Mar. 27, 1923. 1,449,603.

M. HOKANSON.

METHOD OF SEPARATING GRANULAR SOLID MATERIAL.

ORIGINAL FILED JAN. 21, 1919. 3 SHEETS—SHEET 1.

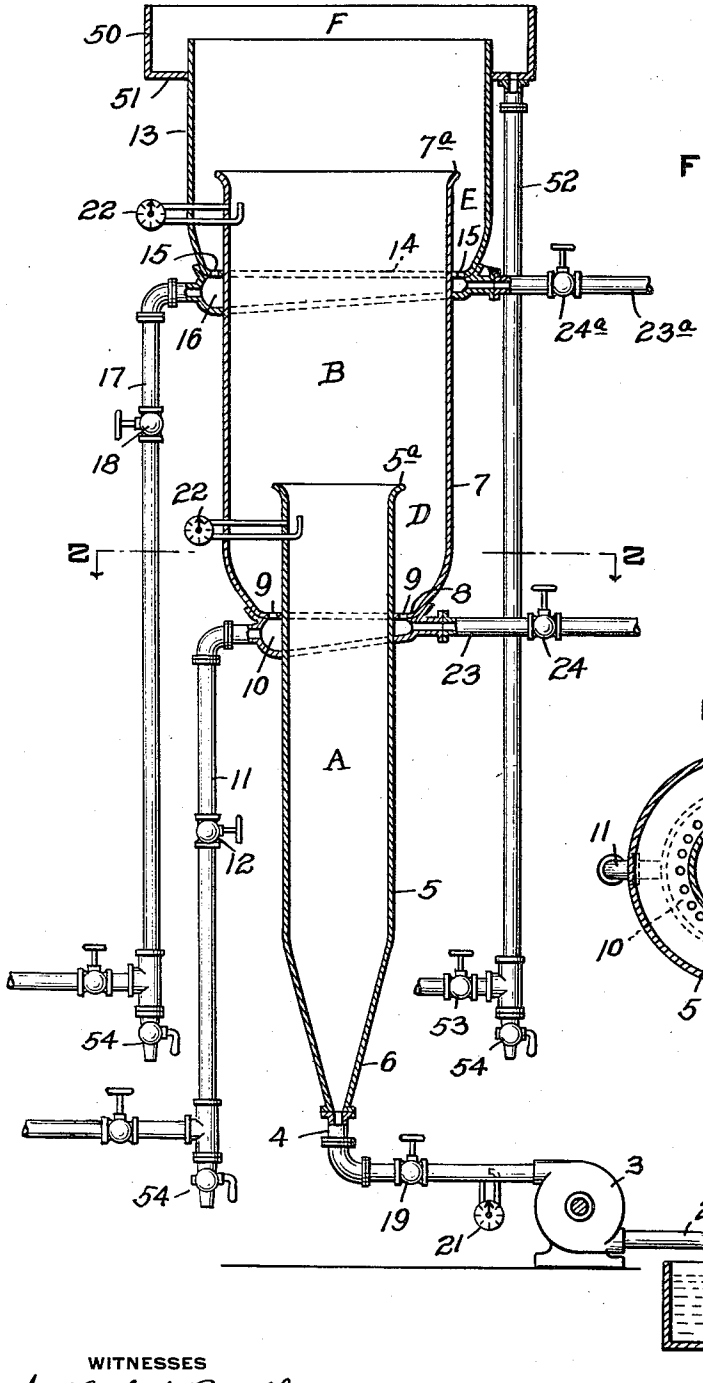
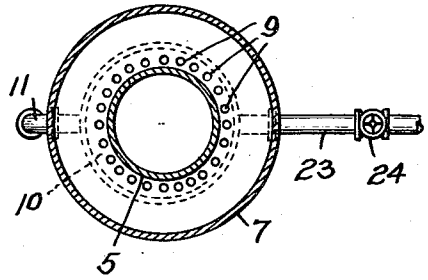


FIG. 1.

FIG. 2.



WITNESSES

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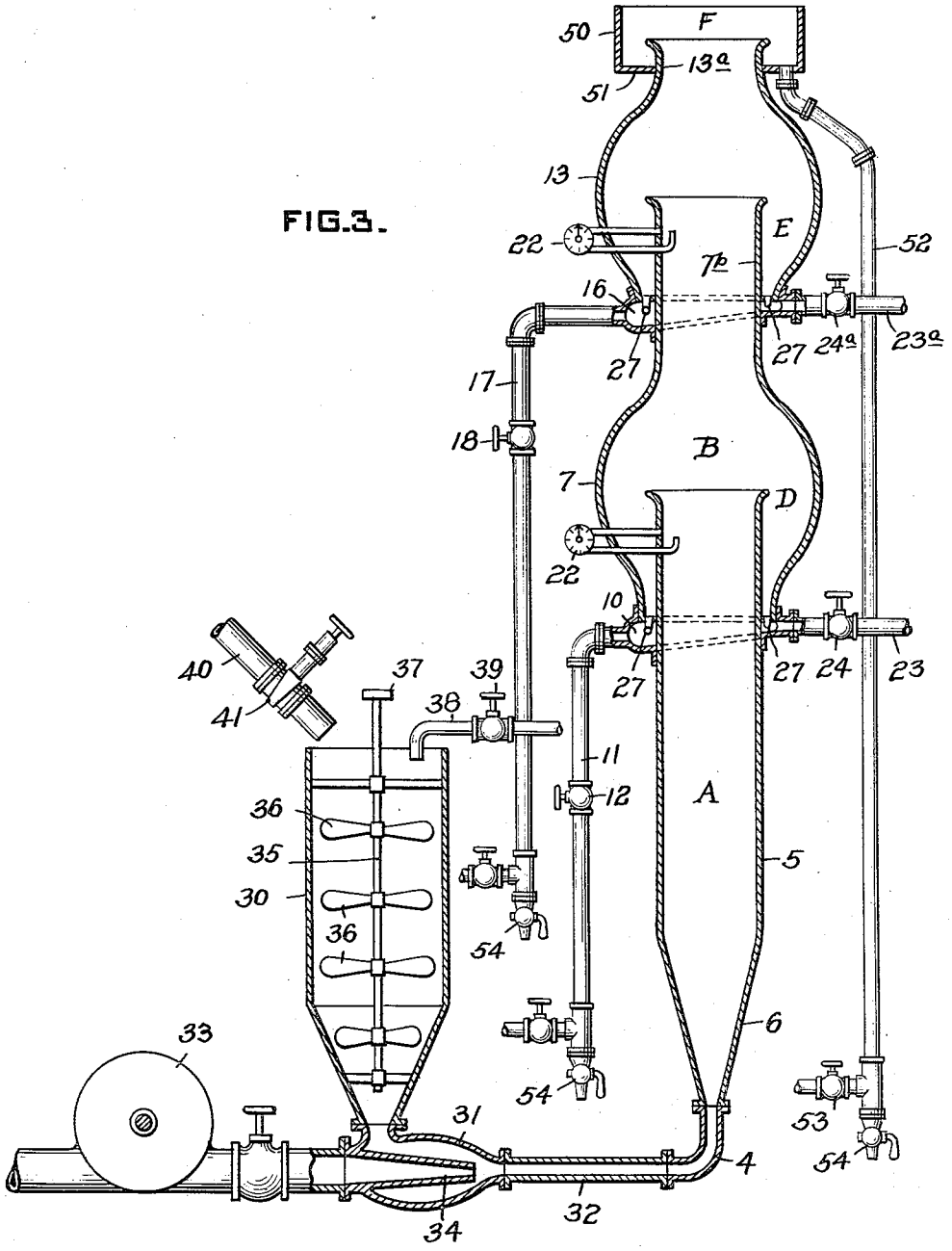
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METHOD OF SEPARATING GRANULAR SOLID MATERIAL.

ORIGINAL FILED JAN. 21, 1919. 3 SHEETS—SHEET 2.

FIG.3.



WITNESSES

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METHOD OF SEPARATING GRANULAR SOLID MATERIAL.

ORIGINAL FILED JAN. 21, 1919. 3 SHEETS—SHEET 3.

FIG.4.

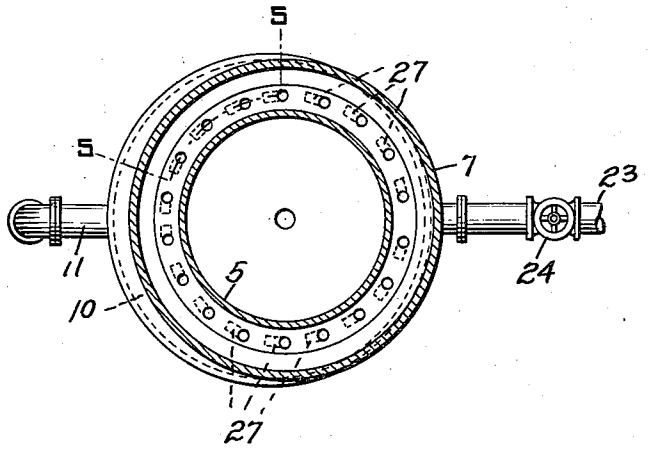


FIG.5.

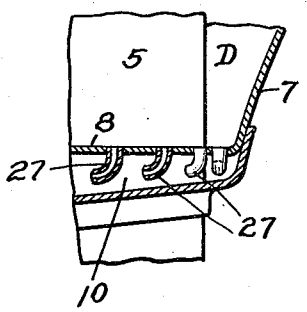


FIG.6.

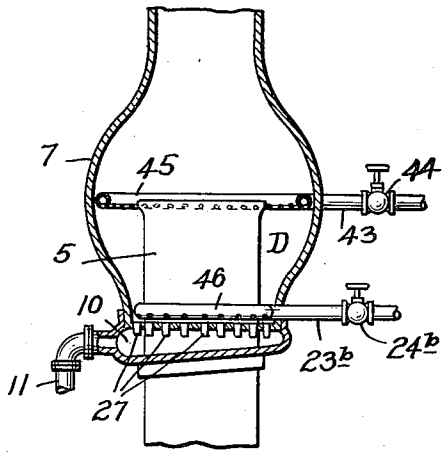
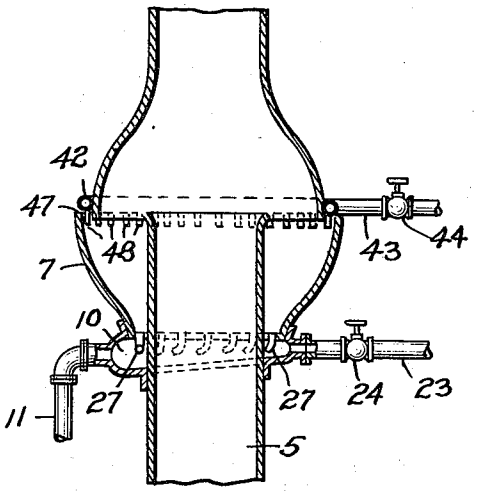


FIG.7.



WITNESSES

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Patented Mar. 27, 1923. 1,449,603

UNITED STATES PATENT OFFICE.

MARTIN HOKANSON, OF DULUTH, MINNESOTA.

METHOD OF SEPARATING GRANULAR SOLID MATERIAL.

Application filed January 21, 1919, Serial No. 272,327. Renewed June 21, 1922. Serial No. 569,881.

To all whom it may concern:

Be it known that I, MARTIN HOKANSON, a resident of Duluth, in the county of St. Louis and State of Minnesota, have invented a new and useful Improvement in Methods of Separating Granular Solid Materials, of which the following is a specification.

This invention relates to a method of separating granular solid materials of different specific gravities, and particularly to a method of concentrating ore, that is, separating the valuable part of the ore from the gangue.

The object of the invention is to provide a method of separating such materials in a simple and economical manner and with the use of apparatus cheap relative to the concentrating apparatus generally in use, and whereby a fairly clean concentrate is secured and a high percentage of values recovered.

Generally stated the method consists in first separating the materials to be concentrated according to size, into several grades, each grade consisting of particles of substantially the same size but of different specific gravities, and then subjecting each grade separately to an upwardly flowing stream of water in a closed system having such a diameter relative to the velocity of the water as to cause the heavier particles to separate out radially of the stream and collect at the outside thereof, said stream of water having such velocity along the walls of said system as to lift the heavier particles barely to the point of withdrawal, and then withdrawing the material from said system constantly, uniformly and at the same velocity entirely around the stream, and maintaining in said system a quiescent condition of flow without splashing, eddies, or the like, so as to not materially disturb the velocity toward the interior of the stream in order that it may carry the lighter material to a higher level, where it is withdrawn from the system, circumferentially, under the same conditions as the heavier material is withdrawn. In addition to this the method consists in maintaining the uniformity of velocity throughout the system by introducing a water supply at the point or points of withdrawal of material from the system, to compensate for the water withdrawn with the material.

Various other additions and refinements may be made in the method, to meet various operating conditions, as will hereinafter appear.

This application is in part a division of my application Serial No. 207,001. filed December 13, 1917, and in part a division of my application Serial No. 245,296, filed July 17, 1918.

The accompanying drawings show several arrangements of apparatus suitable for carrying out the method, in its various phases. These however are merely illustrative of apparatus suitable for carrying out the fundamental method. In said drawings, Fig. 1 is a vertical central section through one form of apparatus or system for carrying out the method; Fig. 2 is a horizontal section on the line 2—2 of Fig. 1; Fig. 3 is a vertical central section through another form of apparatus or system for carrying out the method; Fig. 4 is a horizontal section therethrough taken just above the lowermost withdrawal chamber; Fig. 5 is a vertical fragmentary section of a portion of the apparatus, taken substantially on the line 5—5, Fig. 4; and Figs. 6 and 7 show modifications of supplementary water supply means.

The method depends for its operation upon the well known principle that if solid particles of the same size but of different specific gravities or weights are subjected to an upwardly flowing stream of water of decreasing velocity, the lighter particles will be carried to a higher level than the heavier particles, and the height to which the individual particles are carried varies quite accurately according to their relative specific gravities. It is an also well known principle that water flowing through a conduit has its greatest velocity at the center of the conduit, the velocity decreasing from the center to the walls of the conduit. The present method utilizes both of these principles, but more particularly is dependent for its operation upon the second named principle, and in that way secures a circumferential segregation or separation of the heavier particles, so that the same can be withdrawn from the outside of the flowing stream.

In order to utilize this principle it is essential that the particles be all of substantially the same size but of different specific gravities, and consequently the material to

be treated, if not already in a condition to be sized, is first ground, and then separated, by screens or other well known means, into various grades, according to size, so that each grade consists of particles all of which are of substantially the same size. The method is particularly adapted for the separation of impurities, such as silica and other gangue, from various ores, such as ores of iron, copper, zinc, silver, gold, alumina, and the like. The impurities in some forms of such ores exist in a very finely divided state, so fine that it is usually necessary to crush the ore so that it will pass a one hundred mesh sieve or smaller, before the particles of silica or other impurities will be detached from the particles of ore. The specific gravity of silica and other impurities however is generally considerably less than that of the ores mentioned, with the exception of alumina, which is lighter than the silica. Consequently when particles of ore and particles of silica, of the same size are subjected to a vertical current of water, the particles of silica will be carried at a greater velocity and to a greater height than the particles of ore, with the exception of alumina, which latter will be carried at a greater velocity and to a greater height than the silica. This difference is specific gravities of these materials therefore furnishes a convenient means for separating the one from the other, so that when said materials are carried upwardly in a conduit of the proper dimensions, and at the right velocity, the heavier particles will separate outwardly toward the walls of the conduit. This is accomplished by treating the ground and graded material in a closed system, under conditions of quiescent and uniform flow at all points therethrough, and a uniform and constant withdrawal of the material from the periphery of the system in order not to disturb the accurate separation of the heavier particles from the finer particles.

Referring first to the system shown in Figs. 1 and 2, the graded ore is fed into a receptacle 1 which is kept filled with water and in which the contents are agitated so as to maintain a uniform mixture of water and ore. This mixture is withdrawn from said receptacle through a pipe 2, by any means, such as a centrifugal pump 3, and is discharged through pipe 4 into the bottom of a vertical vessel 5, preferably cylindrical or nearly so, but which may if desired increase in diameter upwardly, and which encloses the chamber A. The cylinder proper is connected to the pipe 4 by a conical portion 6, which preferably merges gradually into the cylinder in order to gradually reduce the velocity of water flowing upwardly through said conical portion and deliver it to the chamber A in the vessel 5 without eddies or swirling. Above the cylinder 5, and surrounding it for some distance below its top, is a vessel 7 of larger diameter, and also preferably cylindrical or substantially so and which encloses the chamber B. The connection between the two vessels 7 and 5 is by means of a substantially conical-shaped bottom 8 of vessel 7, and in said bottom are a series of uniformly and closely spaced, equal sized holes 9 for the withdrawal of the heavier material, which holes lead into a closed annular chamber 10 extending entirely around the vessel 5 and provided at one side with a withdrawal outlet to which a draw-off pipe 11 is connected. A valve 12 is provided in this pipe for controlling the rate of discharge therethrough. The chamber or conduit 10 is of largest size at the draw-off outlet and decreases uniformly in size from that point in both directions to the diametrically opposite point, in order to secure a uniform discharge pressure through each of the perforations 9. In other words, the dimension of this annular withdrawal chamber increases in both directions from its smallest point to the point of withdrawal of the material, at a rate corresponding to the increase of material delivered through the various discharge openings 9, and as these are of uniform size and equal distances apart the outward flow in the withdrawal chamber increases uniformly from the one side to the draw-off outlet. The walls at the upper end of the vessel 5 flare outwardly in a uniform curve as shown at 5^a, in order that the material flowing upward adjacent the walls of said vessel will be discharged quietly and without abrupt change of course into the space D surrounding the same, without producing eddies or swirling at this point.

Similarly, located above the vessel 7 and surrounding the same for some distance below its top, is a still larger vessel 13 which is joined to the vessel 7 by a bottom portion 14 provided with a series of uniformly spaced, equal sized discharge openings 15 leading into an annular chamber 16, similar to chamber 10 above described, that is to say, being of gradually increasing size in both directions to the point of discharge, at which point a withdrawal pipe 17 is connected. The last pipe, like pipe 11, is also provided with a valve 18 for regulating the rate of discharge therefrom, and the upper end of the walls of the vessel 7 are curved gradually outwardly, as shown at 7^a, in order to secure a quiescent overflow of material into the space E surrounding the same.

In order to regulate the amount of water and material entering into the system, a regulating valve 19 is inserted in the pipe 4 between the pump 3 and the point where the mixture is injected into the vessel 5.

Preferably also a valve 20 is applied to the intake end of the suction pipe 2, for regulating the amount of material supplied to the pump.

Means for measuring the velocity of the water entering the system is preferably provided, and this may be either a Venturi meter or a Pitot tube, preferably located between the pump 3 and regulating valve 19, and is shown diagrammatically at 21. Also means are provided for measuring or observing, at any time, the velocity at the walls of the vessels 5 and 7, preferably immediately before the mixture reaches the sudden enlargements. This can be variously accomplished, such as by injecting a small quantity of colored liquid and observing the rate of its rise through a window in the walls of the vessel, or by any other suitable velocity measuring device,—a means for this purpose being diagrammatically indicated at 22.

At the upper end of the system illustrated is another vessel 50 having a bottom 51 connected to the vessel 13 somewhat below its top and thus forming an annular overflow chamber F which has connected thereto a draw-off pipe 52 of sufficient size to take off all of the overflow, and which pipe is provided with a regulating valve 53. The pipes 11, 17 and 52 are also provided with a valve 54 for taking out samples of the mixtures escaping through said pipes.

In case it is not desired to save the water or separate the clay (alumina) from the silica of the gangue, the vessel 50 is unnecessary, and in that case, the second draw-off described would become the end of the system, and this would suffice for separating ore from its gangue. But if the mixture contains two or more minerals of different specific gravities, plus gangue of still another gravity, it is necessary to have additional draw-offs for the additional minerals, plus one draw-off for the gangue, and if the water is to be saved there must be an additional vessel at the top for this purpose. The number of vessels constituting a complete system will therefore be varied according to the material to be separated, and also according to whether it is desired to save the water for re-use or not.

While the several separating vessels are shown in vertical relation to each other, that is, on top of each other, this is not absolutely essential. For certain purposes it may be desirable, after one of more separations have been made, to run the residue into another separator or separators, located at any convenient position relative to the initial separator or separators. If the mixture withdrawn through any one outlet is not sufficiently concentrated, it can obviously be again run through the same apparatus, or through another apparatus to get a still higher concentrate.

In the use of this apparatus according to my method the mixture of materials to be separated, after having been carefully graded to approximately uniform size, is fed into the container 1 and thoroughly mixed with water therein and then forced upwardly through the system. The mixture flows upwardly through the system in a quiet uniform stream, without agitation, splashing, swirling or eddies. The vessel 5 is of such diameter relative to the velocity of the water flowing therethrough and the specific gravities of the particles, that the heavier particles move out radially, and flow up along the walls of said vessel, and the height of such vessel is such that by the time the mixture reaches the top thereof practically all of the heavier particles are segregated out and are flowing in contact with the walls of said vessel, and as the stream reaches the extreme upper end of said vessel these heavier particles move outwardly still farther, over the curved upper end of said vessel, and into the zone of materially decreasing velocity there encountered, by entering the enlarged vessel 7, and fall down in the space D and are withdrawn through the outlets 9 in the bottom 8 of chamber D. The remaining mixture continues its upward flow in the vessel 7, and any heavier particles which may not already have been separated out, move radially outwardly toward the walls of said vessel, where the velocity is so reduced as to no longer sustain such particles and they also drop down along the walls of said vessel 7 to the bottom thereof. This vessel will be chosen of such diameter that the velocity therein will nevertheless be sufficient to carry the silica or other impurities, and these move radially to the walls of the vessel and when they reach the top of said vessel discharge over the curved upper end thereof into the space E and are withdrawn through the openings into the annular discharge conduit 16. The very light materials, scum, froth, etc., discharge with the surplus water over the top of vessel 13.

The discharge pipes 11 and 17, for the ore and gangue respectively, are kept constantly open, so that there is a continuous withdrawal of these two grades of material through the discharge openings into the withdrawal chambers 10 and 16 respectively, and this withdrawal takes place uniformly entirely around the vessels 5 and 7 respectively, so that there is no greater velocity over the tops of the vessels 5 and 7 respectively at any one point as compared with every other point, and the discharge of the material is quiet, and effected in a manner to avoid all eddies and the like. The rate of withdrawal of these materials can be regu-

lated accurately by the valves 12 and 18 respectively, so as to maintain the uniform conditions within the system.

With certain materials the amount of water withdrawn through the withdrawal pipes 11 and 18 may be such that the upward velocity in the vessels 7 and 13 is not sufficient to raise the particles of the next lower specific gravity, to the top of said vessels. To compensate for this loss of water I provide a supplementary water supply, such as by means of a pipe 23, provided with a control valve 24, connected to the smallest point of chamber 10, or a similar pipe 23^a provided with a control valve 24^a connected to the smallest point of chamber 16.

For other materials, and under other conditions, the amount of water withdrawn through the withdrawal pipes 11 and 17 respectively may produce such a decrease in velocity in the vessels 7 and 13 respectively as no longer to move the next heavier grades to the tops of such vessels. In order to further compensate for such loss of water I have found it advisable to make the second vessel as small, or even smaller than the first vessel, in order to maintain the desired velocity therein, and likewise make the third vessel as small or even smaller than the second vessel so that the succeeding vessels are not substantially larger than the preceding, but may be made of approximately the same size, or even smaller sizes successively, according to the circumstances and the materials being treated. When this is necessary the system may be modified as shown in Fig. 3, in which the lower portion of the vessel 7 is of a size to form the necessary enlarged chamber D, while its upper end is contracted to form a substantially cylindrical portion 7^b. Likewise the vessel 13 has its lower portion of such size as to form the enlarged chamber E around the top of the vessel 7, then extends upwardly as a vertical aligning cylinder 13^a, which is surrounded by the overflow basin 50.

In other words, the system must be designed with reference to the materials to be separated, in order to secure in the different vessels the proper velocities for carrying to the top of each vessel the material to be discharged from the top thereof, irrespective of whether the vessels are of successively increased sizes, or with the upper portions thereof of the same size, or even of decreasing size. In all cases the construction must be such as to secure the uniform, quiet, and constant discharge of the several grades of material from the system, without disturbing the quiet flow of the stream within the system. It is necessary to accurately measure the comparative specific gravities of the materials being separated, to determine the exact proportion which each constituent bears to the whole, and to regulate the withdrawal accordingly and also regulate the velocities in the several vessels in order to secure efficient separation. This can most conveniently be secured by controlling the amount of water drawn off and the amount of supplementary water added between the several vessels. Manifestly the rate of escape of water through the ports 9 and 15 is dependent upon the discharge of water and material through pipes 11 and 17, which can be accurately regulated by the valves 12 and 18 respectively. Likewise the supplementary water supply can be conveniently regulated by the valves 24 and 24^a respectively and maintained at such velocity as not to interfere with the proper discharge of the material from the chambers 10 and 16, and yet sufficient to compensate for the amount of water withdrawn and maintain the velocity in the vessel immediately above.

The means for forcing the mixture into the bottom of the system obviously can be varied within wide limits. In lieu of the centrifugal pump shown in Fig. 1, a tank for receiving the mixture of granular material and water can be used, located at such height as to give the necessary head and having its discharge outlet connected to the bottom of the vessel 5. Fig. 3 shows still another arrangement, and which is preferred because the mixture of granular material and water does not pass through the pump and wear out the latter. As here shown I provide a tank 30 for receiving the mixture of granular material and water and having its lower end connected by pipes 31 and 32 to the inlet 4 of the vessel 5, with a suitable pump, such as centrifugal pump 33, to provide the necessary pressure and velocity to force the material into the system. Preferably the connections will be such as to produce an injector action and to this end the pipes 31 and 32 are reduced in size toward their meeting ends and an interior nozzle 34 is connected to the discharge orifice of the pump and projects into the tapered pipes 32, thus producing an injector action on the well known principle. In order to maintain a uniform mixture of material in the tank 30, an agitator may be provided, such as the vertical shaft 35 provided with paddles 36, and which may be driven by any suitable means, such as by belt pulley 37, or which may be driven intermittently by hand. The water is supplied to the tank 30 through pipe 38 having a control valve 39, and the granular material is supplied through a pipe 40 provided with a control valve or gate 41.

In the apparatus shown in Fig. 3 the discharge orifices in the bottoms of the vessels 7 and 13 are provided with curved or funnel shaped spouts 27 having their upper

ends flush with the bottoms of the chambers through which they receive the mixture and their lower ends bent as shown in Fig. 5 and pointing in the direction of the inclination of bottoms of the chambers into which they discharge, thus tending to create current in the chambers 10 and 16 respectively in the direction of the withdrawal outlet therefrom, and assisting in maintaining a uniform discharge of material to said withdrawal outlet at all points in the annular discharge chambers.

Figs. 6 and 7 show modifications of the supplementary water supply means. In Fig. 6 an additional water pipe 43, controlled by valve 44, leads into the lower end of the vessel 7 approximately at the level of the upper end of the vessel 5 and is there connected to an annular pipe 45 extending around the chamber D. The lower side of pipe 45 is perforated, as shown, so that the water escaping therefrom is directed downwardly and aids in leading the heavier particles downwardly into the chamber D, as well as compensating for loss of water. A similar arrangement may be provided for chamber E.

Near the bottom of chamber D is another pipe 23^b provided with a regulating valve 24^b and which connects with a circular perforated pipe 46 lying just above the discharge chamber 10. The perforations in the pipe 46 are on its lower side and are located above the funnels 27 so as to aid in forcing the solids through said funnels. A similar arrangement may be provided for chamber E.

Instead of placing the pipe 45 inside of the vessel 7, as shown in Fig. 6, the walls of said vessel may be provided with an offset 47, as shown in Fig. 7, and the pipe 42 placed on the outside, and connected to the inside of the vessel by nipples or similar extensions 48.

These various arrangements illustrated show merely various ways of introducing an additional supply of water to compensate for that drawn off, and to aid this draw-off, and doing this without disturbance of the separating current. Or any desired combination of these features may be used, or they may all be attached to a standard apparatus, and used or not according to the particular circumstances of each case.

Various other forms of apparatus may obviously be used for carrying out the method, and it will be understood that the systems shown are merely illustrative of some forms that may be used. Likewise the size and proportions of the various parts of the apparatus are not intended to be fixed by the dimensions illustrated, but obviously will have to be made of such size and proportions as to maintain therein the conditions described.

The method described, while particularly adapted for the separation of ore from its gangue, may be used for separating any mechanical mixtures of particles of different specific gravities, where the difference in specific gravities is considerable. Likewise the same method may be used for separating particles of the same specific gravities, but of different sizes, in which, as is well known, the particles will tend to separate according to their size, that is, the coarser particles will separate out first and the smaller particles carried further through the system.

What I claim is:

1. The method of separating solid materials of different specific gravities or sizes, which consists in subjecting the material to an upwardly flowing stream of water of such diameter relative to its velocity as to cause the heavier particles to move radially to the outside of the stream and the lighter particles to remain inwardly thereof, continuing such flow until the particles of a given grade have moved to the outside of the stream, and continuously withdrawing such material and water uniformly around the stream.

2. The method of separating solid materials of different specific gravities or sizes, which consists in subjecting the material to an upwardly flowing stream of water of such diameter relative to its velocity as to cause the heavier particles to move radially to the outside of the stream and the lighter particles to remain inwardly thereof, continuing such flow until the particles of a given grade have moved to the outside of the stream, then reducing the velocity of the stream, and continuously withdrawing such material and water uniformly around the stream.

3. The method of separating materials of different specific gravities or sizes, which consists in subjecting the material to a quiescently upwardly flowing stream of water of such diameter relative to its velocity as to cause the heavier particles to move radially to the outside of the stream and the lighter particles to remain inwardly thereof, continuing such flow until the particles of a given grade have moved to the outside of the stream, and quiescently and continuously withdrawing such material and water from the outside of the stream in the same volume and at the same velocity at all points around the stream.

4. The method of separating solid materials of different specific gravities or sizes, which consist in subjecting the same to an upwardly flowing stream of water of such diameter relative to its velocity as to cause the heavier particles to move radially to the outside of the stream, continuously withdrawing the material and water uniformly around the stream, and adjacent to such withdrawal introducing into the stream additional water to maintain the proper velocity above.

5. The method of separating solid materials of different specific gravities or sizes, which consists in subjecting the same to an upwardly flowing stream of water of such diameter relative to its velocity as to cause the heavier particles to move radially to the outside of the stream, then reducing the velocity of the stream and continuously withdrawing material and water uniformly around the stream, and adjacent to such withdrawal introducing into the stream additional water to maintain the proper velocity above.

6. The method of separating solid materials of different specific gravities or sizes, which consists in subjecting the same to a quiescently upwardly flowing stream of water of such diameter relative to its velocity as to cause the heavier particles to move radially to the outside of the stream, quiescently and continuously withdrawing material and water from the outside of the stream in the same volume and at the same velocity at all points around the stream, and adjacent to such withdrawal introducing into the stream additional water to maintain the proper velocity above.

7. The method of separating solid materials of different specific gravities or sizes, which consists in subjecting the same, in a closed system having a circumferential outlet, to an upwardly flowing stream of water having a velocity just sufficient to lift the heavier particles to such circumferential outlet, and of such diameter as to cause the heavier particles to move radially to the walls of the system and the lighter particles to remain inwardly therefrom, continuing such flow until the particles of a given grade have moved to the walls of the system, and simultaneously and continuously withdrawing such material and water through such circumferential outlet, uniformly around the stream.

8. The method of separating solid materials of different specific gravities or sizes, which consists in subjecting the same, in a closed system having a circumferential outlet, to an upwardly flowing stream of water having a velocity just sufficient to lift the heavier particles to such circumferential outlet, and of such diameter as to cause the heavier particles to move radially to the walls of the system and the lighter particles to remain inwardly therefrom, continuing such flow until the particles of a given grade have moved to the walls of the system, reducing the velocity of the stream at said circumferential outlet, and simultaneously and continuously withdrawing such material and water through such circumferential outlet, uniformly around the stream.

9. The method of separating solid materials of different specific gravities or sizes, which consists in subjecting the same, in a closed system having a circumferential outlet, to an upwardly flowing stream of water having a velocity just sufficient to lift the heavier particles to such circumferential outlet, and of such diameter as to cause the heavier particles to move radially to the walls of the system and the lighter particles to remain inwardly therefrom, continuing such flow until the particles of a given grade have moved to the walls of the system, simultaneously and continuously withdrawing such material and water through such circumferential outlet, uniformly around the stream, and adjacent to such circumferential outlet introducing additional water to maintain the proper velocity above.

10. The method of separating solid materials of different gravities or sizes, which consists in subjecting the same, in a closed system having a circumferential outlet, to an upwardly flowing stream of water of such velocity and diameter as to cause the heavier particles to move radially to the outside of the stream, simultaneously and continuously withdrawing material and water from the periphery of said stream, and adjacent to said withdrawal introducing circumferentially into the stream additional water to compensate for the water withdrawn and to maintain the proper velocity above.

11. The method of separating solid materials of different gravities or sizes, which consists in subjecting the same, in a closed system having a circumferential outlet, to an upwardly flowing stream of water having a velocity barely sufficient to lift the heavier particles to the outlet and such diameter as to cause the heavier particles to move radially to the outside of the stream, simultaneously and continuously withdrawing material and water from the periphery of said stream, and adjacent to said withdrawal introducing circumferentially into the stream additional water to compensate for the water withdrawn and to maintain the proper velocity thereabove.

In testimony whereof, I have hereunto set my hand.

MARTIN HOKANSON.

Witness:
ALICE A. TRILL.