

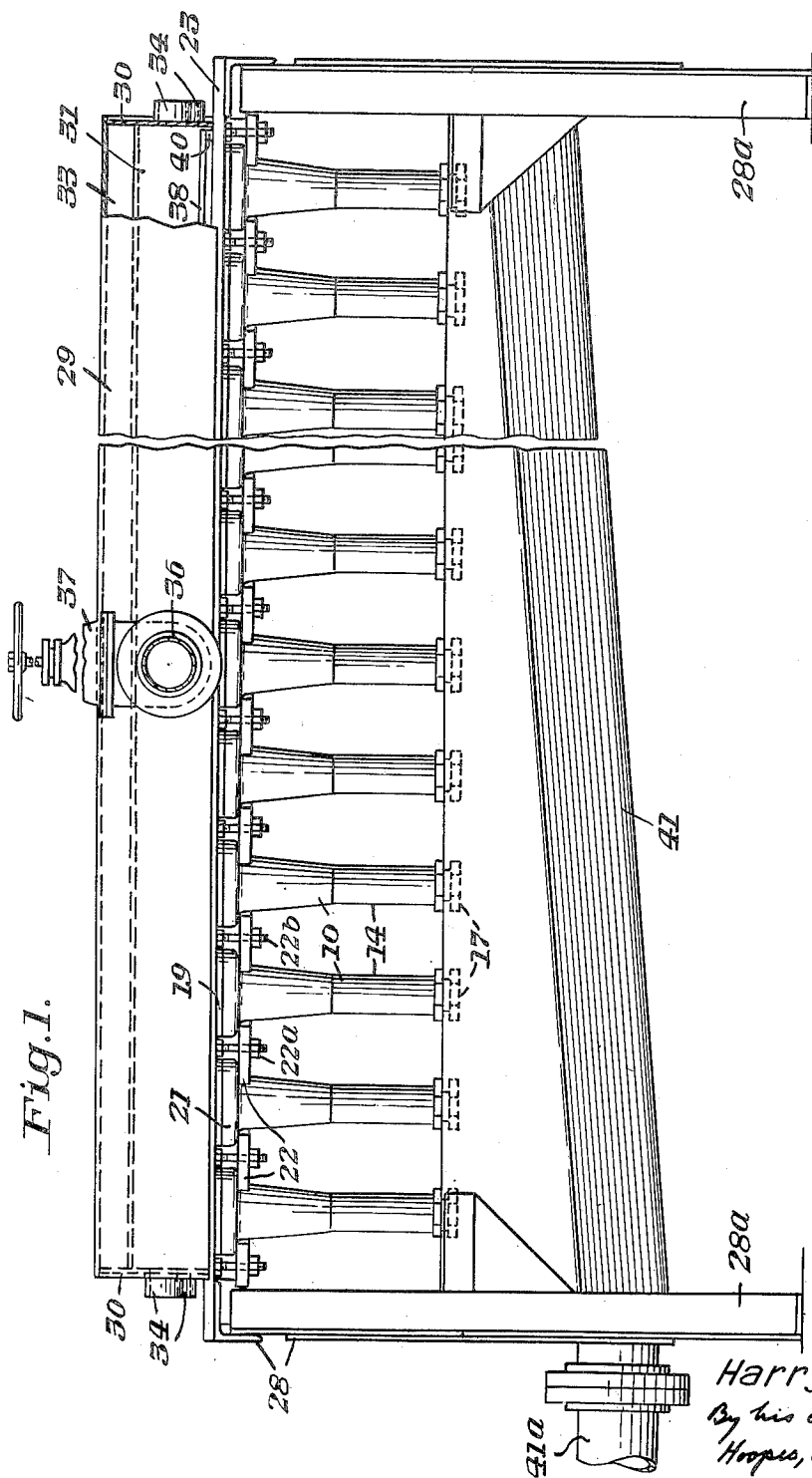
Dec. 23, 1952

H. E. CRINER
VORTEX CONTROL SYSTEM

2,622,735

Filed Sept. 9, 1949

3 Sheets-Sheet 1



Dec. 23, 1952

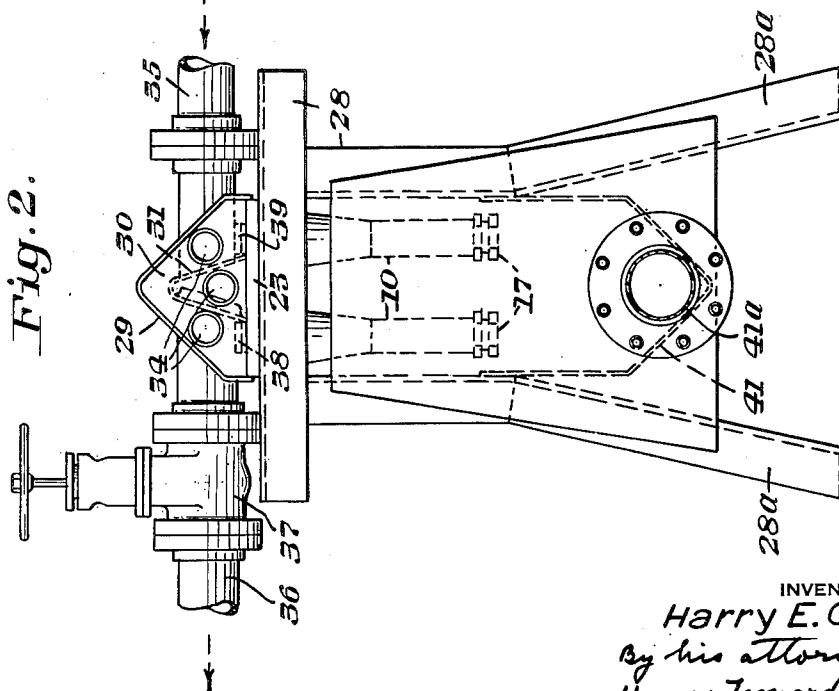
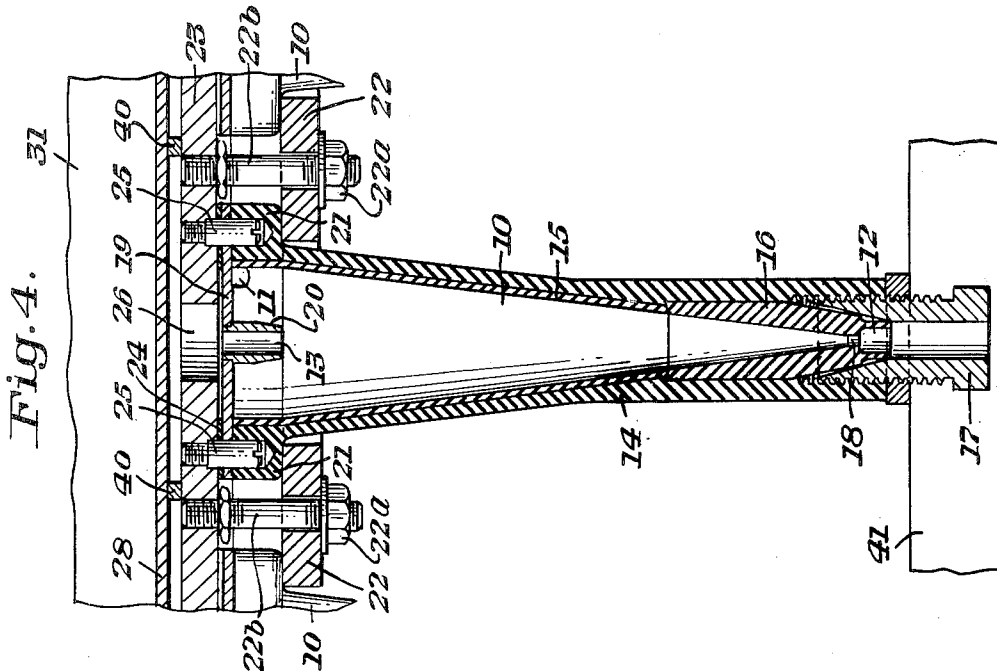
H. E. CRINER

2,622,735

VORTEX CONTROL SYSTEM

Filed Sept. 9, 1949

3 Sheets-Sheet 2



INVENTOR

Harry E. Criner
By his attorneys
Hoopes, Leonard & Glenn

Dec. 23, 1952

H. E. CRINER

2,622,735

VORTEX CONTROL SYSTEM

Filed Sept. 9, 1949

3 Sheets-Sheet 3

Fig. 3.

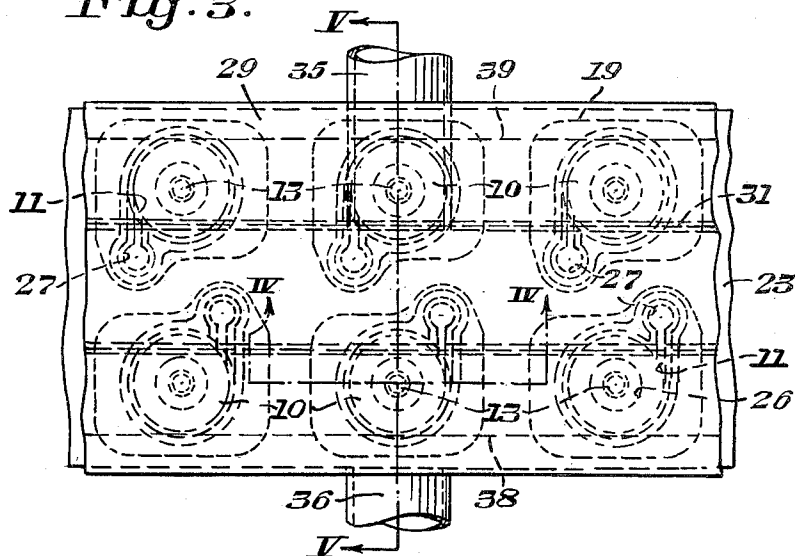


Fig. 5.

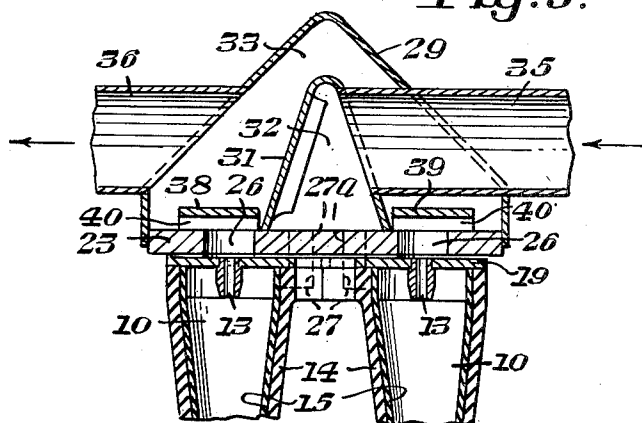
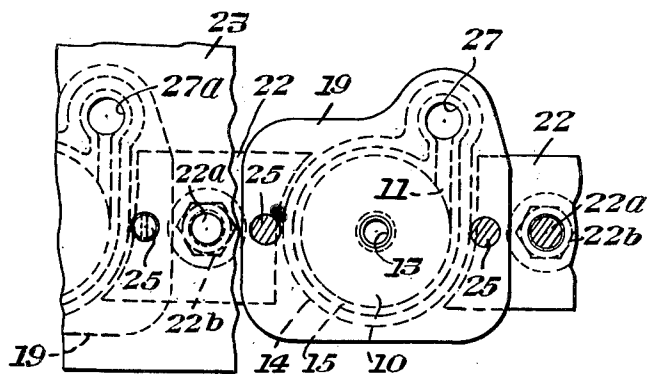


Fig. 6.



INVENTOR
Harry E. Criner
By his attorneys
Hoopes, Leonard & Glenn

UNITED STATES PATENT OFFICE

2,622,735

VORTEX CONTROL SYSTEM

Harry E. Criner, Pittsburgh, Pa., assignor to Heyl
& Patterson, Inc., Pittsburgh, Pa., a corporation
of Pennsylvania

Application September 9, 1949, Serial No. 114,718

7 Claims. (Cl. 209—211)

1

This invention relates to means and method of controlling the degree of concentration of particles in the concentrated effluent from a single vortex chamber or from a battery of vortex chambers connected in parallel, and also relates to means of increasing the maximum value of such concentration under conditions of high outlet back pressures.

A conventional vortex chamber has a hollow interior of generally conical shape with a tangential inlet and with a small axially-located outlet at the tapered end of the chamber and a larger axially-located outlet at the opposite end of the chamber. When a stream of fluid under pressure is introduced into the chamber through its tangential inlet a vortex develops in the chamber which subjects any particles in the fluid centrifugal forces. The effect of the centrifugal action is to force solid particles into the periphery of the vortex where most of the particles are carried by an outer current spirally toward and through the outlet at the tapered end of the chamber with only a small portion of the fluid, while the rest of the fluid joins an inner spiral current which moves toward and through the larger outlet at the opposite end of the chamber. As a result, a small portion of fluid with a heavy concentration of particles emerges from the outlet at the tapered end of the chamber while most of the fluid with a reduced concentration of particles emerges from the outlet at the large end of the chamber. In addition to this concentrating action on the bulk of the particles entering a vortex chamber there is also a separating action because particles of different sizes or densities concentrate in proportion to their static settling rate characteristics when subjected to vortex action. The finer particles with low settling rates are least concentrated by vortex action and therefore mostly pass through the large-end outlet with the greater part of the fluid while the larger and higher density particles concentrate in the heavy effluent through the other outlet. The operation of a vortex chamber is primarily controlled by its form rather than by its position and the heavy concentration of particles always appears in the effluent through the tapered-end outlet, whether the chamber is upright or inverted.

In the past vortex chambers have been designed for uniform vortex action under uniform conditions and changes in the degree of particle concentration or separation have been made either by adjusting the flow through the tangential inlets during operation of the chamber

2

or else by taking the chamber out of operation to readjust some part of its structure. Shut-off valves for the outlets are sometimes provided for use when the chambers are out of operation but these valves have not been intended and are not suitable for use in regulating the action of the chambers while the chambers are in operation. In some cases a throttle valve is provided to control the tangential inlet of a vortex chamber but throttling the inlet varies the vortex action only indirectly and uncertainly and has the disadvantage that when the inlet valve is used to regulate concentration the quantity of fluid passing through the chamber is also changed.

The problem of regulating the concentration of effluent from vortex chambers has arisen, for example, in connection with certain coal cleaning operations. The water used for coal cleaning and the particles in the water are recovered in some cases by first treating the wash water in a battery of parallel vortex chambers to separate the fine particles of coal from the particles of coal flotation media in the water and then the portion of the wash water in which the coal particles are concentrated is passed through a second battery of parallel vortex chambers to recover most of the water for re-use in washing and to pass the balance of the water with a high concentration of coal particles to a coal-recovery tank. The sludge in the tank adheres to cloth filters which are rotated into and out of the tank and while each filter is out of the tank the sludge is formed into a cake by suction through the filter and then the cake is removed from the filter. The concentration of coal particles in the tank affects the rate of removal of the sludge from the tank and the tank must be kept at a constant level in order to immerse the filters completely and thus make the suction on the filters effective to form cakes which will separate from the filters. The best way to regulate the concentration in the tank is to regulate the concentration of the slurry fed to the tank from the battery of parallel vortex chambers which supply the tank, but heretofore vortex chambers have not been successfully controlled to vary the concentration of their heavy effluent. Moreover, a large number of vortex chambers, each having a maximum inside diameter of three inches or less, are needed for efficient handling of a slurry containing very fine solids, and this makes it impractical to use any system of control which requires separate adjustment of individual vortex chambers.

I have discovered that the concentrated effluent

3

through the tapered-end outlet of a vortex chamber may be regulated by variably throttling the outflow through the opposite outlet at the large end of the chamber. Moreover, I have extended this control system to a battery of individual vortex chambers connected in parallel so that a single throttle valve controlling a common manifold connected to all of the large-end outlets of the chambers serves as a flexible single control means to adjust the concentration at the tapered-end outlet of each of the chambers at the same time and to an equal degree. The fact that a single control can be applied to a battery of parallel chambers in accordance with my invention makes it practicable to take advantage of the superior efficiency of small vortex chambers for handling a large volume of fluid in large scale industrial operations and at the same time to control the operation of the whole battery of vortex chambers with ease and convenience.

I have also discovered a way of operating my control system without lowering the efficiency of the vortex chamber with respect to the amount of particles diverted to the tapered-end outlet. When a throttle valve controlling the large-end outlet of a vortex chamber is partially closed the back pressure on the large-end outlet becomes substantially greater than the back pressure on the opposite tapered-end outlet, with the result that some of the flow of fluid is diverted from the large-end outlet to the tapered-end outlet. The diversion of fluid to the small-end outlet decreases the concentration of particles in the small-end outlet effluent, which is a principal object of my invention. Another and undesirable result of the increased back pressure, however, is to cause a backflow of fluid through the large-end outlet into the chamber, where the returning fluid tends to slow down the vortex and thereby reduces the vortex efficiency with respect to the proportion of particles diverted to the tapered-end outlet. This reduction of efficiency is not only undesirable because it interferes with maximum particle recovery through the tapered-end outlet but also because it accelerates the reduction of concentration of the tapered-end outlet effluent to such an extent that it becomes difficult to obtain a predetermined concentration by operation of the throttle valve. In other words, the throttle control becomes too sensitive for gradual and accurate adjustment of concentration. I retain the useful effects of the throttle back pressure while avoiding its ill effects by mounting a baffle-plate outside of the large-end outlet of each vortex chamber. The outflow through each large-end outlet emerges in a flat spiral between the outlet and the plate and the high pressure fluid in the enlarged passage or manifold on the other side of the plate is prevented by the plate from flowing back along the central axis of the outlet. As a result, my throttle valve system is operable to adjust the concentration of the effluent from the tapered-end outlet of the chamber not only over a wide range of values but accurately and gradually, without developing a backflow to interfere with the predetermined concentration or vortex efficiency at any stage of adjustment. Moreover, my baffle plate over the large-end outlet is useful for increasing vortex efficiency in any vortex chamber where there is an excess of back pressure on the large-end outlet relative to the tapered-end outlet for reasons other than throttling; for example, excess back pressure on the large-end outlet may be caused by static head or fluid friction in the lead-off connections, or by an increase

4

of pressure in an enlarged passageway provided adjacent the large-end outlet for the purpose of reducing fluid velocity and fluid friction.

Further novel features and advantages of the vortex system of my invention will become apparent from the following detailed description and in the accompanying drawings. I have shown in the drawings, for purposes of illustration only, the following present preferred embodiment of my invention, in which:

Figure 1 is a side elevation of a battery of vortex chambers connected in parallel and controlled by a throttle valve in accordance with my invention, with an intermediate section of the battery removed and one end of the battery partially broken away;

Figure 2 is an end elevation of the apparatus shown in Figure 1, taken from the left of Figure 1;

Figure 3 is a partial top elevation of the central portion of the apparatus shown in Figure 1; Figure 4 is an enlarged sectional view of one of the vortex chambers shown in Figure 1;

Figure 5 is an enlarged sectional view taken along the line V—V in Figure 3; and

Figure 6 is an enlarged top elevation, partially broken away, of a pair of vortex chambers shown in Figure 3.

Referring in detail to the drawings, the apparatus comprises a series of vortex chambers 10 each having a hollow interior comprising a cylindrical upper portion with a tangential inlet 11, a dependent conical lower portion terminating in an axially-located outlet 12, and a flat circular top with an axially-located outlet 13. Each vortex chamber 10 comprises a hollow hard rubber shell 14 with a soft rubber lining 15 along its upper interior surface and a soft rubber insert 16 fitted within its lower interior surface. The insert 16 has a hollow interior in the form of a cone terminating in a small open orifice 13 which forms the narrowest portion of the outlet 12. A manually adjustable screw member 17 is threaded into the bottom of the shell 14 between the shell and the insert 16 and when the orifice 13 is too large, as when it has become enlarged by wear, the adjustable screw member 17 is screwed upwardly to compress the member 16 radially until the orifice 13 is squeezed to its predetermined size. The inlet 11 extends as a channel through the top of the shell 14 and is closed at the top by a cover plate 19 which extends across the top of the shell 14. A hollow cylindrical insert 20 is secured to and extends downwardly from a central opening in the plate 19 to form the axial outlet 13. Each shell 14 has a pair of oppositely extending lower shoulders 21 which are supported by underlying plates 22 held by nuts 22a on studs 22b screwed into a common frame plate 23. The frame plate 23 extends across the tops of all of the vortex chambers 10 and is separated from the cover plates 19 by sealing gaskets 24. Dowels 25 are screwed into the frame plate 23 and extend downwardly through corresponding openings in the gaskets 24, cover plates 19 and shells 14 to align the parts of each of the vortex chambers 10. The frame plate 23 is bored through to provide two outer rows of openings 26 on either side of two inner rows of openings 27. The outlets 13 each open through one of the openings 26 and the channels leading to the inlets 11 are each connected to one of the openings 27 through corresponding openings 27a in the cover plates 19.

The frame plate 23 is welded to a supporting

5

framework 28 supported by legs 28a. The vortex chambers 10 are mounted in two parallel banks with a common manifold plate 29 extending over all of them. The plate 29 is arched over the plate 23 and its sides welded to the sides of the plate 23. End plates 30 are welded to the opposite ends of the plate 23 and of the plate 29. Within the enclosure thus formed a second arched manifold plate 31 extends over the openings 27 with its sides welded to the frame plate 24 between the rows of openings 27 and with its ends welded to the end plates 30. An inlet manifold 32 is thus formed under the plate 31 with a passage to each of the vortex chambers 10 through the openings 27 and 27a and the inlets 11, and an outlet manifold 33 is formed between the plates 29 and 31 with a passage to each of the vortex chambers 10 through the outlets 13 and openings 26. Access to the manifolds 32 and 33 for cleaning is provided by end plate openings 34 which are kept closed during normal operations. A supply conduit 35 extends through plates 29 and 31 and opens into the inlet manifold 32. An outlet conduit 36 is connected to the outlet manifold 33 through an opening in the plate 29. A throttle valve 37 is mounted on the outlet conduit 36 to regulate the rate of flow therethrough. In order to prevent back pressure in the manifold 33 from causing an axial counterflow through the openings 26 and outlets 13, especially when the valve 37 is in a partially closed position, horizontal baffle plates 38 and 39 are mounted directly over the respective rows of outlet openings 26. Spacers 40 are welded between the frame plate 23 and the baffle plates 38 and 39 to support the baffle plates sufficiently above the frame plate 23 so that a full flow of fluid can pass vertically through the outlets 13 and openings 26 and thence horizontally between the baffle plates 38 and 39 and the frame plate 23 into the outlet manifold 33.

The outlets 12 at the tapered ends of the vortex chambers 10 are open to the atmosphere and the effluent from the outlet 12 spills onto an inclined trough 41 mounted on the frame 28. From the trough 41 effluent drains off through a conduit 41a. The outlets 12 are small relative to the inlets 11 and outlets 13 so that a minimum of fluid will escape with the concentrated particles which pass through the outlets 12.

The operation of the apparatus is as follows: A slurry of coal particles in the water or other fluid containing solid particles is fed under pressure through the inlet conduit 35, into the inlet manifold enclosed by the plate 31 and thence through the openings 27 and the tangential inlets 11 into the several vortex chambers 10. The fluid entering each chamber sets up a vortex which concentrates the particles in the fluid by centrifugal action.

The particles are forced through the swirling fluid toward the wall of the chamber and are concentrated in a current of fluid which descends spirally toward the outlet 12 at the tapered end of the chamber. Most of the particles with a small amount of fluid (about 5% of the feed) pass out of the chamber through the outlet 12 and the balance of the fluid with a small percentage of particles spirals upwardly near the axis of the chamber where some recirculates and some emerges from the chamber through the outlet 13. The baffle plates 38 and 39 prevent a counterflow from developing through any of the outlets 13.

When the valve 37 is fully open the average

6

fluid pressure at each outlet 13 approaches atmospheric pressure and the chamber then operates to produce a maximum concentration of particles in the effluent from each outlet 12. Adjustment of the valve 37 to throttle the outflow through the conduit 36 increases the back pressure in the manifold 33 outside of the outlets 13 while the atmospheric back pressure outside of the outlets 12 remains constant. This diverts some of the fluid entering through the inlets 11 from the outlets 13 to the outlets 12 but does not materially alter the distribution of particles between the outlets 12 and 13. The result is that throttling the outflow from the outlets 13 by means of the valve 37 has the effect of progressively and controllably reducing the concentration of particles in the effluent through the outlets 12, and opening the valve 37 has the reverse effect.

The operation of the valve 37 has a different effect on the outlets 13. The maximum diversion of fluid from the outlets 13 to the outlets 12 is limited by the relatively small size of the outlets 12 and consequently such diversion by means of the valve 37 reduces the flow through the outlets 13 by only a very small percentage. Moreover, as stated above, operation of the valve 37 does not materially affect the distribution of particles through the respective outlets 12 and 13. As a result, operation of the valve 37 regulates the concentration of effluent from the outlets 12 without substantially changing the concentration or rate of flow of the clarified fluid from the outlets 13. The clarified effluent from the outlets 13 and the concentrated effluent from the outlets 12 are used independently and the fact that the valve 37 effectively regulates the outflow from the outlets 12 without interfering with the outflow from the outlets 13 is advantageous.

The range of variation of concentration of particles in the effluent from the outlets 12 is limited at one extreme by the maximum efficiency of the vortex chamber when the valve 37 is fully open, and at the other extreme by the fact that the relatively small size of the outlets 12 compared with the inlets 11 prevents the valve 37 from being fully closed so that all of the fluid entering through the inlets 11 would emerge through the outlets 12 without any increase in concentration. Notwithstanding the limited size of the outlets 12, the valve 37 is effective to vary heavy effluent concentration over a wide range; for example, when water with a 10% concentration of coal particles is fed at 40 p. s. i. into a 3" maximum diameter vortex chamber with an inlet of $\frac{3}{8}$ " effective diameter, a tapered-end outlet of $\frac{1}{4}$ " diameter, and a large-end outlet of $\frac{1}{2}$ " diameter fitted with a baffle plate, tests have shown that a throttle valve controlling the large-end outlet is operable to vary the concentration of coal particles in the heavy effluent over a range of about 20 to 60%, which is ample for practical purposes.

The efficiency of the vortex chambers 10 and the control of the vortex chambers 10 by the valve 37 is improved by the baffle plates 38 and 39. There is usually at least a slight back pressure on the outlets 13 in excess of the atmospheric back pressure on the outlets 12 even when the valve 37 is fully open, and this back pressure increases as the valve 37 is tightened. Even slight excess back pressure starts a backflow through the outlets 13 in the absence of the plates 38 and 39, with the result that fluid is diverted from the outlets 13 to the outlets 12 and

vortex action is slowed down so that less particles are diverted to the outlets 12. The plates 38 and 39 prevent such a backflow and its harmful consequences and thereby increase the effectiveness of the vortex chambers and the range of concentrations controllable by the valve 37. Tests indicate, for example, that removal of the plates 38 and 39 would decrease the maximum concentration of the effluent through the outlets 12 by about 30% (under conditions of slight excess back pressure on the outlets 13). Moreover, as the valve 37 is closed the plates 38 and 39 continue to prevent a backflow through the outlets 13 and thus allow the valve 37 to be operated to adjust the concentration of the effluent through the outlets 12 gradually and accurately to any predetermined value within the range of values controllable by the valve. Tests indicate that in the absence of the plates 38 and 39 the control of the effluent concentration by the valve 37 would be so sensitive that it would be very difficult to adjust the valve to obtain predetermined intermediate values of concentration.

The operation of the vortex chambers 10 is essentially the same when different kinds of particles are present in the fluid fed in through the inlets 11. The less dense and smaller particles are least affected by vortex action and most of the very fine particles are diffused in the major portion of fluid passing through the outlets 13 while the more dense and larger particles concentrate in the effluent through the outlets 12. Adjustment of the valve 37 does not change the kinds or concentration of particles in the effluent through the outlets 13 and changes the concentration but not the kinds of particles in the effluent through the outlets 12. Moreover, the operation of the vortex chambers 10 is not substantially changed by inverting the whole apparatus. The vortex efficiency is slightly reduced by reversal of the static head on the fluid but substantially the same effluent comes from the outlets 12 and 13 irrespective of the upright or inverted position of the vortex chambers.

While I have shown and described certain present preferred embodiments of the invention and have disclosed certain present preferred methods of practicing the same, it is to be distinctly understood that the invention is not limited thereto but may otherwise variously be embodied and practiced within the scope of the following claims.

I claim:

1. A method of progressively regulating the amount of solids being continuously withdrawn from a mixture of the solids in a liquid, comprising the simultaneous steps of subjecting the mixture to the action of a vortex while withdrawing a large proportion of the solids with a small proportion of the liquid from one axial end of the vortex and the balance of the mixture from the other axial end of the vortex, and progressively regulating the amount of said large proportion of solids being withdrawn from the said one end of the vortex by variably throttling the flow of the mixture being withdrawn from the said other end of the vortex while blocking an axial counterflow of the withdrawn balance of the mixture into the vortex.

2. Apparatus for variable concentration of solid particles in a fluid, comprising a vortex chamber having a hollow circular interior with a tangential inlet and axially-located outlets of different sizes at opposite ends of the chamber, a portion of the interior of the chamber being

tapered toward the smaller of the two outlets, in combination with means forming a fluid passageway connected to the larger of said outlets, a baffle within the passageway covering but spaced from the larger outlet to permit an outflow therethrough while preventing a simultaneous counterflow, and a throttle valve connected to said means for variably controlling flow through the passageway, whereby particles in fluid fed under pressure into the chamber are concentrated by vortex action in the effluent through the said smaller outlet, the degree of said effluent concentration being progressively adjustable to predetermined values within a wide range by operation of the said throttle valve.

3. A method of regulating the amount of solids being continuously withdrawn from a mixture of the solids in a liquid, comprising the simultaneous steps of subjecting divided portions of the original mixture each to the action of a different vortex, withdrawing a large proportion of the solids with a small proportion of the liquid in the portion in each vortex from one axial end of the vortex and withdrawing the balance of the portion from the other axial end of the vortex, blocking an axial counterflow of the withdrawn balance into each vortex, combining the balances withdrawn from said other end of each vortex into a single stream, and progressively regulating the amounts of said large proportion of solids being withdrawn from the said one axial end of each vortex by variably throttling said stream of combined balances withdrawn from the said other end of each vortex.

4. Apparatus for variable concentration of solid particles in a fluid, comprising a series of vortex chambers each having a hollow circular interior with a tangential inlet and axially-located outlets of different sizes at opposite ends of the chamber, a portion of the end of each chamber being tapered toward the smaller of its two outlets, a common inlet manifold connected to each of the inlets and a common outlet manifold connected to each of the larger outlets, in combination with a baffle covering but spaced from each of the larger outlets to permit an outflow therethrough while preventing a simultaneous counterflow, a conduit connected to the outlet manifold and a throttle valve controlling flow through the conduit, whereby particles fed under pressure from the inlet manifold into the respective chambers are concentrated by vortex action in the effluent through the smaller outlets in the chambers, the degree of said concentration in the effluent from all of the smaller outlets being simultaneously and progressively adjustable to predetermined values within a wide range by operation of the said throttle valve.

5. Apparatus for selective separation or concentration of a mixture of materials including a fluid by vortex action, comprising a plate having a first group of openings therethrough arranged in two spaced rows with a second group of openings through the plate therebetween, a series of generally conical vortex chambers having their large ends attached to the plate, each chamber having a tangential inlet connected to receive a flow from an opening of one of said groups and having an axial outlet opening at its large end connected to discharge through an opening in the other of said groups, each chamber also having a smaller outlet opening axially located at its smaller end, a manifold cover member enclosing the portion of the plate which includes the intermediate group of openings and is on the op-

posite side of the plate from the chambers, a second manifold cover member enclosing the first manifold cover member and the portions of the plate including the other group of openings, said manifold cover members being spaced apart to provide free access between the outer rows of openings in the plate, an inlet conduit opening into the space enclosed between the first manifold cover member and the plate, and an outlet conduit opening into the space between the two manifold cover members, whereby the inlet conduit is connected to feed into the inlets of all of the chambers and the outlet conduit is connected to receive the outflow from the large end outlets of all of the chambers.

6. Apparatus for selective separation or concentration of a mixture of materials including a fluid by vortex action, comprising a plate having a group of openings therethrough arranged in two spaced rows with a second group of openings through the plate therebetween, a series of generally conical vortex chambers having their large ends attached to the plate, each chamber having a tangential inlet connected to receive a flow from one of the intermediate openings and having an axial outlet opening at its large end connected to discharge through one of the outer openings, each chamber also having a smaller outlet opening axially located at its smaller end, a manifold cover member enclosing the portion of the plate which includes the intermediate group of openings, said manifold cover member being on the opposite side of the plate from the chambers, a second manifold cover member enclosing the first manifold cover member and the portions of the plate including the outer group of openings, a pair of baffle plates extending along, over and spaced from the respective outer rows of plate openings in the space between the two manifold cover members, an inlet conduit opening into the space enclosed between the first manifold cover member and the plate, and an outlet conduit opening into the space between the two manifold cover members, whereby the inlet conduit is connected to feed into the inlets of all of the chambers and the outlet conduit is connected to receive the outflow from the large end outlets of all of the chambers.

7. Apparatus for selective separation or concentration of a mixture of materials including a fluid by vortex action, comprising a plate having

a group of openings therethrough arranged in two spaced rows with a second group of openings through the plate therebetween, a series of generally conical vortex chambers having their large ends attached to the plate, each chamber having a tangential inlet connected to receive a flow from one of the intermediate openings and having an axial outlet opening at its large end connected to discharge through one of the outer openings, each chamber also having a smaller outlet opening axially located at its smaller end, a manifold enclosing the portion of the plate which includes the intermediate group of openings and is on the opposite side of the plate from the chambers, a second manifold enclosing the first enclosure and the portions of the plate including the outer group of openings, a baffle extending along, over and spaced from each of said spaced outer rows of openings within the enclosure of the first manifold, a pair of conduits opening into the spaces enclosed by the respective manifolds, one conduit being connected to the first manifold to feed into the inlets of all of the chambers and the other conduit being connected to the second manifold to receive the outflow from the large end outlets of all of the chambers, and a throttle valve connected to control the outflow through the latter conduit.

HARRY E. CRINER.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
453,105	Bretney	May 26, 1891
762,866	Allen	June 21, 1904
1,197,946	Pardee	Sept. 12, 1916
1,919,653	Hill	July 25, 1933
2,010,128	Arnold	Aug. 6, 1935
2,069,483	Skajaa	Feb. 2, 1937
2,360,355	McBride	Oct. 17, 1944

FOREIGN PATENTS

Number	Country	Date
238,137	Switzerland	Oct. 16, 1945

OTHER REFERENCES

The Institute of Fuel, August 1939, pages 327 to 349, Cleaning of Coal, etc., by Driessen.