The present invention is concerned with the hydraulic classification of solids. As such, it deals with a novel classification process by which a mixture of solids particles may be readily separated into fractions differing in average mass. The novel process of the present invention contemplates both true classification, based solely on size differentials, where the particulate material does not differ greatly in average specific gravity; and also the combination of classification and separation, where the particulate material to be treated contains solids differing, not only in particle size but differing also in average specific gravity.

Problems of classification of solids into size fractions, each of which contains only solids of a definite selected size range are encountered in many different types of industry. For example, such problems are encountered in size-grading and the preparation of foodstuffs for marketing, size-grading of intermediates and final products in chemical manufacturing and in mineral dressing arts, where particles of definite size range are preferable for certain operations, such as froth flotation and the like.

Two general processes are ordinarily used in solving such problems. The first is size-grading by treatment on suitable screens. For some purposes, this treatment cannot be bettered. On the other hand, screening is not wholly satisfactory where the material to be treated is principally in the small size ranges at which the initial cost and upkeep for suitable screens is prohibitive and where small and intermediate sizes require grading after washing, but without drying. In general, too, in the smaller size ranges, suitable screening installations do not have a particularly high capacity for the size of the installation involved.

The other common expedient is hydraulic classification, in which some form of fluid immersion is utilized. The differential settling rates of the different sizes in the fluid, usually exaggerated by an upward flow in the fluid of sufficient strength so that the finer sizes will just settle therethrough, is used to effect the size separation. It is with this latter type of operation with which the present invention is primarily concerned.

Various types of apparatus for hydraulic classifications are industrially available. However, none, in their method of operation, are completely satisfactory for all purposes. Some are capable, for example, of effecting satisfactory classification only under limited conditions. Others, while capable of making effective size separation, have a low capacity for the size of the installation. Others suffer from a defect which is essentially a result of the same phenomenon. The time of treatment required in handling smaller sizes requires an extremely large space for the installation.

It is, therefore, the principal purpose of the present invention to devise a method of hydraulic classification which is suitable for use with widely differing solids. It should be capable of handling solids which require careful handling to prevent damage thereto. It should be capable of handling solids varying over wide size ranges. It should be capable of effecting the separation by size within rather narrow limits. It should not require apparatus which is difficult or complicated in operation or construction.

In general, these objects have been accomplished in the use of a simple handling method. By the use of this method, in which a spirally-flowing fluid is used to direct the desired size ranges into differing discharge and collection means, a number of advantages are obtained. The actual handling is gentle, so that fragile or easily-broken materials may be readily handled. The use of definite directing forces inures a rapid and certain separation. The use of definite directing forces permits the handling of a tremendous volume of solids in an installation of relatively small size, as compared with commercial units now available for the purpose.

In general, the operational steps of the present invention are simple. A suitable fluid, for true classification without density separation, usually water as the most readily-available liquid of approximately unitary density, is caused to flow spirally around and downwardly within a confined space. The fluid is introduced at an upper level of the confined space, usually tangentially, under flow conditions which will impart to the fluid an angular veocity sufficient to form an open, downwardly-extending free vortex, the lower end of which is directed into some central but lower discharge opening. If so desired, a plurality of successively lower concentric discharge openings may be employed. The final fraction is separately discharged from the lowest levels in the confined space.

Material to be classified is immersed in the fluid at a level at or near the upper outer surface of the free vortex. As a result of the centrifugal and centripetal forces exerted by the spirally-flowing fluid, particles of greater mass move to the outside of the confined space and the particles of smaller mass tend to accumulate at or near the face of the central vortex. The solids in process of classification in accordance with their respective masses are carried around and down through the confined space. The fraction of the solids of smaller mass is carried through the central opening with the liquid forming the vortex face and its immediately concentric volume. The remaining material is carried to lower levels and discharged therefrom.

The classifying effect is exaggerated to some extent by the fact that at any one zone, both radially and vertically, there will be particles of the correct mass to remain in that zone or of sufficiently larger mass to be passing therethrough. This accumulation of differing mass particles in different zones slows down the passage of particles of larger mass therethrough and increases the tendency of materials of the correct mass to accumulate in their correct zone.

Because of the simplicity of the operational steps of the present invention, they may be carried out in any of a wide variety of apparatus combinations. In my copending applications for United States Letters Patents, Serial Nos. 241,721 and 241,722, filed of even date, a number of different types of apparatus suitable for the purposes of the present invention have been described and claimed. To assist in the discussion of the operation of the present invention, several illustrative forms of apparatus have been set forth in the accompanying drawings in which:

Fig. 1 is an elevation, partly in section, showing an apparatus which is well suited for the practice of the present process; and

Fig. 2 is another modification of a suitable apparatus.

This is also shown in elevation and partly in section. Since these figures will aid in a discussion of the practice of the process, they will be used illustratively for that purpose.

As seen in Fig. 1, a suitable open space is confined by a vertical tubular shell 1 closed by a bowl-shaped bottom
2. In the side wall of tube 1 is a tangential port 3 to which is attached a conduit 4 for the introduction of classifying liquid into the confined space. At the bottom center of the shell is a collar 5, surrounding an open center 6. Milled in the open center 6 and supported by collar 5 is a central discharge cylinder 7, which extends from an intermediate level within the vessel down through opening 6 to some designated delivery point, which forms no part of the present invention.

Concentrically located within cylinder 7 is a third tubular element 8, extending from a level higher than the upper end of conduit 7, down through conduit 7, to some level usually below the bottom 2, at which level it is turned out through the side of conduit 7. It, too, passes to some convenient delivery point.

Below the upper end of conduit 7 and at a point near the bottom of the vessel is an open port 9, through which material may be discharged into conduit 10 and a suitable elbow 11. Elbow 11 is normally turned upward and connected to a riser 12 which carries up to a suitable discharge launder 13, from which the material may be delivered to any suitable designated treatment, illustratively the screen 14 in Fig. 1, upon which the solids may be drained, if so desired. Elbow 11 is equipped with a downward extending flange 15 through which a smaller conduit 16 is connected and passes into the interior of the elbow. Solid material to be classified may be delivered through the open top of the tubular element 1, through a suitable solids feed chute 17.

It is believed that the operation of the process in a vessel such as that of Fig. 1 is apparent from the description. Classifying liquid is introduced through conduit 4 and port 3 into the confined space within the tubular shell 1. It is introduced under sufficient force to form under its own tangential velocity a free vortex of the approximate profile shown by the dotted line 18. This vortex forms from the side wall of the tubular element 1 at some level above port 3, inwardly and downwardly to the top of conduit 8, down which it normally will pass.

Conduit 8 is of sufficient diameter so that an appreciable volume of the fluid, together with any solids carried with it, will pass down into conduit 8. This flow will pass down through conduit 8 and out of the vessel. The remaining fluid flow, however, will continue on down through the confined space. An additional fraction of this flow is discharged through the top of conduit 7, passing down through conduit 7 and out of the vessel. The remainder of the fluid will pass to the bottom of the vessel and out through port 9, conduit 10, elbow 11 and riser 12. Air introduced through conduit 16 makes an air lift of elbow 11-riser 12 combination suitable for raising the fluid and solids to a desired delivery height into the launder 13.

When solids are delivered through chute 17 onto the surface of the free vortex 18, the smaller size particles of less mass tend to concentrate at or near the surface of the vortex and are carried down into conduit 8. Slightly larger particles tend to accumulate at a deeper zone and are carried into the open top of conduit 7. The remainder of the fluid, together with the particles of greatest size and mass are carried to the bottom of the vessel, out through port 9 into conduit 10.

One modification should be noted. It may be desired from time to time, in different operations, to introduce increased or decreased amounts of fluid into the central conduit or into the intermediate conduit without appreciably altering the total volume of liquid supplied through conduit 4. This can be accomplished by adjusting the opening into conduit 8. As shown in Figure 1, an increase is obtained by flaring the top of the conduit outwardly and upwardly.

Another type of vessel is shown in Fig. 2. Here, a suitable tubular closed shell is provided by a conical frustrum 19, the upper and wider diameter of which is unitarily attached to a cylindrical segment 20. The top of the vessel is closed by a cover plate 21 and the bottom by cover plate 22. Cover plate 21 is a large, concentric opening 23 in which is mounted an open-ended, cylindrical element 24, extending both above and below the cover plate for an appreciable distance. Cover plate 21 is also pierced by a suitable opening 25 which contains the lower end of a suitable feed chute 26. Side wall of cylindrical element 28, at a level higher than the bottom end of cylinder 24, is pierced by a suitable port 27, about which is connected a conduit 28.

Cover plate 22 has a central opening 29 in which is mounted a central discharge conduit 30, extending from a level within the confined space down to some suitable delivery point, the exact nature of which forms no part of the present invention.

The lower part of the vessel is pierced by an additional port 31, connected to a suitable conduit 32, for the discharge from the lower levels. As shown in Fig. 2, conduit 32 is a return-bend pipe for directing fluid flow in the discharge conduit to a vertical direction. Conduit 32 is connected to a suitable flexible hose 33 which is given a return bend 34 and discharges through open end 35 to some suitable discharge receiver, which forms no part of the present invention.

The operation of the process in an apparatus such as that shown in Fig. 2 is also believed to be apparent from the description. Classifying fluid is introduced through conduit 25 and port 27 into the annular space between the lower end of the cylindrical element 24 and the inner wall of the confining shell 20. This fluid flows down and around the annular space to a level at the bottom of the cylindrical element 24. At this level, the confining effect of the baffle or cylindrical element 24 is released and, as a result, fluid climbs up within the space inside cylindrical element 24 to some height, depending upon the inherent angular velocity of the entering fluid. A free vortex will form from the side wall of cylinder 24, downwardly into the open upper end of conduit 30, assuming some profile such as that shown by dotted line 36.

Particles of less mass will thereby be swept down into conduit 30, whereas the remaining fluid and particles of larger mass will be carried on down outside conduit 30 and out through port 31. Due to the hydrostatic head within the vessel and the circular flow, conduit 32 and flexible hose 33 act as an inverted siphon and thereby raise the flow. Raising or lowering the discharge end of the hose 33 will act as a regulator for increasing or decreasing the rate of discharge through port 31.

As noted above, it may be desirable from time to time to alter the volume of fluid taken into the central discharge conduit. In Fig. 1, this is done by giving conduit 8 an outward-flaring top 37. In Fig. 2, this is done in the reverse direction by constraining the top of the conduit at 38. It is also desirable from time to time to vary this volume of flow through the central discharge conduit by altering the height to which the central discharge conduit, or conduits, extend up into the confined space. One modification, and probably that most suitable for the purpose, is shown in Fig. 2. Therein, conduit 30 is shown as being surmounted by a plurality of detachable rings 39, 40, and 41. These rings may be varied in number and height, to accomplish the desired height regulation. The rings should be flanged in a manner, as for example, the mating flanged flanges shown at 42 for joining of rings 40 and 41. The upper end of conduit 30 proper should be machine in a similar way. As noted above, the top of the upper ring 41 may be given any constriction or flare desired to permit changing the effective area of the opening into the conduit.

Solids entering through chute 26 and port 25, as a result of the centrifugal and centripetal forces exerted on them, are classified into fluid flow zones, each of which will contain particles of predominantly uniform mass,
mass particles through the discharge conduit at or near the bottom of the vessel. In Fig. 2, only one central discharge conduit has been shown. It is believed to be obvious, however, that the number of central conduits can be altered as desired.

From time to time, adjustment in the flow may be required to proportion the fractions into those having the desired size ranges. This may be accomplished in several ways. The principal control occurs in proportioning the amount of fluid flow between the central discharge conduit or conduits and the lower discharge conduit. Perhaps the most readily accomplished method of bringing this into adjustment is to start the process and then examine the fraction carried down to the lower levels and out of the vessel. If this fraction contains the higher mass particles in too low a proportion, it is an indication that insufficient fluid flow out through the bottom port is occurring. This flow may be increased in any of several ways. For example, in the modification using an air lift the amount of air used may be increased. Using an inverted siphon, the discharge level of the siphon may be lowered. Similar results may be obtained by raising the level of the intake into the central discharge conduit or conduits or by decreasing the effective opening thereinto. A further adjustment may be effected by varying the incoming separatory fluid volume rate. The converse of these adjustments is obvious.

Once the desired solids content of the lower discharge flow is established, the volume of flow through the apparatus is adjusted to insure the remaining sizes being carried into and out through the central discharge conduit or conduits. Where a plurality of such conduits are used, they may be independently adjusted both in height and effective intake opening. Once operating equilibrium is established, the process will continue to run almost indefinitely without added supervision. It is sufficiently flexible in operation so that any but extreme variations in the operating conditions will average out in the course of an extended run.

The effectiveness of the separatory procedure is shown by the following example, which is illustrative only and not by way of limitation. Since the finer sizes of material are the more difficult to classify, effectively and speedily, a fine size solids test is taken as illustrative.

EXAMPLE

In a suitable sump, raw coal of minus 10 mesh top size and water at the rate of 1½ gallons of water per pound of coal is slurried. Slurry is pumped to a vessel generally corresponding to the type shown in Fig. 2 in the foregoing discussion. The product discharged from the central discharge conduit is referred to as fine, and that from the lower outlet designated as coarse. Samples were taken of these flows and screen analyses thereon are given in the following table. The weight percent of the solids in the fine fraction was 3.4 and that of the coarse was 23.8.

<table>
<thead>
<tr>
<th>Mesh</th>
<th>Course Product Feed</th>
<th>Fine Product Feed</th>
<th>Whole-Percent Weight Composite Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>10+20</td>
<td>60.48</td>
<td>54.35</td>
<td>6.40</td>
</tr>
<tr>
<td>60+100</td>
<td>27.94</td>
<td>55.28</td>
<td>6.40</td>
</tr>
<tr>
<td>100</td>
<td>6.99</td>
<td>106.23</td>
<td>4.58</td>
</tr>
<tr>
<td>Total</td>
<td>100.00</td>
<td>90.48</td>
<td>9.52</td>
</tr>
</tbody>
</table>

One additional feature of the present invention should be noted. In United States Letters Patent No. 2,429,436, entitled "Combined Gravity Classification and Screening of Ores," issued October 21, 1947, to G.B. Walker, there is shown a combination classification and separation method. The process of that patent shows that a combination of classification and screening can be used to effect density separation of mixed solid particles. Particles of the same mass, regardless of size, tend to accumulate in the same zone in a classifier. Thus, large solids of low density will accumulate together with smaller solids of higher density in the same zone. The size differential of materials of the different densities accumulating in the same zone may be exaggerated by increasing the density of the classifying liquid. Using a classifying liquid of density greater than unity, it is perfectly feasible to separate fractions of the same mass in which the low density particles are sufficiently larger than the high density particles, so that a subsequent simple screening of any such classified solids fraction discharged from a classifier results not only in classifying both the low density and high density solids, but separates them into fractions according to density. The classification process of the present invention is particularly well adapted for use in this process. This is because of its tremendous treating capacity for its relatively small size. For example, with an open top vessel of the type generally corresponding to that of Fig. 1, having a diameter of 2-4 feet and a height of from about 4-6 feet, feed rates of up to 150 tons or more per hour of solids may be handled.

A further important application of this invention is in a combined separation-classification system in which a density separation is first made. This density separation may be accomplished in any of several known devices. For instance, it may be conducted in a cyclonic type separator, or in a separatory cone of standard design such as employed in the separation-classification system of United States Letters Patent No. 2,307,966 to G.B. Walker. Other very desirable methods and devices for effecting density separation are disclosed in applicant's copending applications for United States Letters Patent Serial Nos. 214,721 and 214,722. In any method of separation, however, in which an unsized feed is treated, it is desirable to classify by size the light and heavy density fractions obtained. This is accomplished, for example, in United States Letters Patent 2,307,966 mentioned above, by subjecting each density fraction to a screening treatment. Substitution of the present invention may be made for the screening described, or for any other classifying method, with thorough classification at high capacity.

I claim:

A method of classifying particulate solids of substantially the same specific gravity into size fractions, each...
of which contains only solids of a definite selected size range, which comprises: continuously introducing a classifying fluid of density less than that of the solids to be treated into a horizontally confined space and causing said fluid to flow spirally downward therein, the fluid volume flow and the angular velocity imparted thereto being such as to form a free vortex opening and extending downward from a level within said space substantially above the level of fluid introduction; discharging a central flow including the open vortex face downwardly and out of the confined space at a level substantially above the lower extremity thereof; causing the remaining confined fluid to continue to flow spirally down within the confined space; discharging said remaining confined fluid at a level below said vortex discharge; feeding solids of substantially the same specific gravity to be classified into the confined moving fluid at a level above the level of vortex discharge so that all the solids are initially adjacent the vortex face of said spirally flowing fluid; and adjusting the volume of fluid dis.

charged from the lower level and the total flow of fluid into the confined space so as to remove with the lower fluid discharge a solid fraction comprising particles of a predetermined average size and with the vortex discharge a second solid fraction of a predetermined and smaller average size; said adjustments being such as to maintain the free vortex.

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