June 20, 1939. H. L. McNEILL 2,163,285

CLASSIFICATION

Filed July 9, 1937 5 Sheets-Sheet 1

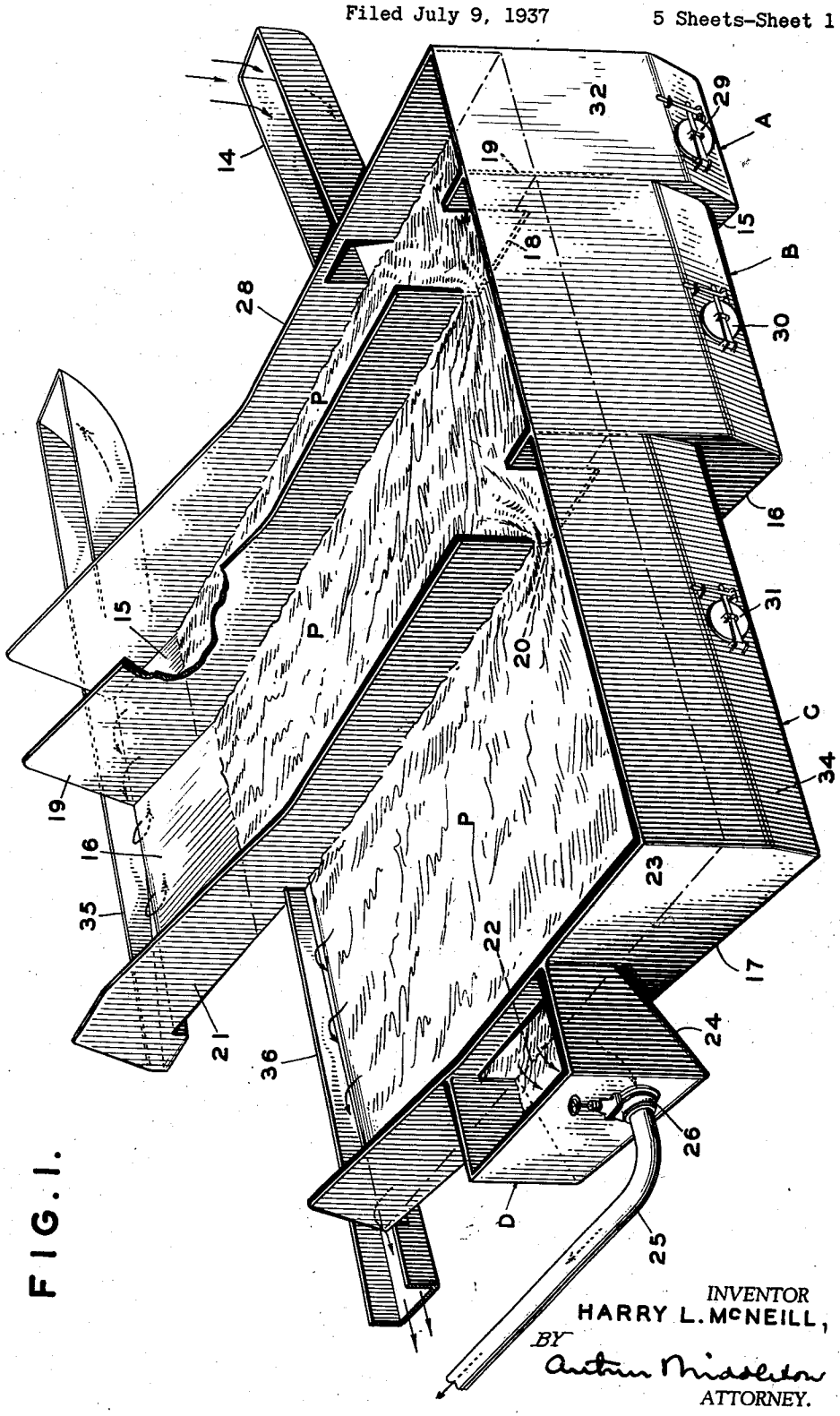


FIG. 1.

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CLASSIFICATION

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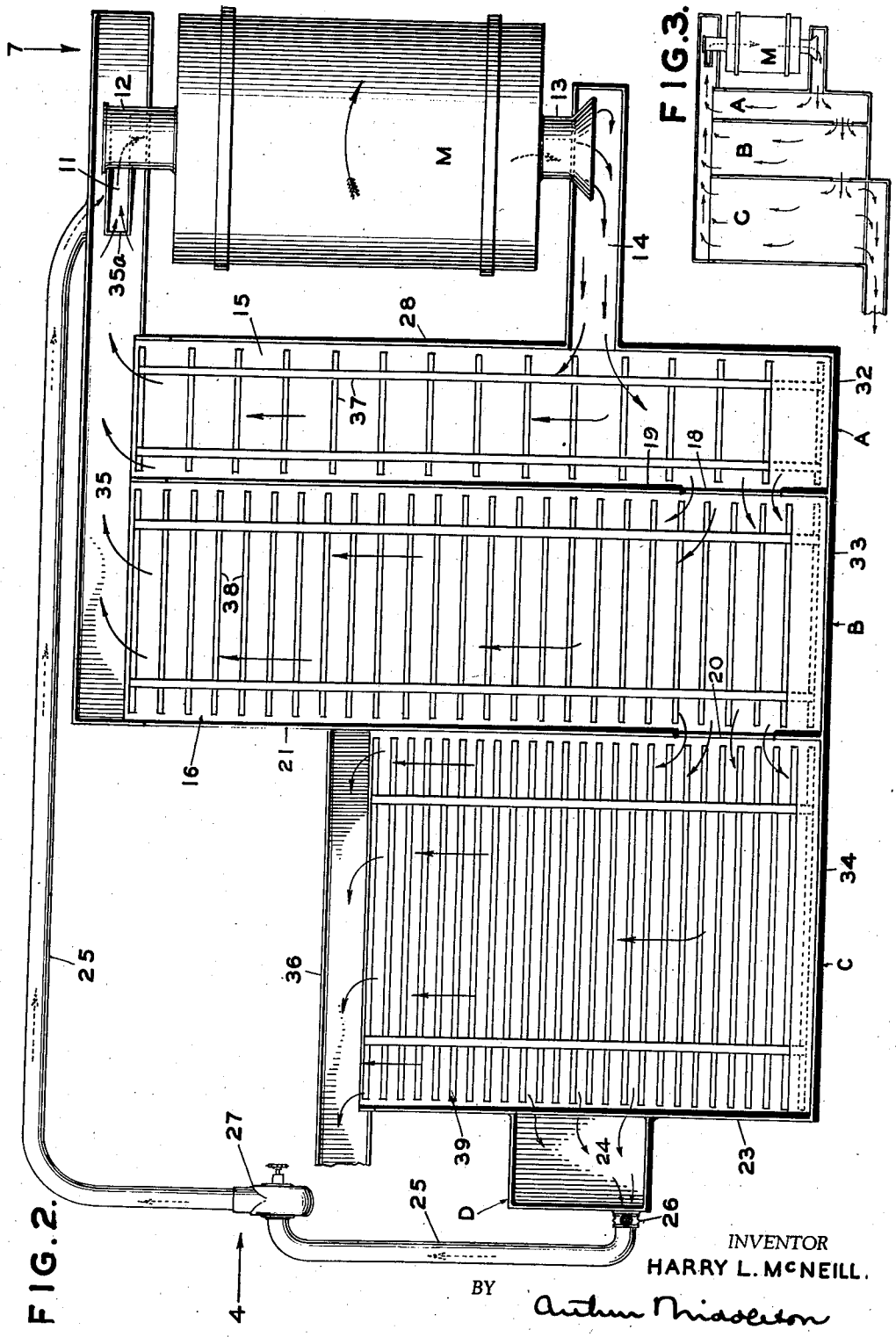


FIG. 2.

FIG. 3.

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CLASSIFICATION

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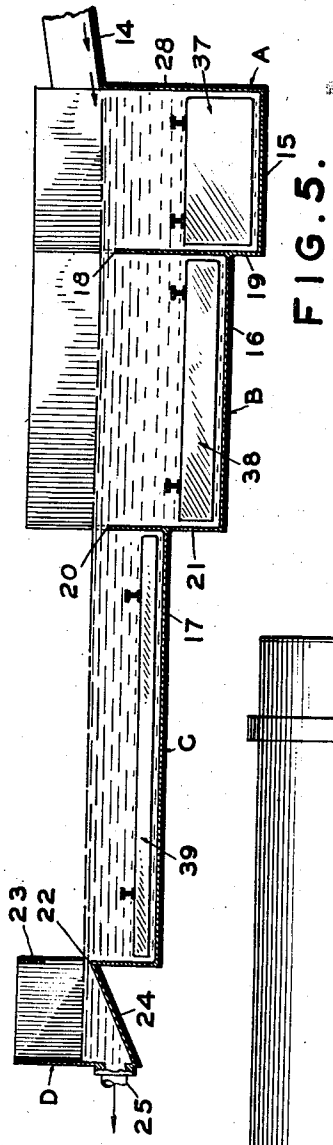


FIG. 5.

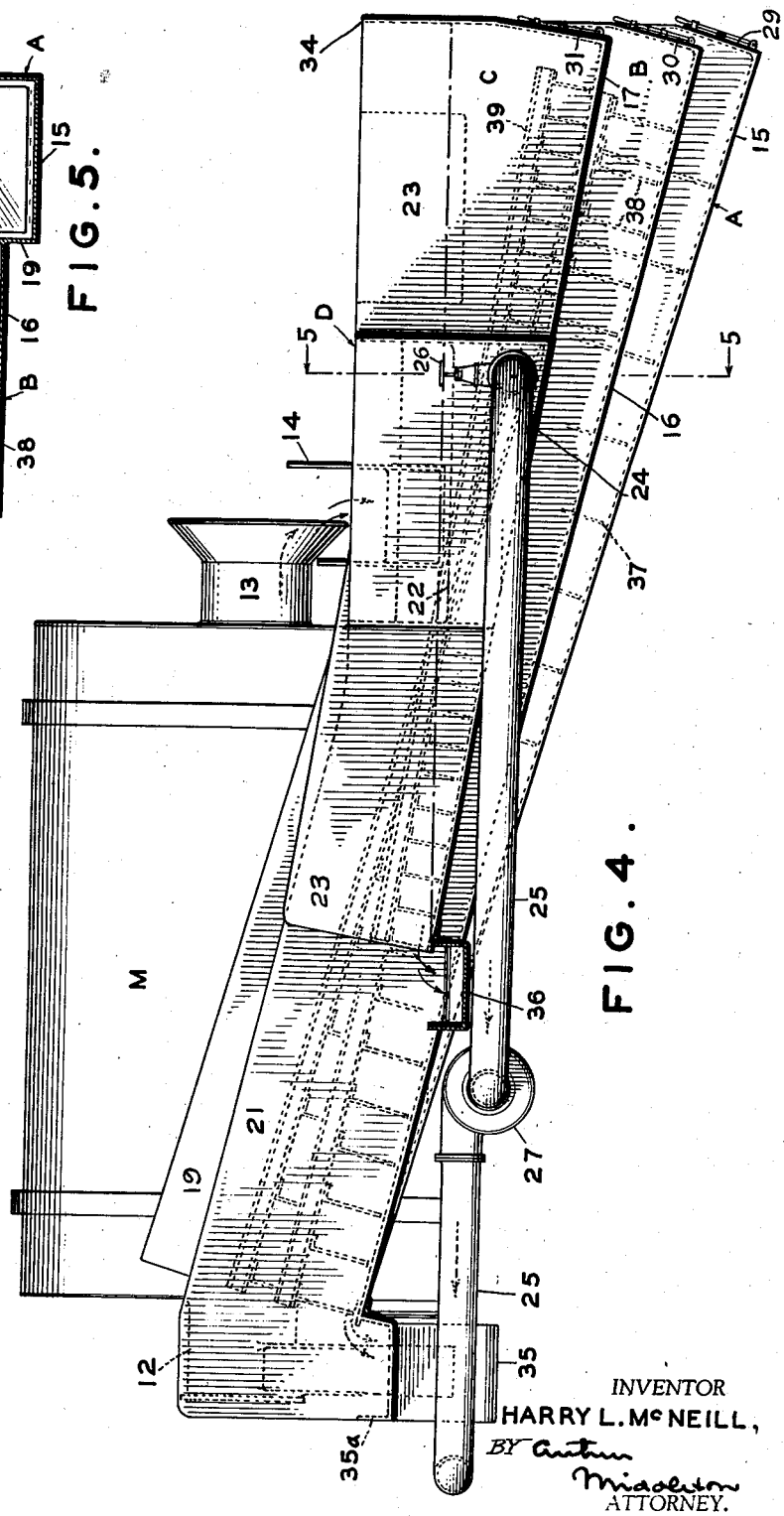


FIG. 4.

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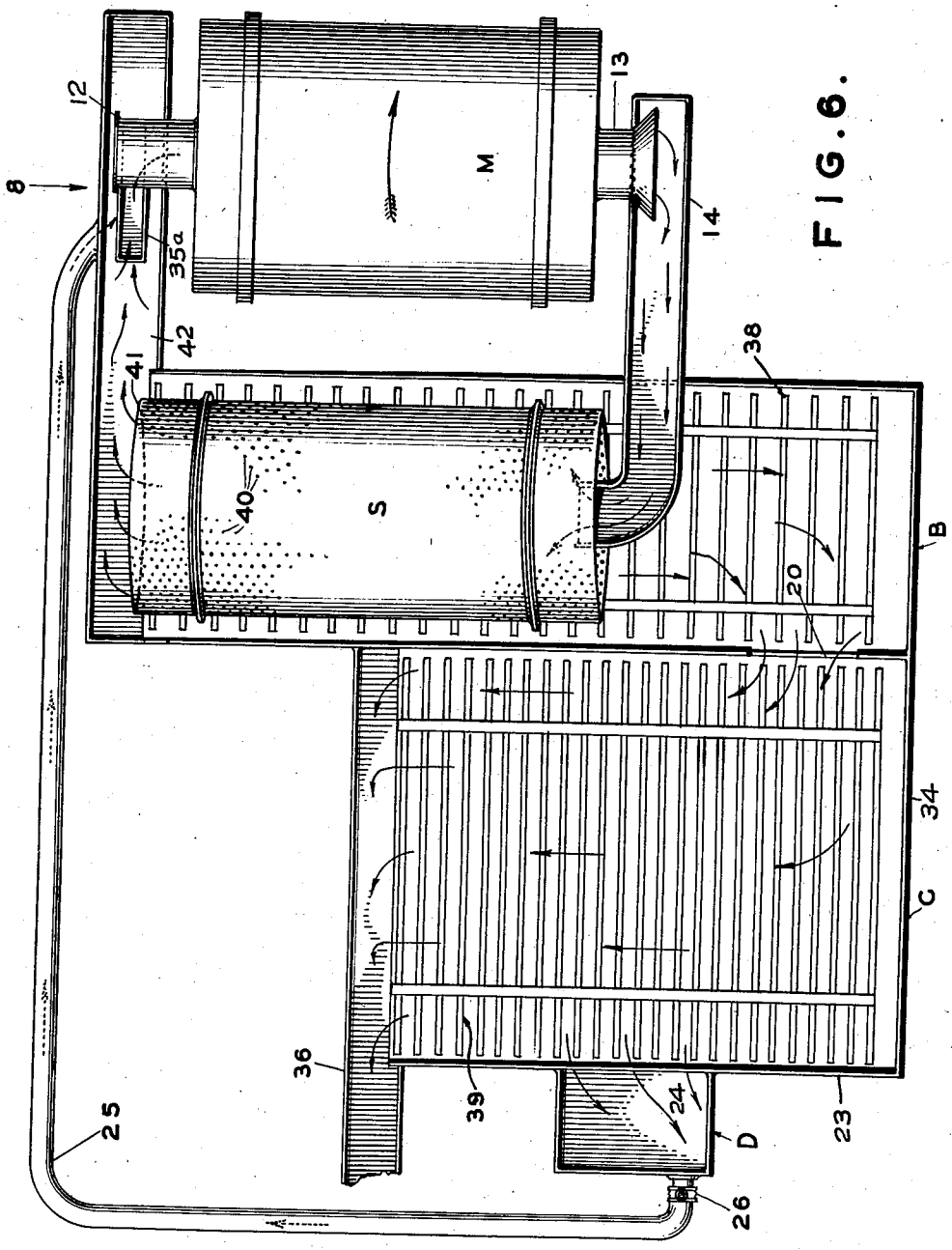


FIG. 6.

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CLASSIFICATION

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FIG. 7.

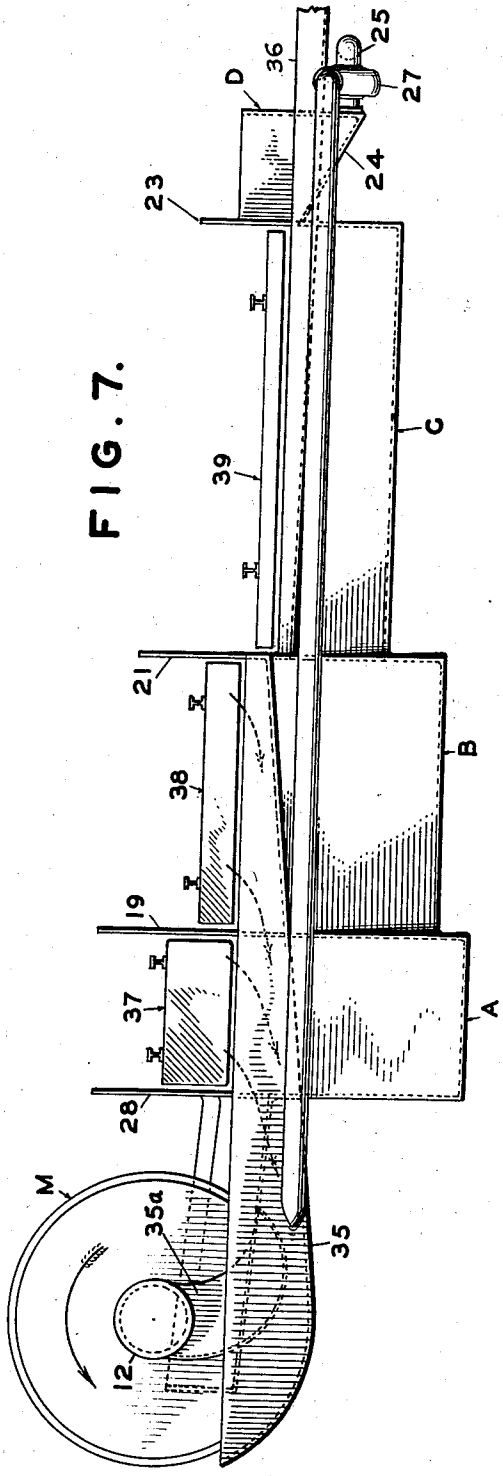
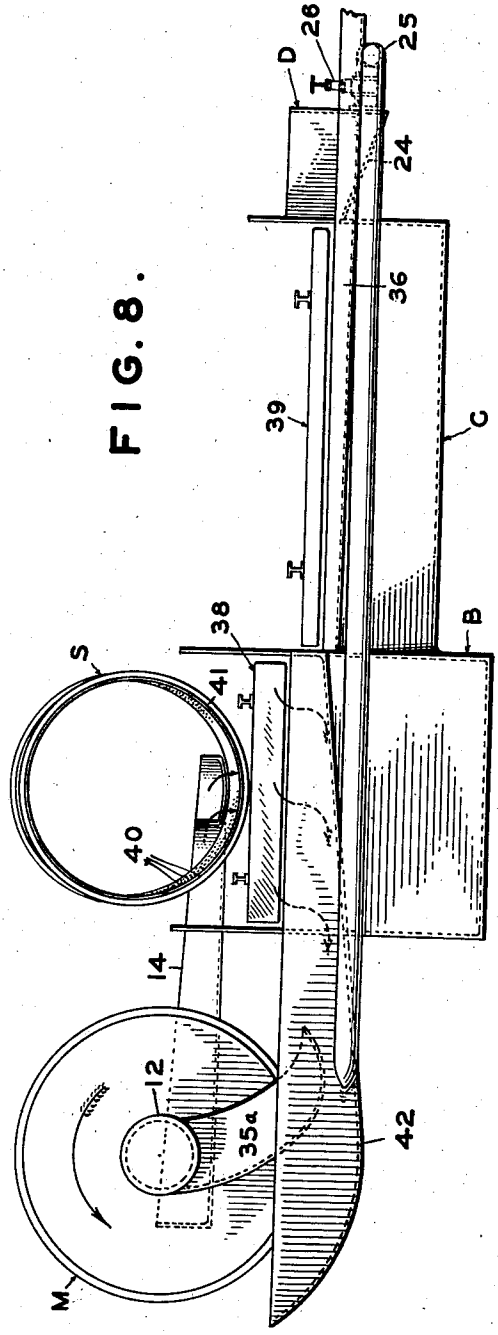


FIG. 8.



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UNITED STATES PATENT OFFICE

2,163,285

CLASSIFICATION

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Application July 9, 1937, Serial No. 152,737

8 Claims. (Cl. 209—462)

This invention relates to improvements in grinding, such as is carried out in the metallurgical and cement industries and the like, wherein are used mills provided with balls or rods as the grinding elements. Such mills are frequently used in what is called "closed circuit grinding". In such a circuit the discharge from the grinding mill is supplied to a classifier. The overflow from the classifier of solids in suspension go to further treatment, while the coarser solids emerged from the classifier bath, are returned to the mill for re-grinding.

It has been evident lately that a new process of classification was necessary to handle adequately the volume of recirculating solids in the closed-circuit system.

Any pulp to be classified, such as a grinding-mill discharge, is composed of coarse particles; critical sizes (namely, the size at which the separation is to be made); fine particles; slime, and water, or some liquid. In contemporary classification, the critical sizes, fine particles, and slime, are separated out from the presence of the particles of larger than the critical sizes, which larger particles are called "coarse" or "sands".

One object of the present invention is to provide for the removal from the mill discharge of the major portion of the coarse particles before classifying for the critical and smaller sizes of particles.

The invention may be said to be founded on the proposal of using, for instance, in closed circuit with a grinding mill, a plurality of classifiers or classifying compartments, hydraulically-communicating to contain a common liquid bath, each forming a zone of separate treatment, wherein, in the combined machine, step-wise selectivity can be effected by rejecting from each zone emerged coarser solids while passing from one zone to a subsequent adjacent zone finer solids in suspension. The overflow from the final compartment with fine solids or slime in suspension, goes to further treatment. Separated or raked coarser solids are returned to the mill for re-grinding.

Another feature is the use of raking devices in the classifier zones, with the speed and/or raking capacity being different from that in the next adjacent zone, whereby there is permitted adjustment, without mechanical modification, of the various classifying elements to the optimum condition for obtaining therefrom solids sized to the particular critical mesh desired, over a wide range. The coarse sizes really require no delicate separation at all and so are removed rapidly from the classifier bath or pulp.

This invention further may be definitely considered as an improvement over the disclosures of the patent applications of Weinig, Serial No. 604,151, filed April 9, 1932; Serial No. 74,833, filed April 17, 1936, and Serial No. 129,197, filed March 5, 1937.

The inventions of those patents are based upon the discovery that the degree of grinding in the mill can be controlled so that a minimum of undersized particles is produced—and therefore the expenditure of needless energy by preventing the too-fine grinding of certain particles. This control can be exercised by supplying to the mill, and having present therein during grinding, material that is suspensoidal as defined in the copending application of Arthur J. Weinig, No. 604,151.

The effect of this presence of suspensoidal and/or colloidal material in the mill is that it envelopes or enamels the balls of the mill with a coating or film having adhesive properties to an extent that ore particles to be ground adhere to the balls so that when a plurality of balls is thrown together, they are so plastered with ore particles sticking to the slime that a metal to metal contact of the balls is practically impossible without the reduction of the intervening grains.

Such suspensoidal and/or colloidal material must be continually supplied to the ball mill in a certain proportion to the mill feed of ore, and this entails a ready source of supply of the material. The Weinig inventions teach how the material may be obtained from the grinding-mill discharge by classification to select out ultimately what is called the favorable fraction of slime. The favorable fraction is the suspensoidal and/or colloidal material that is fed to the mill with the mill feed and that produces the beneficial results in increasing grinding-mill efficiency.

Weinig recovers his favorable fraction by first classifying the mill discharge and then passing fines and slime overflowed from the primary classifier to a secondary classifier arranged to be highly selective as to its ability to overflow only suspensoidal and quasi-colloidal particles.

So an object of this invention is to improve the method and arrangement for deriving and obtaining the favorable fraction from the mill discharge over that which Weinig used. This invention, therefore, revolves about stage classification, which although useful specifically to carry out this object, is also useful for more general classification practices.

For attaining this object, the invention may be said to be founded on the proposal of using, for instance, in closed circuit with a grinding ball mill, a plurality of classifiers or classifying compartments hydraulically communicating to contain a common liquid bath, each forming a zone of separate treatment therein, wherein step-wise selectivity can be effected, by rejecting from each zone emerged coarser solids while passing from one zone to a subsequent adjacent zone finer solids in suspension. And overflowing over a submerged weir from the final zone, is a supply of the thus selected-out favorable fraction—that is drawn upon under controlled conditions for active use. From the final zone, the awash raked product goes to subsequent treatment.

Other objects and features of advantage will appear from the following description of preferred but illustrative embodiments of my invention. These embodiments are illustrated in the accompanying drawings, in which:

Fig. 1 is a perspective view of my multi-stage classifier, from which has been omitted the classifier raking elements and the associated grinding mill;

Fig. 2 is a diagrammatic view of my multi-stage classifier in an ordinary closed circuit with the grinding mill;

Fig. 3 is a plan view, although partly diagrammatic, of a species of my stage classifier structure in closed circuit with the grinding mill;

Fig. 4 is an end elevation looking in the direction of the arrow **4** in Fig. 2;

Fig. 5 is a transverse vertical sectional view taken along the line **5—5** in Fig. 4;

Fig. 6 is a view similar to Fig. 2, but of a modified classification arrangement;

Fig. 7 is a view in elevation looking in the direction of the arrow **7** in Fig. 2; while

Fig. 8 is a similar view looking in the direction of the arrow **8**, in Fig. 6.

The manner in which this invention may be carried out in ordinary closed-circuit grinding, is to provide, in circuit with the grinding mill M, a classification stage comprising a basin for maintaining therein a common pool of pulp or material being treated, and provided with hydraulically-communicating compartments A, B and C, wherein step-wise classification treatment is effected. Means are provided for emerging from each compartment solids settling therein, and also for effecting different degrees of classifying agitation in one or more of the compartments with the intensity of agitation decreasing after the first, or A. An overflow of liquid, having the finer solids in suspension therein, is provided from the final compartment, or C, which goes to further treatment; while means are provided for conducting back to the mill the coarser solids rejected to emergence by the classifier compartments. The structural details of the classifier compartments A, B and C will be described later. This paragraph is designed to read upon the showing of Fig. 2.

In Fig. 3 the arrangement differs from that of Fig. 2 by having solids from all compartments A, B, C, raked to emergence and jointly go back to the mill M for re-grinding as a matter of closed circuit grinding practice. As shown this embodiment involves overflowing all the suspended fine solids from the last compartment bath.

The showing of Figs. 1, 3, 4, 5 and 7 will now be described with greater particularity:

New feed **11** is passed to the grinding mill M, through trunnion **12**. Mill discharge passes out through the trunnion **13** into a launder **14**, and is therefore supplied to the primary classification zone A, that forms a part of the multi-stage classification assembly, to which this invention is directed.

Referring now to Fig. 1, the multi-stage assembly comprises a plurality of classifier compartments, such as A and B, each having an inclined deck **15** and **16** respectively, and which decks are adapted to be partially submerged by a common bath of pulp P. A third and rake operated compartment C is shown to extend parallel and alongside of the classifier compartment B and has hydraulic communication therewith. In distinction from and as compared with the compartments A and B, compartment C has its rake discharge end of the sloping bottom or deck foreshortened approximately to the point of liquid level so that it is awash to permit discharge of a fraction of suspended solids to take place in a manner to be more clearly described. The compartments A and B are in hydraulic communication such as by a submerged weir **18** located in a divisional wall **19** that separates that portion of the bath in the two compartments into separate zones of classification treatment. Similarly, there is a submerged weir **20** between compartments B and C located in divisional wall **21** that divides compartment B and C into separate zones of classifying action, although hydraulically communicating. The number of these compartments is not necessarily limited to 3, since two can be used under circumstances where that is enough; or more can be used, if desired. Extending off from the final classifying compartment C is an extended or extension zone D, separated from the final zone C, by another submerged weir **22** in the end wall **23** of the final classification zone. This is a box-like arrangement, preferably having an inclined bottom **24**, inclined away from the classifier C. The zone D is located preferably about mid-length of the bath P in the final classifier zone C. In the zone D the favorable fraction accumulates and is drawn therefrom through a pipe or other connection **25**, under controlled conditions, through the medium of the valve **26**, and/or the measuring pump **27**. The pipe **25** is for use in returning the favorable fraction back to the feed end of the ball mill M. **28** represents the front end wall of the primary classifier A. **29**, **30** and **31** represent, respectively, drain-out valves in the front walls **32**, **33** and **34**, respectively, of classifier compartments A, B and C.

In order to return to the ball mill coarser solids emerged from classifier zones A and B, over their inclined decks **15** and **16**, respectively, there is provided a launder **35**, with which may be associated the usual scoop **35***a* for elevating the material in the launder up to the intake trunnion **12** of the ball mill. In order to convey emerged solids from the final classification zone C to further treatment, there is provided a launder **36**, preferably passing the material therein in a direction opposite to that flowing along the launder **35**.

According to the structure shown in Figs. 1 and 2, the compartment C is designed so as to make a separation of the fine suspension or slimes therein into the aforementioned favorable fraction for re-use in the mill and a slightly coarser although suspended fraction and which may be termed the unfavorable fraction of the slimes, because its

presence is not desired in the mill. Due to the relative foreshortening of the rake discharge end of the deck of compartment C so that it is awash, there is realizable a cascading discharge of suspended unfavorable slimes or solids fraction over the edge of the deck. In view of the fact that two suspended fractions are caused to leave the compartment C, it can be said that the type of separation effected in that compartment differs in character from that which takes place in the preceding classifying steps as performed in compartments A and B where solids are brought to emergence. In other words, compartment C by comparison can be said to function in the way of a hydro-separator and consequently embodiments to realize an operative structure for this purpose are not of necessity restricted to the form of the reciprocating classifier mechanism shown, but other separation aiding mechanism, such as an endless mechanism may be used, or else any suitable device to effect the desired type of hydro-separation may take the place of compartment C herein shown.

A classifier conveying or raking mechanism **37** is provided in classifying compartment A. Apparatus **38** for the same purpose is provided in compartment B, while apparatus **39** for the same purpose is provided in compartment C. These can be typical known raking mechanism of the Dorr reciprocating rake type, or they can be of other types as hereinafter described. In Fig. 7, and also in Fig. 1, it is to be noted that primary compartment A is deeper and narrower than compartment B; while compartment B is deeper and narrower than compartment C; and so on, for the purpose of attaining different classification effects in the different compartments.

Since one object of my stage classification is to remove from the mill discharge the coarse sizes (since they really require no delicate separation), it is possible to use an arrangement revised over that shown in Figs. 1, 3, 4, 5 and 7, and revised as shown in Figs. 6 and 8, wherein the mill discharge passing through the trunnion **13** and launder **14** is supplied to a rotatable trommel screen S of known construction, preferably located over and above the classifier compartment B. The screen is adapted for the passing through the perforations **40** therein of the critical and smaller sizes of solids in the mill discharge, to be received by the classification compartment B, underneath the screen S, to which they pass by gravity. The coarser or larger-sized solids rejected from passing through the apertures **40**, flow out from the lower end **41** of the screen, preferably into a gathering hopper **42**, from whence they are returned to the mill through the feed trunnion **12** thereof, either by a suitable launder, or by some elevating equipment **35***a* that is usual in such cases.

In carrying out the invention of Figs. 1, 3, 4, 5 and 7, which, as has been stated, is an improvement on the said Weinig inventions, for providing in the mill of a closed circuit grinding system, a favorable fraction of slime for the purpose of reducing the number of smaller than critical sized particles produced in the grinding operation, the feed of new ore **11**, or other material to be ground, is fed to the ball mill M, from whence it emerges through trunnion **13** and flows through launder **14**, into my multi-stage classification assembly. Here the pulp discharged from the mill is subjected to step-wise classification treatment in hydraulically connected zones, so arranged, however, that while hydraulically connected, different classification treatment can be given to the material in each zone. In zone A a treatment is given the pulp for the purpose of getting the coarse solids removed therefrom as rapidly as possible. To that end, the inclined deck **15** of the classifier A is given a steep slope and the compartment is made relatively narrow; also the classifying rakes **37** have a rather rapid motion, because no attention needs to be paid to any other classification requirement than to get out quickly the coarse or over-size solids. These are emerged from submergence by being raked up the inclined partially-submerged deck **15**, from whence they pass into the launder **35** and are therein conducted back to the ball mill M, through the medium of the scoop **35***a* and the intake trunnion **12**.

In the zone A there is intense agitation due to the object of getting out the coarse solids quickly. This agitation keeps well stirred into suspension all of the solids that are not large enough to settle under the distributed conditions in the bath in the zone A. These solids in suspension are impelled by the agitation in zone A and the hydraulic head provided by the mill discharge coming into the zone A through the launder **14**, to flow over the submerged weir **18** into the compartment B.

In the zone B with its lesser inclination of its deck **16**, and with a corresponding increase in width and decrease in intensity of agitation produced by wider and shallower raking blades **38**, in comparison to those—**37**—in compartment A, certain solids will settle in compartment B, sized in a group smaller than those which settled in compartment A, because of the greater intensity of agitation in compartment A. The settled solids, although smaller than those settled in compartment A, are still above the critical size desired, so they are raked to emergence along deck **16** and pass into launder **35**, from whence they are conveyed back to and into the ball mill M, for re-grinding. Those smaller solids which do not settle in compartment B, due to the degree of agitation in the bath in that compartment, overflow the submerged weir **20** into compartment C. Here agitation maintained in the bath is much less than that maintained in compartment B, because the inclined deck **17** has less slope, the compartment C is wider, and the speed of the classifying rakes **39** is much less than the correspondences in compartment B.

As has been indicated above, no emerged product comes from this last compartment, inasmuch as the suspended fraction of fine solids or unfavorable slimes passes therefrom in suspension substantially at the liquid level. This type of withdrawal might appropriately be called a cascading discharge in distinction from the well-known weir overflow effect. Withdrawal of this type might be realized or aided by reason of a more or less perceivable surging effect resulting from the operation in the compartment of a reciprocating or other raking mechanism. The suspended unfavorable fraction thus removed from the awash discharge end of compartment C may be conveyed to further treatment, such as to cyanidation in metallurgical processes. But the agitation maintained in the final zone C, as slight as it is, maintains in suspension certain colloidal or quasi-colloidal and/or suspensoidal solids that are too small to settle in the presence of this agitation. They overflow the submerged weir **22** into the favorable fraction zone D. Here the favorable fraction of slime, made up of col-

loidal material which ranges from quasi-colloids up to suspensoids in particle size, accumulates, from whence it is drawn off under carefully-controlled conditions through the pipe **25** and conveyed to and into the ball mill M. The drawing off of the favorable fraction from the compartment D can be controlled in a number of ways, either by means of a valve such as **26**, although it is preferably done by means of a pump **27**, that should be of the measuring type and that is operable at variable speeds to attain the pumping capacity desired. The reason for the control of the withdrawal of the favorable fraction is that the amount of favorable fraction fed to the ball mill must bear a certain relationship to the requirements of the material being treated in the mill, all as specified in the Weinig cases.

Also one may choose, as a means of controlling grinding results to treat the favorable fraction of slimes thus derived in one or a number of additional refinement steps. These may include a desanding step as on a vibrating table for the purpose of removing remnant undesirable grains from the slimes, and following this a dewatering or thickening step for adjusting the water condition of the slimes to the requirements of dilution desired for the subsequent mill operation. Consequently such slime treatment steps may be inserted in the slimes return conduit of pipe **25** (see Fig. 2). Details of this proposal are to be found described in my co-pending patent application.

Figs. 6 and 8 represent a slightly modified arrangement of the classification stage, but not in the technical effect attained, in that for the primary classification zone A, which is shown in the other forms as a typical classifier, there is substituted the rotatable trommel screen S for making the preliminary classification by a screening operation rather than by a selective sedimentation process. The coarser solids rejected from passing through the apertures **40** during rotation of the screen, are returned to the mill for regrinding; whereas the smaller size solids that pass through the apertures **40** fall to the secondary classification zone B. The process is the same from there on as previously described. The principle of cooperative relationship between screening and classification for closed circuit grinding, as exemplified in Fig. 6, may also include the combination of a screen such as the trommel screen, with a standard classifier; but the combination may also comprise a single stage classifier corresponding in function to the classifier zone C of Fig. 3 and the trommel.

However, some of the principles enunciated herein are applicable to standard circuits in closed-circuit grinding by a slight modification of the classifier assemblies, as shown by Fig. 3.

In using the Weinig principle in evolving the favorable fraction, a ball mill is necessary; whereas, if that principle is not used, the grinding mill M may have other grinding elements such as rods. So, in Fig. 3, M represents generically a grinding mill. The feed from the mill to the classification zones A, B and C is the same as previously described, the major difference being that the solids raked to emergence in the zones A, B and C pass into a launder **45**, for return to the mill M. The favorable fraction compartment D is absent; so instead of overflowing a pulp from the compartment C into the compartment D, it is overflowed into a launder **46**, and this overflowed product comprises the end product of the classification assembly that goes for further treatment; that is, the product overflowed in the launder **46** in this arrangement, corresponds generally to the product overflowed in the launder **36**, in the previously-described modifications, except that no favorable fraction of slime has been separated out from it.

The advantages accruing from the use of this multistage classification are as follows:

It permits of the conservation of floor space and headroom to a degree not possible heretofore. It permits of the carrying out in one machine of all classification steps from the primary down to extremely fine sizes.

Other advantages are: a quick removal of the coarse sizes which really have no place in a classifier. This is accomplished by a deep rake, screw, drag or other means, running at high speed; the coarsest sand particles are discharged nearest to the mill, saving launder fall; the finer particles have progressively shorter distances to sink before being picked up by the rake; in the last compartment, the finished product and the sand product are both travelling in the same direction during separation, avoiding eddy currents; all weirs may to advantage be submerged, avoiding knife-edge velocities. This also applies to the finished product weir, though not shown; maximum agitation occurs where the particles are coarsest, diminishing as the particle size diminishes; the equivalent of bowl classification can be accomplished in the primary classifier and without the necessity of a re-grind mill; eliminates pumping between primary and secondary classifiers; requires less attendance than both primary and secondary machines; in the last compartment on fine separation, the pool is so shallow that the slow-moving raking mechanism of the Dorr type could lift clear of the pool on the backward stroke,—minimizing agitation; rake lifting device will only be necessary on the coarse rakes; and higher density in the finished product.

It is an important advantage that an increasing dilution is obtained in each of the successive classification steps, without the addition of more water. That is to say, the removal of the rapidly settling coarse solids in the first stages leaves an ever increasing amount of water for the classification of critical sizes. It is this dilution obtained by removal of solids rather than by increasing the fresh water supply to the classifier, that permits a final discharge with an appreciably higher percentage of solids, whereas in previous practice classifier dilutions have been controlled by adding fresh water or solutions to the ball mill discharge. With the method of stage classification according to this invention, a relatively lesser amount of water need be added, inasmuch as, at the same time, solids are being subtracted. This is especially of benefit with respect to the favorable slimes fraction thus to be removed for reuse in the mill.

I claim:

1. The method of classification which comprises maintaining liquid having therein in suspension solids being classified in a common pool subdivided into a plurality of zones of step-wise treatment with the adjacent zones separated by a partial partition, continually supplying to the zone of primary treatment new material in suspension to be classified, separately removing from the pool solids settling in each zone, continually withdrawing over a submerged weir in the zone of final treatment liquid having a final fraction of fine solids in suspension therein while causing in said last zone at a point spaced from said weir a local superelevation or surfe effective to

float from said zone an intermediate fraction of said fines, and agitating the liquid in a quantity of the zones at a slower rate than that in the next preceding zone whereby solids removed from each zone are less coarse than those removed from the next preceding zone.

2. Classification apparatus comprising tank means for holding a bath divided into zones and hydraulic communication by means of a submerged weir between adjacent treatment zones providing a common liquid level in said zones, a feed of solids bearing liquid into a first zone, said zone having a sloping bottom extending as a deck to emergence above the liquid level, a second zone having a sloping bottom terminating at substantially the liquid level, bladed raking means operating in the first zone for raking sediment to emerged discharged, bladed raking means operating in the second zone for raking solids therefrom in suspension, an outlet from said second zone spaced from the suspension discharge end therefrom and provided with a submerged weir, and means for controlling the outflow of liquid with suspended solids therein from the outlet of the second zone.

3. Classification apparatus according to claim 2, comprising means for operating the bladed raking means so that the operating speed in the second zone is less than that in the preceding zone.

4. Classification apparatus according to claim 2, in which both treatment zones extend substantially parallel to one another, and in which the raking means in both zones are effective in the same direction.

5. Classification apparatus according to claim 2, in which the second zone has a relatively greater width than the preceding zone.

6. Classification apparatus according to claim 2, in which the bottom of the second zone has relatively less slope than that of the preceding zone.

7. Classification apparatus according to claim 2, in which the bladed raking means in each zone comprise a reciprocable rake structure having transverse raking blades, and in which the raking blades in one zone are of less depth than those in the preceding zone.

8. Classification apparatus according to claim 2, in which the raking means in each zone comprise transversely extending blades, and in which the blades in the second zone are of less depth than those in the preceding zone.

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