11b to a point about 3" above the upper flow equalization positional limit A described, which is advantageous for reasons hereinafter described. To facilitate manual selectivity in the vertical setting of restricter 20 lengthwise of collector 11, the restricter is depended from a suspension rod 21 calibrated along its vertical length to correspond to various settings of restricter 20 within collector 11. Rod 21 is slidably mounted within a collar 22 fixedly attached to the top of flange 16 provided with a set screw 23 for locking the rod at any predetermined vertical setting. Handle portion 21a, bent at an angle of 90° to the vertically disposed length of rod 21, extending outwards radially from the relatively closely arrayed plurality of down-coming solids introduction pipes 10 entering the collector from the top, is provided as a handle for convenient grasping by the operator.

As will be hereinafter more fully explained in regards to the operation, flow equalization is obtained according to this invention by the throttling action exerted on solids particles traversing the restricter 20—inside wall 11b interspace. In the embodiment of FIG. 1, this is an annulus of regulable width, the maximum limit of which is dimension x taken in the radial plane, defined by the restricter at its uppermost flow equalization position A. However, there is no reason why the throttling interspace between restricter periphery and collector side-wall cannot be shaped to a highly irregular profile in the plane of projection, a design with scalloped edge restricter

periphery being detailed in FIG. 3 as an example. The only requirement is that the open peripheral area be uniformly distributed, by which it is meant that open space be provided in a regular modular pattern throughout the full 360° periphery of the restricter. Under these circumstances solids flow equalization proceeds relatively smoothly, quite independently of the shape of the interspace orifice presented to solids flow therethrough, provided, however, that interspace relied upon for flow equalization action have a minimum radial dimension greater than the self-bridging dimensional limit for solids processed through the flow equalizer (the self-bridging dimensional limit for the 1/8" polyethylene cubes, as an example, is 0.5"), a maximum radial dimension less than about 50% of the minimum radius of the collector 11 within the region in which the flow restricter is disposed (i.e., at the level where restricter 20 abuts collector wall 11b) and a total area, measured as projected on the radial plane of the collector, aggregating greater than the area of the common solids discharge opening 18 but less than the collective inside areas of solids introduction pipes 10. The area ratio relationship for the design specifically described here is, typically, 2 pipes 10 63: restricter-collector interspace (range) 23 to 43: opening 18 7.

In operation, the mechanics of solids flow according to this invention apparently consists of a two-stage sequence. During the first stage, solids escape from the discharge ends of each of the solids introduction pipes 10 and flow in substantially identical streams into the upper part of collector 11, attaining an equilibrium state in passage through the vertical distance exceeding three times the diameter of a pipe 10, thereby assuming a flow rate independent of the individual solids heads applied to each of the several pipes 10. A short interval after start-up, the region above restricter 20 becomes quite full of solids, so that the operation of the flow equalizer of this invention can be described as "flooded," although, even at complete cessation of solids passage through the apparatus, the upper volume of cylindrical section 11a will be free of solid material between the sloping limits of the individual solids piles backing up into the discharge ends of pipes 10. Essentially, then, what is achieved in the collector region above restricter 20 is the combining of the plurality of pipe 10 flows, at equal flow rates one with another, within a common vessel.

The second stage of operation is the withdrawal, at equalized flow rates peripherally of restricter 20, of solids from the collector 11. This is accomplished by permitting the escape of solids through the throttling collector-restricter interspace at a rate less than that of free fall, which is achieved by the restrictive action of the smaller diameter opening 18, which thus backs up solids flow below restricter 20 to maintain solids flooded conditions in the lower part of collector 11. Thus the collector is always filled with solids below restricter 20, except in the regions between the sloping limits of solids piles built up around the entire periphery of the underside of restricter 20. Under the circumstances, there is obtained equalized solids flow originating at the peripheral orifice consisting of the collector-restricter interspace and terminating in a common solids drawoff through outlet 18.

Equalization of solids flow as hereinabove described necessitates that the limiting collector body surface in confrontation with the solids piles built up below the several solids discharging orifices present a uniform peripheral configuration. Collectors circular in horizontal cross section are therefore necessary to good flow equalization obtainment; however, a wide choice of longitudinally defining forms may be employed, including the conical and cylindrically shaped collector bodies specifically described herein, which are especially preferred because of their self-cleaning solids clearing action, sections of spheres, or inter-combinations of more than one of the forms together.

Outlet 18 discharges to a solids removal conveyor (not

shown), for example, into the receiver of a pneumatic conveying system of a type employing a pressure (or vacuum) induced gas stream for entrainment or other propulsion of solids in return circuit to the solids blender, if repetition of the blending cycle is desired, or to some subsequent processing step if blending is complete enough for the purposes. It is essential that discharge via outlet 18 be at a rate below that which would choke the conveying system utilized, and provision of a suitable flow control is necessary. This can optionally be a conventional slide valve mounted within discharge outlet 18, as hereinafter shown for the embodiments of FIGS. 3 and 4.

Sometimes the solids processed build up collected shape anomalies, such as streamers or "snakeskins" of polymer or the like, above the restricter, and these eventually interfere with smooth throughput of solids through the apparatus. These objectionable materials can be readily dislodged by momentary elevation of the restricter to its full limit of vertical travel, an operation which is preferably accomplished during a shut-down of the apparatus for repairs or service, since solids flow equalization is lost whenever the restricter is raised above the level preserving the proportioned open area relationship hereinbefore described.

Experiments in varying the locations of the solids introduction pipe discharge openings of the apparatus have demonstrated that this has considerable effect on the operation. Even a relatively slight eccentric positioning of flange 16 and its associated solids introduction pipes 10 is accompanied by appreciable unbalancing of flows through the pipes 10, those pipes disposed nearest the collector wall operating at decreased solids throughputs as compared with those farther removed from the collector wall. This indicated that pipe discharges might vary depending on their radial spacings from the collector axis, and this was indeed found to occur, maximum solids flows out of pipes 10 being achieved when the centers of pipes 10 are in vertical line with the center line of the annular restrictor-collector interspace of the embodiment of FIGS. 1 and 2.

Referring to FIG. 3, there is shown a specific design of solids flow equalizer employing five vertically disposed solids introduction pipes 30, only two of which are shown for simplicity in the representation, each of which had a 2" inside diameter. Pipes 30 were arranged at equiangular spacings of 72° apart around a circle of radius 5" drawn from the axis of the equalizer apparatus as center. Collector body 31, into which pipes 30 discharged, was an inverted frustum of a cone measuring 13" inside diameter at its upper end and converging at a 60° angle to its 2" inside diameter common discharge outlet 32 at the bottom end. The flow restricter 33 was an upright frustum of a cone, made from an imperforate metal sheet coned to a vertex angle of 60°, welded at the top end 34 to its coaxial support element. In this design restricter 33 was concentrically depended within collector 31 from vertically disposed threaded rod 35 fixedly attached thereto and engaging with anchoring nut 36 welded to the top flange 37 of the collector.

The base diameter of restricter 33 measured approximately 6" and was scalloped at the periphery with five equiangularly spaced through-going notches 40, measuring approximately 2" in width by 2" high. The lowermost position at which flow equalization was obtained was that denoted at level *a*, FIG. 3, at which the restricter periphery was in contact with the inside wall of collector 31, which was 3.7" above the upper opening of discharge outlet 32. Similarly, the uppermost position at which flow equalization was obtained was level *b*, disposed approximately 6.3" below the level of the discharge ends of pipes 30, thus defining a range of about 2" vertical movement of restricter 33 regulative of solids flow through the apparatus. Slide valve 42, installed within discharge line 32, enabled wide range regulation of solids flow rate.

Operating tests conducted with the apparatus of FIG. 75

3 demonstrated that good flow equalization was obtained even through the restricter-collector interspace clearance of highly irregular boundary outline defined by the projection on the diametral plane of notches 40, together with any additional annular interspace area opened up at progressively higher raising of restricter 33 above level *a*. However, it was necessary that the interspace area be uniformly distributed around the entire periphery in the sense that a regular modular pattern of open area presentation was adhered to. Thus, if one of the notches 40 was appreciably blocked off, flow equalization was immediately lost.

The FIG. 3 apparatus design is particularly advantageous where relatively large sized, irregularly-shaped solid particles must be handled, either alone or with accompanying fine sizes of particles. Thus, polymer chips of a typical average size $\frac{1}{2}$ " x $\frac{1}{2}$ " x $\frac{1}{8}$ " were readily equalized in flow with the specific apparatus described. Another situation which is accommodated by the scalloped periphery restricter embodiment is that where more or less transient agglomerates of a number of small size solids particles occur with any great frequency. These are cleared through the notches without any hold-up above the restricter and thus cannot accumulate athwart the normal solids flow path in a manner disturbing the regular solids flow patterns upon which flow equalization depends.

FIG. 4 shows yet another embodiment of flow equalizer dispensing entirely with regulable longitudinal restricter positioning and relying on static restricter disposition solely for flow equalization.

In a specific fabricated apparatus, four vertical, equiangularly disposed 2.75" inside diameter solids introduction pipes 46, located on a circle of $3\frac{3}{8}$ " radius drawn from the longitudinal axis of the apparatus as center, were employed. These discharged into the collector, indicated generally at 47, which comprised a top cylindrical portion 47a of 10" inside diameter, 12" long, within which was concentrically mounted a flow restricter 48, in the form of an upright frustum of a cone made up from an imperforate metal sheet coned at a vertex angle of about 90°, with base measuring 8.5". Restrictor 48 is conveniently mounted by suspension from a screw 49, to the lower end of which the restricter is fixedly attached by welding or brazing, screw 49 in turn being threaded through an anchor nut 50 welded to the outside of the top of the collector vessel.

The invariant interspace presented to solids flow ($\frac{1}{8}$ " polyethylene cubes) between the inside collector wall and the base periphery of restricter 48 was an annulus measuring $\frac{3}{4}$ " in radial width. The apparatus was closed off at the bottom by a frusto-conical collector portion 47b, having side walls sloped at an angle of 45° from the vertical, terminating in a common solids discharge pipe 52 (2" inside diameter) disposed coaxially of the collector. The discharge pipe was provided with a conventional slide valve 53 for complete cut-off of solids flow through the apparatus.

In the specific apparatus described, the skirt end of restrictor 48 was spaced vertically a distance of $8\frac{1}{4}$ " from the discharge ends of pipes 46, and $7\frac{3}{4}$ " from the upper end of discharge pipe 52.

A glass model of the FIG. 4 apparatus showed clear development of symmetrical solids boundary flow limits, as shown in broken line representation in FIG. 4, after long enough operation, with slide valve 53 adjusted to completely open position, to achieve equilibrium conditions, confirming visually that flow equalization was obtained. This was further verified by observing the time rate of drop of solids levels through all four pipes 46 simultaneously when the pipes were cleared of solids by permitting emptying of the pipes without replenishment by more solids supplied to the top ends.

From the foregoing, it will be understood that this invention can be modified in numerous respects within the skill of the art without departure from the essential con-

cept, and it is intended to be limited only by the scope of the following claims.

What is claimed is:

1. A gravimetric solids flow equalizer comprising, in combination, a substantially vertically disposed solids collector circular in horizontal cross section with side walls of vertical inclination in excess of the angle of repose of solids processed through said flow equalizer, a plurality of equi-sized solids introduction pipes discharging into the top of said collector, said solids introduction pipes being sloped at substantially equal angles of inclination with respect to the horizontal in excess of said angle of repose of solids processed through said flow equalizer over straight lengths upstream of said collector exceeding a distance of about three pipe diameters with discharge ends spaced radially from the center of said collector at locations disposed symmetrically both peripherally and longitudinally of said collector, a concentrically disposed common solids discharge opening in the bottom of said collector and a flow restrictor mounted concentrically inside said collector intermediate said discharge ends of said solids introduction pipes and said common solids discharge opening defining with said side walls of said collector a uniformly distributed open peripheral area having a minimum radial dimension greater than the self-bridging dimensional limit for solids processed through said flow equalizer, a maximum radial dimension less than 50% of the minimum radius of said collector within the region in which said flow restrictor is disposed and a total extent aggregating greater than the area of said common solids discharge opening but less than the collective inside area of said solids introduction pipes, said flow restrictor being disposed within a region spaced length-

wise from said discharge ends of said solids introduction pipes a minimum vertical distance equal to about said three pipe diameters magnitude and from said common solids discharge opening a minimum vertical distance equal to about three times said maximum radial dimension of said open peripheral area magnitude.

2. A gravimetric solids flow equalizer according to claim 1 wherein said solids flow collector has the general form of an inverted frustum of a cone sloped at a vertical inclination in excess of the angle of repose of solids processed through said flow equalizer, said flow restrictor has the general form of an upright frustum of a cone sloped at a vertical inclination in excess of said angle of repose of solids processed through said flow equalizer, and there is provided means for selectively shifting said flow restrictor axially of said collector throughout at least a span inclusive of the region wherein said uniformly distributed open peripheral area has a total extent aggregating greater than the area of said common solids discharge opening but less than the collective inside area of said solids introduction pipes.

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