

March 7, 1950

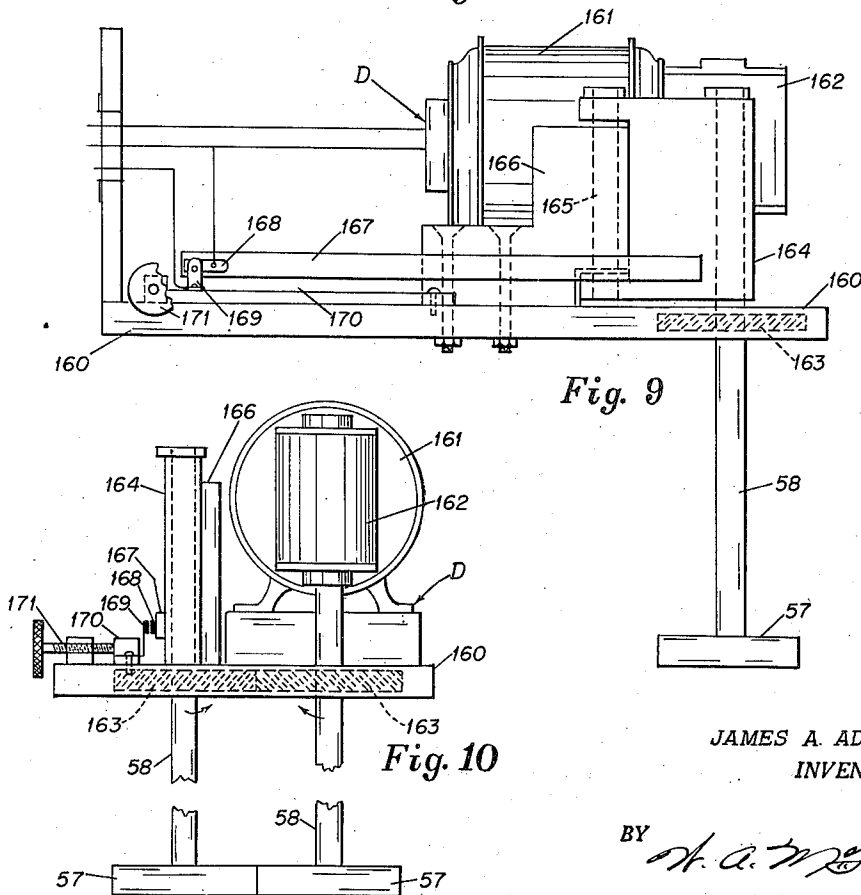
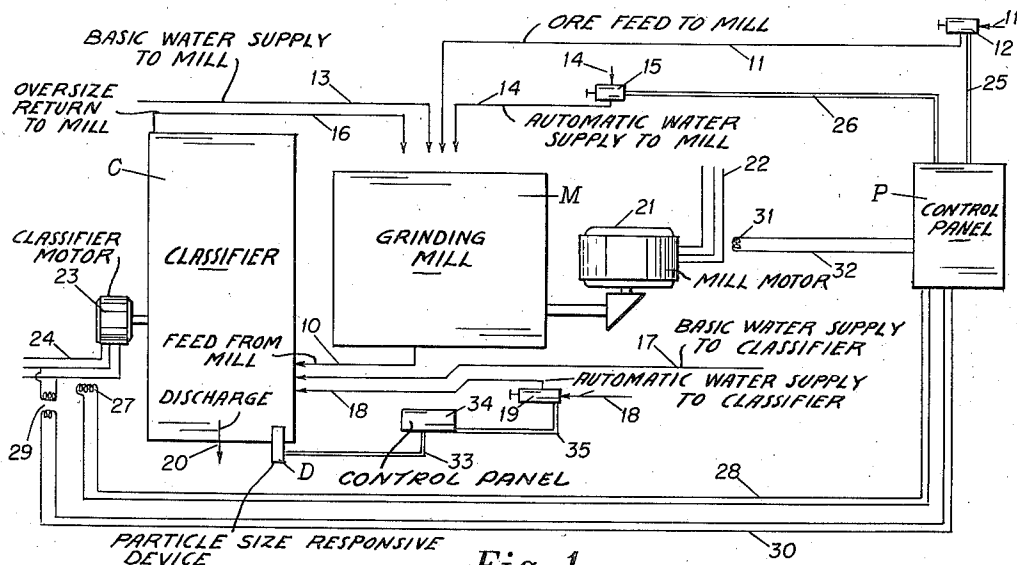
J. A. ADAMS

2,499,347

ELECTRICAL CIRCUITS FOR GRINDING MILLS

Filed April 16, 1945

3 Sheets-Sheet 1



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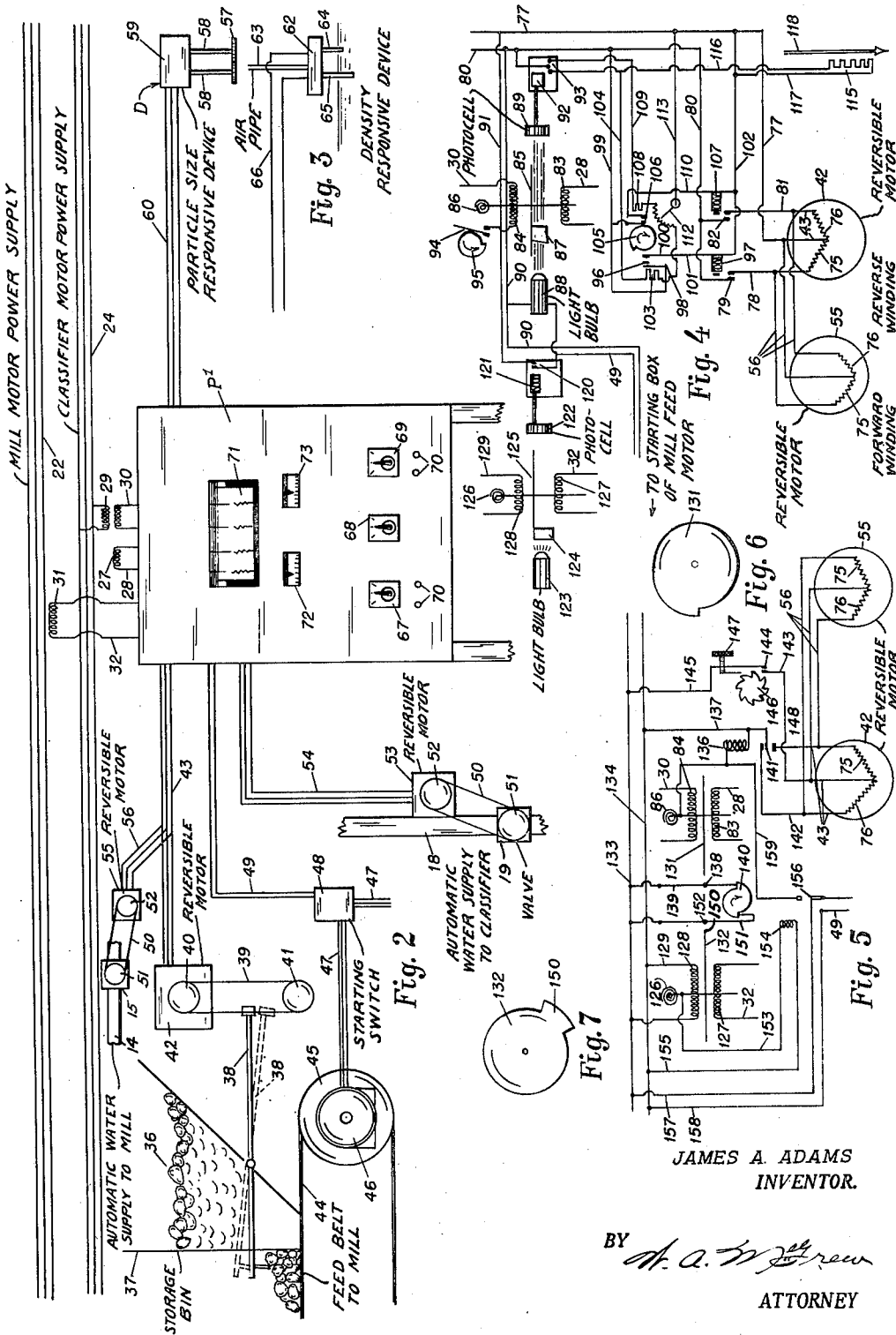
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ELECTRICAL CIRCUITS FOR GRINDING MILLS

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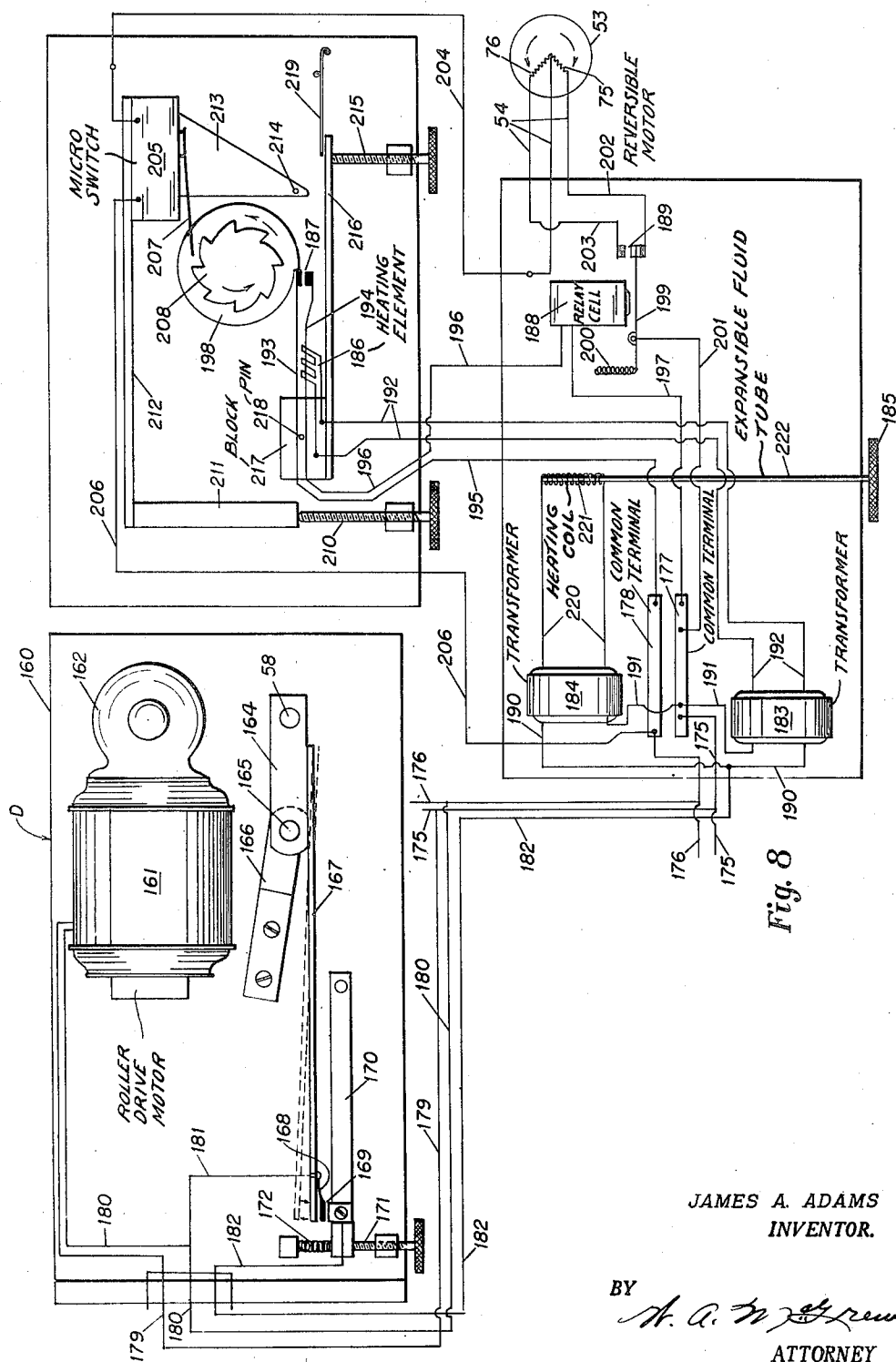
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3 Sheets-Sheet 3



UNITED STATES PATENT OFFICE

2,499,347

ELECTRICAL CIRCUITS FOR GRINDING MILLS

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Application April 16, 1945, Serial No. 588,479

11. Claims. (Cl. 241—33)

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This invention relates to a method of and apparatus for controlling the grinding and/or separation of solid material particles or mixtures of solids and liquids, and more particularly to the control of one or more elements of a grinding circuit, such as a mill and a classifier in series. The principles of this invention are particularly applicable to the grinding and separation of ore for treatment in a mill or the like to recover valuable mineral constituents, but are also applicable to the grinding and/or separation of other solid material, as for use in chemical processes or for other purposes.

Previously, attempts have been made to control grinding and separation of ores by suspending a solid body in the pulp at the overflow of a classifier and attempt control of the size of particles in the overflow by measuring the varying buoyancy of the suspended body. However, such attempts have not been particularly successful because solids tend to adhere to the body and change its buoyancy, which leads to considerable inaccuracy and inconsistency because a change of only 1% or 2% solids in an ore pulp, for example, may be the equivalent of only .2 or .3 grams of solids adhering to the suspended body. Also, such inaccuracies cannot be avoided by increasing the change necessary to actuate the control mechanism since the sensitivity of the device is thereby decreased and changes which should be compensated for remain unchecked.

A considerable improvement over the foregoing involves the use of the density regulator of my U. S. Patent No. 2,294,844, wherein the difference in resistance to flow of air or the like blown into different levels of a pulp body causes a difference in pressure against opposite sides of a diaphragm or against two balancing diaphragms. A change in the pulp density causes a corresponding change in the difference in resistance to flow of air at the different levels, so that the diaphragm or diaphragms reflecting such differences may be used to actuate a control mechanism which may control a component of the pulp so as to maintain the density constant. Such a pulp density regulator has been used with marked success in mining districts all over the world, since it is sensitive to less than 1% solids. However, there are numerous instances in which a density controller, no matter how accurate, is ineffective to maintain a desired particle size, as in the overflow of a classifier. Particularly when the ore or solids of the pulp is not itself homogeneous in specific gravity, the density controller cannot

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reflect accurately changes or differences in particle size. Consequently, the particle size—which is often the desideratum of the next step, such as flotation—is not maintained uniformly.

Another solution of the problem, adequate and effective in numerous instances, is that disclosed and claimed in my U. S. Patent No. 2,240,822, granted May 6, 1941, and in my pending application Serial No. 505,894, filed October 12, 1943. As disclosed therein, the sound of the grinding mill is utilized in controlling the feed to the mill, as it has been found that the sound of the mill differs for various conditions of operation, and that the sound varies in volume in accordance with the load on the mill and the grinding results. The foregoing improvement thus includes the use of a noise meter or sound detector to control a mill feed circuit, by changing an element or elements of the mill feed.

While highly successful in certain installations, such improvement is limited to mills in which there are very few extraneous noises to interfere with the accurate reflection of the mill condition, and also where the ore is sufficiently uniform that the nuisance of continual resetting is avoided. Such difference in feed may be due to variations in the ore, and sufficient difference in feed sometimes to be objectionable may be caused by the tendency for ore from a crusher to segregate in a storage bin. Thus, as a storage bin is being filled, material collects in a cone-shaped pile, the larger lumps rolling to the edges of the pile, against the wall of the bin. As the bin is filled, the material therein is somewhat segregated, with an inner cylinder or the like of fines or small lumps being in the center and larger material and lumps surrounding the cylinder. When ore is withdrawn from the bin, the small lumps and fines in the center tend to be removed first, the ore in the bin forming an inverted cone with its apex at the outlet. Thus, the ore withdrawn from the bin tends to be smaller in size at first, with the average size of the lumps gradually growing larger, so that the feed to the mill will vary in size and proportionate ease of grinding. A sufficient disparity in the average size at different times may require frequent adjustment of a mill controlled in accordance with sound.

Among the objects of the present invention are to provide a control device which accurately reflects the actual size of particles, such as separated in a predetermined zone of a classifier.

Among other objects of the present invention are to provide a novel method for automatically

maintaining a desired particle size or density condition in a predetermined zone of a separator, classifier, or the like; to provide such a method which will regulate the feed of liquid to a classifier or separator and/or grinding mill in accordance with conditions in the classifier or separator; to provide such a method which will regulate the feed of solids and/or liquid to a grinding mill; to provide such a method which will utilize conditions, such as the particle size, the power requirements of the classifier, and the mill load, in controlling the operation of a grinding mill and classifier in series; to provide such a method which will prevent an overload in a grate type mill from adversely affecting the classifier operation; to provide such a method which will be effective in operation; to provide apparatus for carrying out the above method; to provide a novel control device responsive to the actual size of particles; to provide such apparatus which may include the above novel particle size responsive device; to provide such apparatus which may include a device responsive to the specific gravity of the pulp discharged from or in a predetermined zone of the classifier; to provide electrical circuits for effecting control of the mill and classifier and thereby automatically regulating the grinding operation; and to provide such apparatus which will be efficient and effective in operation.

Additional objects and the novel features of this invention will become apparent from the description which follows.

In accordance with this invention, the operation of a separator, such as a classifier, is controlled by varying the liquid or water feed thereto in accordance with the actual size of particles of a predetermined zone of the classifier. Normally, such zone will be the overflow which comprises finished product of the grinding circuit, and the water added to the classifier feed is increased in case the particle size increases and is decreased in case the particle size decreases. Thus, the classifier feed water is varied in accordance with the actual size of particles in the overflow. Such direct regulation will operate to maintain the discharged particles of a predetermined size or range of sizes, because if there is an increase in the amount of smaller particles, without a corresponding increase in the classifier feed water, the density of the pulp in the classifier will increase, so that the larger particles will not settle as quickly and will begin to come over in the overflow. As soon as these larger particles are detected, if the classifier feed water is increased, the pulp is diluted and the larger particles will again settle, so that the overflow will again contain particles of the desired size range. On the other hand, if the number of smaller particles decreases, the pulp will become more dilute, with the result that some of the particles in the overflow range will settle, and the average of the overflow particles will be smaller. As soon as this difference is detected, if the classifier feed water is reduced, then the density of the pulp will increase and the overflow particles will again fall within the desired range.

It will be observed that control of the classifier feed water in accordance with the particle size in effect controls the density of the pulp in the classifier, but more effectively provides the desired result—a desired overflow particle size range. Also, the foregoing method may be applied individually, but may also be a valuable step of the following further method of this invention.

In further accordance with this invention, the

operation of a circuit which includes a grinding mill operating in series with a classifier is controlled by varying the feed to the mill in accordance with the power requirements of the classifier, preferably with accurate control of the classifier feed water, in accordance with changes in the density or in the actual size of particles of a predetermined zone of the classifier. The feed to the mill so controlled may comprise the feed of solids, such as ore, or also the feed of liquid, such as water. By controlling the feed to the grinding mill in accordance with the power requirements of the classifier, variations such as in the hardness of the ore will be compensated for. Thus, if the ore becomes harder, the smaller particle output of the mill will decrease and the average size of the particles will become greater, and a larger proportion of the classifier output will be returned for regrinding. Also, the increase in recirculated particles will increase the amount of material necessary to be moved by the classifier, so that the power requirements of the classifier, or sand load, will increase. Unless corrected by decreasing the feed to the mill, to cause the particles to be ground fine, the load on the classifier, and also on the mill, will increase until either or both become overloaded. Thus, when the power requirements of the classifier increase, the feed to the mill is decreased, in accordance with this invention.

Similarly, if the ore becomes softer and softer, the mill products become finer, so that there is less return of oversize particles to the mill, so that the load on the classifier becomes less. To correct this condition, the feed to the mill is increased when the power requirements of the classifier, or sand load, decrease, also in accordance with this invention.

In further accordance with this invention, in the case of a grate type mill—whose output and the corresponding sand load decrease on the occurrence of an overload—the mill feed is stopped when the power requirements of the mill reach a predetermined minimum. At the same time, the normal control based upon the power requirements of the classifier is reversed so that the setting of the feed to the mill will have decreased by the time the feed belt is started up again. Thus, the mill feed will decrease until the overload is cleared, whereupon the power requirements of the mill will increase until a predetermined minimum is reached; at this time, the control of mill feed is varied normally, i. e., directly in accordance with the power requirements of the classifier. With respect to grate type grinding mills, the foregoing is a valuable feature of this invention, since the steps thereof not only provide overload protection, but also eliminate the factor which caused the overload, i. e., too high a feed rate.

Apparatus for carrying out the above methods may be constructed in any suitable manner, but a preferred form of apparatus, constructed in accordance with this invention, is illustrated in the accompanying drawings, in which:

Fig. 1 is a simplified diagram of a mill and classifier circuit provided with control apparatus constructed in accordance with this invention;

Fig. 2 is a simplified diagram of an ore and water feed control for the grinding mill;

Fig. 3 is a diagram of a device responsive to the density of pulp, such as disclosed in my U. S. Patent No. 2,205,678;

Fig. 4 is a diagram of an electrical circuit for a control panel of Fig. 2;

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Fig. 5 is a diagram of an alternative electrical circuit for the control panel of Fig. 2;

Figs. 6 and 7 are plan views of discs formed as cams and utilized in the circuit of Fig. 5;

Fig. 8 is a top plan view of a particle size responsive device and a connected diagram of an electrical circuit associated therewith;

Fig. 9 is a side elevation of the particle size responsive device of Fig. 6; and

Fig. 10 is an end elevation thereof.

Apparatus constructed in accordance with this invention, as illustrated in Fig. 1, may be utilized in controlling the operation of a grinding mill M and a classifier C in series therewith, the ground product of the mill passing to the classifier through a conduit 10. Material fed to the mill may include solids, such as ore, passing to the mill through an ore feed line 11, the flow through which is regulated by a feed control device 12; a basic liquid supply, such as water, supplied through a pipe 13; automatically supplied liquid, such as water, which may comprise about 25% of the mill water requirements and the flow of which through a pipe 14 is regulated by a valve 15; and pulp containing oversize particles returned from the classifier through a conduit 16.

In addition to the feed from the mill through conduit 10, the feed to the classifier may include basic liquid, such as water, supplied through a pipe 17, and automatically controlled liquid, such as water, supplied through a pipe 18, and the flow thereof regulated by a valve 19. The feed control device 12 and the regulating valves 15 and 19 are preferably actuated or controlled electrically, although other types of control may be utilized, if desired. The overflow or discharge of pulp containing a desired size range of particles, through a conduit 20, is normally supplied to the next step in the process, such as to a conditioner or flotation apparatus in an ore separation treatment. The motive power for the mill M is preferably supplied by an electric motor 21 having power leads 22, and motive power for the classifier is preferably supplied in a similar manner by an electric motor 23 having power leads 24. It will be understood, of course, that the parts as shown in Fig. 1 are diagrammatic only and that no attempt is made therein to show the exact relationship of parts or to show the exact position of pipes or conduits leading to or from the mill or classifier, but such relationship and position will be apparent to those skilled in the art, including the position of a device D which is responsive to a condition of the pulp, such as the density or actual size of particles, in a predetermined zone of the classifier, such as the overflow.

In one embodiment of this invention, the ore feed control device 12 and automatic mill water supply valve 15 are regulated in accordance with the power requirements of the classifier, and for this purpose a control panel P may be connected by leads 25 and 26 with the ore feed control device 12 and water valve 15, respectively, the electrical parts installed within the control panel P, which will be described in detail later, being connected with a classifier current transformer 27 by leads 28, and with a classifier voltage transformer 29 by leads 30.

In case the mill M is a grate type mill or similar mill in which the power requirement drops upon an overload, in further accordance with this invention control means are provided in panel P which will operate to reverse the ordinary control procedure in the case of an overloaded mill, and at the same time stop the ore conveyor

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belt. For this purpose, the control devices in panel P may be connected with a mill motor current transformer 31 by leads 32. A mill motor voltage transformer may also be utilized or, as will appear subsequently, a voltage source such as 110 volts may be utilized in measuring the mill power requirements.

The classifier power requirement elements and the grinding mill power requirement elements are interconnected and integrated in such a manner that when the power requirements of mill motor 21 drop, due to the overload, the feed mechanism is stopped and the feed rate is reduced to prevent the overload from occurring again when the feeding mechanism is started up. Thus, the manner of control is reversed, so that a low power requirement of the classifier motor 23, caused by the decrease of discharge from the mill to the classifier and a consequent decrease in the classifier load, will cause a decrease in the feed to the mill instead of an increase in the same. Also, as soon as the overload is cleared and the power requirements of the mill motor 21 rise, the normal control is reinstated.

As indicated previously, the water feed to the classifier is preferably regulated in accordance with the size of particles or the density of the pulp discharged from the classifier and measured by device D which is responsive to such conditions in the pulp. For controlling valve 19, device D may be connected by leads 33 to a control panel 34, which may contain electrical apparatus to be described in detail later, and which is connected by leads 33 with valve 19.

The variations in particle size in the discharge from the classifier may be due to one or more of a number of different causes. Normally, the density of the pulp will vary in accordance with the size of particles therein, but there are some ores which are not homogeneous in specific gravity, so that measurement of the pulp density of the classifier discharge is not sufficiently exact to determine the particle size. Thus, with respect to those ores which produce a pulp which is homogeneous in density, the device D may be responsive to the pulp density, but for those ores with respect to which the pulps produced are not homogeneous in density, the device D preferably is responsive to the actual size of the particles. Also, even for ores which produce pulps homogeneous in density, a device which is responsive to the actual size of the particles is equally operative, so that such a device can be used on all ores, and is, therefore, more universally applicable than a device responsive only to density.

The apparatus of Fig. 1 operates to control the particle size or discharge of the grinding circuit, in which the mill and classifier are in series and the oversize or classifier reject is returned to the mill, but it will be understood that the principles of this invention are equally applicable to a circuit in which there is no return from the classifier to the mill. The apparatus of Fig. 1 is particularly adapted to carry out the method previously outlined, as follows.

Variation in particle size may be affected by the amount of dilution water added to the classifier, as through pipe 18. Thus, an increase in the dilution water supplied to the classifier tends to cause a decrease in the larger particles present in the overflow and a decrease in the dilution water tends to have the opposite effect, so that normal variations in particle size will be automatically compensated for through device D.

However, an increase or decrease in the larger particles passing to the classifier from the grinding mill tends to change the volume of material handled by the classifier rakes and thereby tends to increase or decrease the load on the classifier, reflected in the power requirements of motor 23. Such change in the larger particles requires further control in addition to a change in the amount of dilution water added to the classifier, since the mill will now be working at less or greater than desired capacity. This control may be effected, as through panel P, by increasing or decreasing the amount of ore fed to the mill, and at the same time increasing or decreasing the amount of water fed to the mill, upon an increase or decrease in larger particles. Also, a compensating control upon a decrease in larger particles tending to decrease the load on the classifier is effected, as through panel P, by decreasing the amount of ore and water fed to the mill, since the mill is now attempting to produce at a rate greater than its capacity and is overloaded. As soon as the mill produces the required amount of finer and larger particles, such as predetermined for efficiency of operation of the circuit, the mill feed is maintained at the new level. At the same time, the particle size or density of the classifier overflow is maintained substantially constant, throughout changes in the mill feed, which may be occasioned by changes in the size or hardness of the ore feed.

The mill power requirement transformers may also be utilized to stop the conveyor belt upon a heavy overload on the mill, and to start the conveyor belt again when such overload is removed, as by control effected in a manner to be described subsequently.

When the feed to the mill is increased to increase the size of particles fed to the classifier, such increase also compensates for the reduction in oversize particles returned by the classifier to the mill through conduit 16. The oversize sands returned decrease when the amount of larger particles to the classifier decreases upon an increase in the amount of finer particles, and vice versa. Thus, when the feed to the mill is increased, the amount of oversize particles tends to increase, and vice versa, so that the grinding mill may be relatively quickly brought back to the desired production rate, in accordance with the hardness of the ore and the size of the feed.

From the foregoing, it is apparent that the method and apparatus of this invention, as described so far, provide automatic maintenance of the particle size overflow of the classifier and automatic regulation of the grinding mill operation to increase feed when the mill is operating below capacity and to decrease feed when the mill is overloaded. This holds true for all ball and rod mills, because the classifier sand load is indicative of the mill load at all times in the overflow type mill, and control by the combination of the mill power requirements and the classifier sand load satisfies conditions when a grate type mill is used.

The feed to the grinding mill may be controlled in the above manner by apparatus constructed as illustrated in Fig. 2, and including electrical elements of panel P' which may be constructed in any suitable manner, as including the elements of panel 34 of Fig. 1 and further including elements connected as in the manner of the circuit of Fig. 4, or, alternatively, the circuit of Fig. 5. In the apparatus of Fig. 2,

power leads 22 to the mill motor and power leads 24 to the classifier motor correspond to the same elements of Fig. 1, as well as the classifier current transformer 27 and leads 28 therefrom to panel P, classifier voltage transformer 29 and leads 30 therefrom to panel P, and mill motor current transformer 31 and leads 32 therefrom to panel P.

For controlling the feed of ore 36 to the grinding mill, a storage bin 37 may be provided at its lower end with any suitable type of discharge control, such as a gate operated by a lever 38. One end of lever 38 is attached to the gate and the opposite end of the lever may be attached to an endless V-belt 39, or the like, which circumscribes pulleys 40 and 41. Pulley 40 is rotated in either direction by a reversible motor 42, connected by wires 43 with panel P. From bin 37, the ore may be moved to the grinding mill by a suitable conveyor, such as including an endless belt 44 which at one end passes around a pulley 45 driven by a motor 46. Leads 47 to motor 46 pass through a starting switch 48, to which control wires 49 lead from panel P. As will be evident, reversible motor 42 is adapted to vary the amount of ore passing from bin 37 to belt 44 in small increments, whereas the belt motor 46 is stopped to terminate the feed to the grinding mill, such as upon the occurrence of an overload on a grate type mill. In lieu of the gate operated by lever 38, belt 44 may be driven at different speeds to vary the amount of ore fed to bin 37 by small increments.

For controlling the flow of water to the classifier through pipe 18 in which a suitable valve 19 is installed, as also indicated in Fig. 1, an endless V-belt 50 may be utilized to open and close the valve by engagement with a valve wheel 51, the opposite end of belt 50 engaging a pulley 52 turned by a reversible motor 53, similar to reversible motor 42 and connected with panel P' by wires 54. The flow through pipe 14 controlled by valve 15 of Fig. 1, may be regulated in a similar manner, as by a reversible motor 55 similar to motor 42 and connected to panel P' by a set of wires 56 tributary to leads 43. Or, the flow of water to the grinding mill may be controlled by motor 42, connected with the valve therefor in the same manner as motor 53 and valve controlled thereby.

A control device D responsive to the size of particles of a predetermined zone of the classifier may be constructed generally as in Fig. 2. Such device may include a pair of rollers 57 mounted on and rotated in opposite directions by shafts 58. One shaft 58 is relatively fixed as to bodily movement, and the other movable with respect thereto, so that a change in the size of particles passing between the rollers will cause the shafts to move closer together or further apart as the case may be to operate a suitable switch. Shafts 58 extend from a housing 59, in which is installed bearings, shaft rotating means, and other control apparatus, including a switch for transmitting the effect of changes in the size of particles through wires 60 to panel P'.

A control device responsive to changes in the density of the pulp of a predetermined zone of the classifier may, as in Fig. 3, include a housing 62 to which an air pipe 63 leads, for supplying air to a shorter tube 64 and a longer tube 65. The difference in back pressure caused by air escaping from the tubes is measured by sensitive diaphragms in housing 62 and transmitted elec-

trically by wires 66, which may be connected, to control panel P' in lieu of wires 60 of the control device of Fig. 2. Further details of the construction of preferred devices operating in the above manner are to be found in my U. S. Patents No. 2,204,644, granted June 18, 1940, and No. 2,205,678, granted June 25, 1940.

As in Fig. 2, the apparatus of this invention may be constructed so that at least some of the regulation may be made manual or automatic at the operator's option, by including on panel P' switches 67, 68 and 69, respectively, for changing the ore feed and water control, the ore conveyor belt, and classifier water from hand control to automatic control, and vice versa. Control panel P' may further include push button switches 70 for starting and stopping motors 42 and 53, and motor 55, or one of the positions of switches 67 and 69 may be an "off" position. Also, a record of the various steps carried out by the apparatus, may be provided by a chart 71 and cooperating pens for recording various factors, such as the particle size or density of the classifier overflow, the classifier motor load or power requirements, the mill motor load, the amount of ore fed to the mill, the amount of water fed to the mill, and the amount of water fed to the classifier, any of which may be omitted, if desired. The panel P' may include direct reading meters 72 and 73 for indicating the classifier motor load and the mill motor load. Also, a suitable meter, such as indicating the particle size of the classifier overflow, or density thereof, may be added or substituted for one of the other meters.

The elements installed in panel P' may include those necessary to form the circuit shown in Fig. 4, which is adapted to regulate the reversible motors 42 and 55, respectively adapted to control the feed of ore to the grinding mill, and the water to the grinding mill. The circuit of Fig. 4 is also adapted to stop the conveyor motor 45 of Fig. 2 when the grinding mill is overloaded, and is particularly applicable to a grinding mill, such as a grate type mill, whose power requirements decrease upon an overload. Aside from the forward windings 75 and reverse windings 76 of motors 42 and 55, leads 43 and 56 for these motors, and also control wires 49 leading to the starting box of the conveyor belt drive motor, the remainder of the wiring and elements of Fig. 4 are preferably installed in panel P'. As will be evident, motors 42 and 55 may be controlled in parallel, the central wires of the leads connecting a wire 77 or one side of a suitable supply of electricity, such as 110 volts A.-C., with a common terminal of the forward and reverse windings of the motors. One set of outside wires of leads 43 and 56 lead from the forward windings, and connect at a common terminal with a wire 78, in turn adapted to connect the forward windings of the motors, through a relay switch 79, with a wire 80 forming the opposite side of the 110 volt A.-C. supply. Similarly, the other set of outside wires lead from the reverse windings of the motors and connect at a common terminal with a wire 81, which in turn connects through a relay switch 82 with wire 80. As will be evident, when switch 79 is closed, motors 42 and 55 will run in the forward direction, and when switch 82 is closed, the motors will run in the reverse direction.

The circuit of Fig. 4 is so designed that the motors 42 and 55 tend to turn first in one direction, then the other, such alternation insuring that slack in the valve or the gate will be taken

up if an added impetus in either direction is given to effect a change in the feed and also to effect changes in slight increments to prevent overrunning of the control. For the above purpose, and to effect necessary changes in the feed due to variations in the power requirements of the classifier, coils 83 and 84, connected by leads 28 and 30 with the classifier current and voltage transformers, respectively, are operatively disposed with respect to a disc 85, similar to a watt meter disc. Whenever the current drawn by the classifier motor increases, and the voltage remains substantially constant or decreases insufficiently to counteract the increase in current, disc 85 will be rotated against the force exerted by a torsion spring 86 through an angle corresponding to the increase in the power requirement of the classifier. Such rotation of the disc 85 will cause a flag or tab 87 attached to disc 85 to intercept a greater proportion of the light directed from a bulb 88 toward a photoelectric cell 89. Bulb 88 may be connected across wires 99 and 91 leading from source wires 77 and 80, respectively, in series with a normally closed switch 120. Photoelectric cell 89 controls a relay 92 which in turn controls the position of a double throw switch 93, the central contact arm of which is connected with wire 80. Preferably, disc 85 is oscillated by interrupting current to coil 84 by a switch 94 in one of leads 30, alternately opened and closed by a cam 95 rotating at a suitable speed, such as about 30 R. P. M. This causes a proportional amount of light to reach the photoelectric cell, and causes the control change to be based on cumulative effect, rather than temporary variations.

When switch 93 is in one closed position, a relay arrangement is actuated to close switch 79 and cause motors 42 and 55 to run in the forward direction, and when switch 93 is in the opposite closed position, another relay arrangement is actuated to close switch 82 and cause motors 42 and 55 to run in the reverse direction. Such relay arrangement for causing the motors to run in the forward direction may include a switch 96 in series with a solenoid 97 for closing forward motor control switch 79, one contact of switch 96 being mounted on a bi-metallic strip 98 and connected with power wire 80 by a tributary wire 99. The other contact of switch 96 is mounted on a pivoted or flexible arm 100 and connected by a wire 101 with solenoid 97, a tributary wire 102 completing the circuit to the other power wire 77. Bi-metallic strip 98 may be heated by a resistance coil 103 in accordance with the current passing thereto through a wire 104 from one contact of switch 93. To insure positive action of switch 96, a cam 105 is provided to periodically move pivoted arm 100 toward strip 98 and cause the contacts of switch 96 to close in case strip 98 is bent sufficiently in the required direction. Cam 105 is preferably rotated at a relatively slow rate, such as about 3 R. P. M., so that the motors normally will not run continuously in either direction, but only periodically.

A similar relay arrangement for causing the motors to run in the reverse direction may be provided by a switch 106 in series with a solenoid 107 for closing reverse motor control switch 82, switch 106 being similar to switch 96. Thus, one contact of switch 106 is mounted on a bi-metallic strip adapted to be heated by a resistance coil 108 in accordance with current passing thereto through a wire 109 from the reversing contact of switch 93, switch 106 being connected to solenoid

107 by a wire 110 and the solenoid being connected to wire 102. The other contact of switch 106 is mounted on a pivoted arm and connected to wire 99, thus completing the circuit to the other power wire 80. The action of cam 135 in tending to close switch 106 is periodic and alternates with the action on switch 96, so that during normal operation switch 96 is closed for a short period, then switch 106, and so on.

Heating coils 103 and 106 are connected in parallel through a rheostat 112 and a wire 113 to the other power wire 77. The heating coils may be connected to the same end of the rheostat winding, so that heating of the coils will be identical, or the coils may be connected to opposite ends of the rheostat, as shown, to obtain a greater range of adjustment and a differential in adjustment. Thus, if the rheostat arm is set at the center of the winding, as shown, the resistance of each portion of the winding will be the same, so that the same current difference will be necessary to cause switch 96 to be closed for a longer period than switch 106, or vice versa. However, if the rheostat arm is set to one side of the center to place a greater resistance in series with coil 103, for instance, a greater current difference will be necessary to cause switch 96 to be closed for a longer period than switch 106, and vice versa.

If the amount of light intercepted by tab 87 is less than that for which the photoelectric cell 89 is set, the forward contact will close, sending current through heating coil 108, to bend the bi-metallic strip toward the pivoted strip and cause switch 106 to remain closed for a longer period than switch 96. The ultimate effect will be that the motors will turn in the reverse direction a sufficiently greater amount to reduce the feed of ore and water to the grinding mill. Similarly, if the amount of light intercepted should be greater than that for which the photoelectric cell 89 is set, the reverse contact will close, sending current through coil 103 and causing switch 96 to remain closed for a longer period of time, thereby increasing the feed of ore and water to the grinding mill.

For recording the classifier load on chart 71, a heating coil 115 may be connected in series with one of the contacts of switch 93, such as by a wire 116 from coil 115 to wire 104 connected with the forward contact, the circuit being completed by a wire 117 from coil 115 to wire 102 and thence to power wire 77. Heating coil 115 is adapted to cause a bi-metallic strip 118 to bend in accordance with the current passing through the coil, and strip 118 carries a pen which marks a line on the chart corresponding to the classifier power requirements.

For shutting off the conveyor belt motor and reducing the setting of the mill ore and water feed upon an overload on the grinding mill motor, contact wires 49, which lead to starting box 48 of Fig. 2, may be connected across a suitable power source, one wire 49 being connected to wire 90, and the other wire 49 being connected at a common terminal with bulb 88 through normally closed switch 120 with wire 91. Switch 120 is thereby adapted to be opened to stop the conveyor motor and also to shut off bulb 88, which automatically causes motors 42 and 55 to run only in the reverse direction and thereby reduce the setting of the ore and water feed to the grinding mill.

To open switch 120 upon an overload on the grinding mill motor, a relay solenoid 121 is con-

trolled by a photoelectric cell 122 responsive to the amount of light from a bulb 123 and intercepted by a tab or flag 124 mounted on a disc 125. Disc 125 is rotated against the force of a torsion spring 126 in accordance with the amount of current passing through a coil 127 connected to leads 32 from the mill motor current transformer 31 of Fig. 2, so that the angle through which the disc is rotated will correspond to the load on the mill motor. A voltage coil 128 may be provided, to complete a set-up similar to that of a watt meter, and may be connected by leads 129 with a mill motor voltage transformer or with power wires 77 and 80, as desired, the latter being preferred as simpler.

It will be evident that switch 120 may be omitted, along with the remainder of the mill motor power requirement circuit, so that bulb 88 may be connected directly to the power leads. This provides a circuit adapted to control the usual type of grinding mill, wherein the mill ore and water feed is at all times regulated directly in accordance with the classifier motor power requirements.

An alternative circuit, as illustrated in Fig. 5, is particularly useful in controlling the operation of a grate type grinding mill and a classifier in series and includes a pair of discs 131 and 132, respectively rotated in accordance with the power requirements of the classifier and the grinding mill. The circuit is operated from power leads 133 and 134, connected to a suitable source of electricity, such as 110 volts A.-C. The disc 131 is adapted to be rotated, similarly to disc 85 of Fig. 4, against the force of a torsion spring 86 and in accordance with a load on the classifier as determined by current and voltage coils 83 and 84, respectively connected to the classifier current and voltage transformers by leads 28 and 30. Similarly, disc 132 is rotated against the force of a torsion spring 126 and in accordance with the load on the mill motor as determined by a current coil 127 connected with the mill motor transformer by leads 32, and also by a voltage coil 128 connected by leads 129 with power leads 133 and 134, as shown, or alternatively with a mill motor voltage transformer.

Disc 131 may be made in the form of a cam, as in Fig. 6, having an outline similar to an involute curve or spiral. Disc 131 is connected by a wire 135 to a solenoid or relay coil 136, the opposite end of the solenoid being connected by a wire 137 with power lead 134. The angular position of the disc determines engagement thereof with a contact 138 mounted on a pivoted arm 139 connected to power lead 133, as shown. Pivoted arm 139 is periodically moved toward disc 131 by a rotating cam 140, so that whenever the disc is in an angular position to cause engagement with contact 138, current will flow through coil 136 to close a double throw switch 141, also connected by wire 137 with power lead 134, against its upper contact. This causes current to pass from switch 141 through a wire 142 and one of the outside leads 43 and 56 to the reverse windings 76 of motors 42 and 55. The circuit is completed through a wire 143 connecting the central leads 43 and 56 with a time delay switch 144, which is connected by a wire 145 with the power lead 133 and is periodically opened and closed by a rotating cam 146. Cam 146 breaks the motor circuit a sufficient number of times, such as 8 per minute, to cause the control motors to stop a predetermined period of time. The relative period during which the control motors are

stopped may be regulated by an adjusting screw 147 which moves one contact of the switch toward and away from the other contact. Such regulation prevents the motors from running continuously and also causes changes in the ore and water feed to the mill to take place by increments.

In order to stop the ore conveyor and reverse the direction of control upon a predetermined overload on the grinding mill motor, disc 132 may be provided, as in Fig. 7, with an extending portion 150 so positioned that as cam 140 rotates to move a pivoted arm 151 periodically toward disc 132, a contact 152 will normally fail to engage disc 132. However, when an overload of predetermined amount is imposed upon the grinding mill motor, disc 132 will be moved angularly sufficiently, so that contact 152 will engage extending portion 150. This will cause current to pass from contact 152 and arm 151, connected with power lead 133, as shown, through the disc and a wire 153 to a relay coil 154. The opposite end of coil 154 is connected by a wire 155 with power lead 134, and coil 154 is adapted to move a double throw switch 156 from closure against a lower contact, in the position shown, to closure against the upper contact, in the opposite position.

In the normal position as shown, current flows through a wire 157 from power lead 133 and through the lower contact of switch 156, and also through a wire 158 connected with power lead 134, to wires 49 leading to starting box 48 of Fig. 2, for controlling the conveyor drive motor. Thus, with switch 156 closed against the lower contact, current will be supplied through wires 49 to the starting box and the conveyor drive motor will keep running.

However, when coil 154 is energized by engagement of contact 151 and disc 132 when an overload in the grinding mill motor rotates disc 132 to a predetermined position, switch 156 is moved to the upper contact, thereby opening the lower contact and shutting off the supply of current through wire 49 to the starting box of the conveyor motor, and thus stopping the motor and conveyor. At the same time, switch 156 energizes coil 136 through a wire 159, so that switch 141 will move to the upper contact, even though disc 131 is not in engagement with contact 138. When switch 141 moves to the upper contact, current passes through wire 148 to the reverse windings 76 of the control motors, thereby continuously reducing the ore and water feed to the grinding mill as long as the overload continues, thereby reversing the direction of control of the mill feed. The delay switch 144 may, of course, delay the time at which such decrease in feed will begin, so that a momentary overload may not cause such decrease but a sustained overload will have such effect. Thus, when the overload disappears and contact 152 and disc 132 are no longer in engagement, switch 156 will drop back to the lower contact to start the conveyor motor, and normal regulation of the feed to the grinding mill in accordance with the power requirements of the classifier motor will begin again. It will be evident that the foregoing control not only stops the conveyor belt to protect the grinding mill upon overload, but also removes the cause of the overload by reducing the feed until the time the conveyor belt is again started.

It will again be evident that the circuit of Fig. 5 may be adapted to control an overflow type mill, as distinguished from a grate type mill, by eliminating the action of switch 156, as by leav-

ing leads 32 and 129 disconnected, as well as leads 153. This will cause the regulation of the mill ore and water feed directly in accordance with the classifier power requirements at all times.

It will be understood that the grinding mill, and particularly a grate type mill, is started up through hand control, and then switched over to automatic control after the mill and classifier are operating properly at the desired load. This is preferable because the classifier operation should be stabilized before automatic control is effected, and also in the case of a grate type mill, because the mill overload circuit is responsive to a decrease in the mill power requirements and when a mill is started, especially if there is no ore in the mill initially, the power requirements will be less than required to stop the conveyor belt, etc. Thus, any tendency for the overload relay to operate at low initial load is obviated.

The novel particle size responsive device D of this invention may include, as illustrated in Figs. 8 to 10, inclusive, a base 163 on which is mounted a motor 161 provided with speed reduction gearing 162 adapted to drive directly one of shafts 58 on which rollers 57 are mounted. The other shaft 58 is rotated in the opposite direction by interengaging herringbone gears 163 mounted on shafts 58, as in Fig. 10. The gears 163 permit slight movement of the rollers 57 toward and away from each other in accordance with the size of particles passing therethrough, the rollers preferably being immersed in the pulp in the overflow or any other desired zone of the classifier or separator. The driven shaft 58 is journaled in a block 164, pivotally mounted by a pin or stud 165 on a standard 166 attached to base 160, as in Figs. 9 and 10. As in Figs. 8 and 9, a relatively long arm 167 is attached at one end to block 164 and carries on its opposite end a contact 168. The length of arm 167 in comparison with the distance between the axes of pin 165 and driven shaft 58, provides a ratio of movement of contact 168 of three or more times the movement of the rollers 57 when different sized particles pass therethrough. Contact 168, upon sufficient movement of the rollers toward each other, will engage a relatively fixed contact 169, such contact being mounted upon an arm 170 pivoted at one end for adjustment by a screw 171 acting against the pressure of a compression spring 172. As will be evident from Fig. 8, in case the size of the particles passing between rollers 57 increases, arm 167 will tend to be moved from the full toward the dotted position of Fig. 8, thereby causing contacts 168 and 169 to separate. However, as soon as the size of particles decreases sufficiently, the contacts 168 and 169 will again engage upon pivotal movement of arm 167 from the dotted to the full position.

The control device D, as illustrated in Figs. 8 to 10, inclusive, may be placed so that the shafts 58 extend vertically or horizontally or at any other desired angle into the pulp, either in a zone of the classifier or outside the classifier in a receptacle or pipe connected with the classifier overflow. Also, such device may, as in Fig. 8, be connected with a control circuit, the elements of which may be mounted in panel 34 of Fig. 1 or panel P' of Fig. 2. Such circuit may include power leads 175 and 176 connected to common terminals 177 and 178, respectively, and supplying current to motor 161 through wires 179 and 180. Contact 168 is connected by a wire

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181 with wire 180, while contact 169 is connected with the remainder of the circuit by a wire 182.

Elements of such circuit include an operating transformer 183, an indicating transformer 184 connected in parallel with transformer 183, and adapted to show on a gage 185 the size of particles passing through the rollers 57, a heating element 186 operated by transformer 183 and controlling a thermal switch 187, and a relay coil 188 in series with switch 187 for controlling a double throw switch 189 and thereby controlling the passage of current through forward and reverse windings 75 and 76 of classifier dilution water control motor 53. Transformers 183 and 184 are utilized to convert the voltage of power leads 175 and 176, which is sufficiently high to operate motor 161, to a lower voltage, such as 10 volts, to provide greater sensitivity in heating element 186 and in the indicating parts. One side of the primary winding of each transformer 183 and 184 is connected by wires 190 with wire 182 leading from relatively fixed contact 169 of the particle responsive device D. The opposite side of the primary winding of each transformer is connected with common terminal 177 by wires 191, so that when contacts 168 and 169 are in engagement, current will flow through the primary winding of each transformer.

The secondary of operating transformer 183 is connected by wires 192 to heating element 186, so that the amount of current passing through the heating element and the cumulative effect thereof will correspond to the relative amount of time that contacts 168 and 169 are closed. Thermal switch 187 is provided with a relatively flexible, pivoted, or otherwise movable arm 193 and an opposite arm 194 comprising a bi-metallic strip adapted to bend in accordance with the heating thereof by element 186. Movable arm 193 of switch 187 is connected by a wire 195 with common terminal 178 and the bi-metallic strip 194 of switch 187 is connected by a wire 196 with relay coil 188, the circuit through switch 187 and relay coil 188 being completed by a wire 197 connecting coil 188 with the other common terminal 177. Thus, coil 188 will be energized whenever switch 187 is closed.

Relatively fine particles passing between rollers 57 will not cause contacts 168 and 169 to open, while relatively coarse particles will hold the contacts open continuously, and intermediate particles will cause the contacts to open and close in accordance with the variation in size of particles, so that the transformers 181 and 182 will be energized continuously, intermittently, or not at all depending upon the size of particles. When the desired size range is passing between the rollers, the transformers will be energized intermittently, so that the cumulative effect of heating element 186 will be to maintain bi-metallic strip 194 in such a position that switch 187 will be opened and closed periodically by a timing cam 198 which is rotated at a relatively slow speed, such as 3 R. P. M. Thus, relay coil 188 will be energized for longer or shorter periods, in accordance with the time during which switch 187 is closed.

Relay 188 is adapted to move a pivoted arm 199 of switch 189 upwardly against the force of a tension spring 200 to move the switch from engagement with the lower contact to engagement with the upper contact. Switch 189 is connected to common terminal 177 by a wire 201, so that with the lower contact closed, current tends to pass through a wire 202 to one of the outside

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leads 54 and to forward winding 75 of motor 53, while with the upper contact closed, current tends to pass through a wire 203 to the other outside lead 54 and to reverse winding 76. The circuit through the windings of motor 53 is completed from lead 54 common to windings 75 and 76 through a wire 204 to a micro-switch 205, and thence through a wire 206 to common terminal 178.

Micro-switch 205 is utilized to interrupt periodically the flow of current to the windings of motor 53, an operating lever 207 thereof being intermittently contacted by the teeth of a cam 208, to open the switch for a short time interval, cam 208 being attached to or driven at the same rate as cam 198. The plurality of teeth of cam 208 cause the micro-switch to be opened a considerably greater number of times per minute than the switch 187 tends to be closed. Due to the intermittent opening and closing of the micro-switch, the motor 53 will not run continuously in either direction, but will open or close the valve controlling the classifier water supply by increments. Since the lower contact of switch 189 is normally closed, a further advantage of the interruption of current to the motor windings by micro-switch 205 lies in the fact that in case switch 189 is being shifted from the lower to the upper contact, the circuit will normally be open if switch 189 is only momentarily closed, or when switch 189 closes, so that when micro-switch 205 again closes, switch 189 will have been moved into engagement with the upper contact by energization of relay 188.

The foregoing also produces a slight time delay in activation of the control motor, which delay may be adjusted by a set screw 210 acting against a block 211 attached to a lever 212, in turn attached to the micro-switch, the micro-switch being mounted on a plate 213 pivotal about a pin 214. By adjusting the angular position of the micro-switch by set screw 210, the length of time during which one of the teeth of cam 207 will depress lever 206 sufficiently to close the micro-switch may be varied.

An additional adjustment may be obtained through a set screw 215 adapted to engage one end of a lever 216 attached at the opposite end to a block 217 on which switch 187 and heating element 186 are mounted, and which is pivotal about a pin 218. Set screw 215 is adapted to move the end of lever 216 against a leaf spring 219, to adjust the relative position between switch 187 and cam 198 and thereby determine the amount of time the switch 187 will tend to be closed during operation.

For indicating the relative fineness of the particles passing between the rollers, the secondary of indicating transformer 184 is connected by wires 220 with a heating coil 221, the coil surrounding one end of a closed tube 222 containing an expansible fluid adapted to actuate a pointer mounted in gage 185, as by a Bourdon tube, in substantially the same manner as an ordinary dial thermometer. Gage 185 may be calibrated in terms of particle size fineness, so that the average size of the particles will be indicated thereby, since the measurement indicated by gage 185 will correspond to the cumulative heating effect of current passing through coil 221, which, in turn, corresponds to the relative portion of time during which the contacts 168 and 169 are closed.

The operation of the control device and cir-

cuit of Fig. 8 may be described briefly as follows: Assuming that the lever 167 remains in the full position of Fig. 8, the particle size will be smaller than that desired, so that the contacts 168 and 169 will remain closed, thus causing current to flow through transformers 183 and 184. Through transformer 183, heating coil 186 will cause bi-metallic strip 194 to bend toward flexible strip 193, thus causing switch 187 to be closed sooner than normal by cam 198 and thereby energizing relay 188 and causing current to be supplied through the reverse winding 76 the next time and each time micro-switch 205 closes. This will move the valve controlling the flow of water to the classifier toward its closed position and thereby reduce the amount of water (the result desired when the particle size is less than normal).

When a sufficient number of larger particles being to pass between the rollers to cause contacts 168 and 169 to separate a sufficient portion of the time, the result will be that switch 189 will alternate between the upper and lower contacts equally, thereby resulting in motor 53 remaining at a standstill in case the micro-switch 205 is open at the times that switch 189 closes either contact, or will cause the motor 53 to run in the forward and then in the reverse direction an equal amount, intermittently, in accordance with the setting of time delay adjusting screw 210.

If the average size of particles passing between rollers 57 should become larger than desired, contacts 168 and 169 will remain open all or a greater part of the time. This will reduce the amount of heat produced by element 186, thus causing bi-metallic strip 194 to bend away from flexible strip 193, so that switch 187 will be open a greater amount of the time during each revolution of cam 198. Consequently, relay 188 will be energized during a smaller proportion of the time, so that switch 189 will remain in engagement with the lower contact a greater proportion of the time. As a result, current will be supplied the forward windings 75 of motor 53 a greater proportion of the time, and the dilution water control valve will be opened by increments, thus increasing the amount of dilution water supplied to the classifier (the result desired when the particles are larger than desired).

From the foregoing, it will be apparent that the method and apparatus of this invention, including the various modifications described, are effective in controlling operations of the character described which may vary widely. The principles of this invention find profitable application in wet grinding of ore, i. e., in which water is introduced into the grinding mill and a slurry or pulp consisting of water carrying more or less finely divided solid ore particles, as in suspension, is supplied to a classifier in which additional water may be added and larger particles are separated from the smaller particles by settling of the larger particles. The circuit may be so arranged that oversize particles are returned to the mill for regrinding and so that only particles of a predetermined size range are supplied to the next treatment step, such as a flotation machine. However, the principles of this invention are applicable generally to grinding wherein a liquid is added to the solid, either at the grinding mill, or at the classifier or other type of separator, or at both; and certain aspects of this invention

are applicable to other types of grinding, such as dry, and to material other than ores.

It will be apparent that various changes and additional modifications may be made. For instance, the photoelectric cell control of the circuit of Fig. 4 may be utilized in place of either the cam disc control responsive to the mill load or the classifier load, in a circuit similar to that of Fig. 5, and also the cam control of the circuit of Fig. 5 may be substituted for the photo-electric control responsive to the mill load or the classifier load in a circuit similar to that of Fig. 4.

In addition, a circuit including a condenser and a varying capacitance for regulation, may be utilized for time delay in any of the circuits described. Also, the discs 131 and 132 of Fig. 5 may be connected in series in such a manner that when the load on the grinding mill reaches a predetermined value, disc 132 will regulate the water to the classifier and decrease the same until the mill load is reduced.

It will further be apparent that various other changes may be made, all without departing from the spirit and scope of this invention.

What is claimed is:

1. Separation apparatus comprising a classifier; means responsive to the size of particles of a predetermined zone of said classifier including a pair of rollers submerged in said zone rotatable in opposite directions and movable toward and away from each other in accordance with the size of particles passing between said rollers; and means actuated by said responsive means for controlling the operation of said classifier.

2. In apparatus for controlling a grinding circuit which includes a mill and a classifier, and responsive to the size of particles in a predetermined zone of said classifier, a pair of rollers submerged in said zone movable toward and away from each other in accordance with the size of particles passing between said rollers; means for rotating said rollers in opposite directions; and an electrical switch constructed and arranged to be opened and closed in accordance with the distance between said rollers.

3. Apparatus for controlling a grinding mill and a classifier in series, comprising electrically operated means for regulating the feed of solids and liquid to said mill; electrically operated means for controlling the dilution liquid supplied to said classifier; a conveyor for carrying solids to said mill; an electric motor for furnishing motive power to said classifier; an electric motor for furnishing motive power to said mill; a transformer responsive to the current drawn by said mill motor; a transformer responsive to the current drawn by said classifier motor; a transformer responsive to the voltage in the line to said classifier motor; an angularly movable disc in a field produced by said mill motor current transformer; a source of radiant energy and an electronic cell normally intercepting such radiant energy; an interrupter attached to said disc for regulating the amount of radiant energy intercepted by said cell upon angular movement of said disc due to a change in the current passing to said mill motor; a relay operable by said electronic cell; a switch adapted to be opened and closed by said relay to stop and start said conveyor; a second source of radiant energy and an electronic cell normally intercepting such radiant energy; an angularly movable disc in a field created by said classifier motor current and voltage transformers; an interrupter attached to said second mentioned

disc for regulating the amount of energy intercepted by said second mentioned cell; a relay controlled by said second mentioned cell; a double throw switch controlled by said relay; a heating coil connected in series with each side of said switch; a thermal switch in operative proximity to each heating coil; a rheostat in series with said heating coils; a reversible motor for controlling said means for regulating the feed of solids and liquid to said mill; a cam for periodically closing said thermal switch; and electrical relays in series with said thermal switches for causing current to pass to the forward and reverse winding of said control motor upon closing of the respective switch.

4. Apparatus for controlling a grinding mill and a classifier in series, comprising electrically operated means for regulating the feed of solids and liquid to said mill; a conveyor for moving solids to said mill; electrically operated means for regulating dilution liquid supplied to said classifier; an electric motor for furnishing motive power to said classifier; an electric motor for furnishing motive power to said mill; a transformer responsive to the current drawn by said classifier motor; a transformer responsive to the current drawn by said mill motor; a voltage transformer responsive to the voltage in the line to said classifier motor; an angularly movable disc in a field produced by said classifier motor current and voltage transformers, said disc being in the form of a cam; a movable arm carrying a contact adapted to engage said disc; means for periodically moving said arm toward said disc; a relay coil adapted to be energized normally upon engagement of said disc and contact; a double throw switch normally closed in one position but adapted to be closed in the opposite position upon energization of said relay coil; a reversible motor for controlling said means for regulating the feed of solids and liquid to said mill and having forward and reverse windings connected respectively in series with the opposite sides of said double throw switch; a time delay switch in series with each said motor winding; a cam for periodically opening and closing said switch; a second disc in a field produced by said mill motor current transformer, said disc having an extending portion and being movable angularly in accordance with the power requirements of said classifier; a movable arm having a contact adapted to engage said disc and periodically moved toward said disc; a second relay coil in series with said disc and arm; a double throw switch normally in a first position and movable to the opposite position upon energization of said second relay coil; electrically operated means for driving said conveyor and controlled by said switch, so that when said switch is moved from said first position said conveyor will be stopped; and a connection between said switch and said first disc for energizing said first relay coil to reverse the control of solid and liquid feed to said mill when said second relay coil is energized.

5. Apparatus for controlling the operation of a classifier in accordance with the size of particles of a predetermined zone of said classifier, comprising a pair of rollers movable toward and away from each other in accordance with the size of particles passing between said rollers; means for rotating said rollers in opposite directions; an electrical switch constructed and arranged to be opened and closed in accordance with the distance between said rollers; means for regulating the supply of dilution water to said

classifier; a reversible motor for controlling said regulating means; a pair of transformers having primary windings in series with said switch; a heating element in series with the secondary of each transformer; a heat responsive indicator actuated by one heating element; a thermal switch having a heat responsive contact carrying arm and a flexible contact carrying arm, said heat responsive arm being adapted to be moved toward and away from the flexible arm in accordance with heat produced by the other heating element; a cam for periodically moving said flexible arm toward said heat responsive arm to close said contacts; means for adjusting the relative position of said thermal switch with respect to said cam; a relay coil in series with said thermal switch; a double throw switch normally closed in a first position and movable to the opposite closed position upon energization of said coil, said switch being in series with the forward winding of said reversible motor when in said first closed position and in series with the reverse winding of said motor when in the opposite closed position; a quick-acting switch in series with a common lead of said motor windings; cam actuated means for periodically opening and closing said quick-acting switch; and means for adjusting the relative periods during which said quick-acting switch is open and closed.

6. Control apparatus responsive to the size of particles carried by a liquid, comprising a pair of rollers immersed in said liquid and movable toward and away from each other in accordance with the size of particles passing between said rollers; parallel shafts for rotating said rollers in opposite directions; means for rotating one of said shafts; a pivotal mounting for the other of said shafts; a pair of engaging gears on said shafts; an arm attached to said pivotal mounting; an electrical switch constructed and arranged to be opened and closed in accordance with the distance between said rollers, one contact of said switch being mounted on said arm; and means for adjusting the position of the opposite contact of said switch to regulate the amount of separation of said rollers required to open said switch.

7. Apparatus for controlling a grinding circuit which includes a mill and a classifier, said mill being of a type in which the load and output each decrease upon an overload, comprising means for regulating the feed to said mill; means for regulating the feed of dilution liquid to said classifier; electrically operated means responsive to the power requirements of said classifier for controlling said mill feed regulating means; electrically operated means responsive to the power demands of said mill and associated with said electrically operated means responsive to the power requirements of said classifier for stopping said mill feeding means a predetermined period and reversing the regulation of said mill feed upon an overload on said mill; and means responsive to the size of particles in a predetermined zone of said classifier inclusive of a pair of rollers submerged in said liquid and movable toward and away from each other in accordance with the size of particles passing between said rollers for controlling the flow of liquid into said classifier.

8. Apparatus for controlling a grinding mill and a classifier in series, comprising electrically operated means including a reversible motor for regulating the feed of solids and liquid to said mill; an electric motor for furnishing motive

power to said classifier; a transformer responsive to the current drawn by said classifier motor; means for causing successive reversals in small substantially equal increments of said reversible motor during normal operation of said mill and classifier; and electrical means operable by current produced by said transformer for increasing the increments in one direction to effect an increase in the feed to said mill upon a decrease in current required by said classifier motor, and for increasing the increments in the opposite direction to effect a decrease in the feed to said mill upon an increase in the current required by said classifier motor.

9. Apparatus for controlling a grinding mill and a classifier in series, comprising means for supplying basic water requirements to said classifier; means for supplying additional water to said classifier; electrically operated means, including a reversible motor, for regulating the feed of solids and liquid to said mill; an electric motor for furnishing motive power to said classifier; a transformer responsive to the current drawn by said classifier motor; means for causing successive reversals in small substantially equal increments of said reversible motor during normal operation of said mill and classifier; electrical means operable by current produced by said transformer for increasing the increments in one direction to effect an increase in the feed to said mill upon a decrease in current required by said classifier motor and for increasing the increments in the opposite direction to effect a decrease in the feed to said mill upon an increase in the current required by said classifier motor; means responsive to a condition of the pulp in said classifier; and means actuated by said responsive means for controlling said additional classifier water supply means.

10. Apparatus for controlling a grinding mill and a classifier in series, said mill being of a type decreasing in capacity upon overload, comprising electrically operated means including a reversible motor for regulating the feed of solids and liquid to said mill; a conveyor for carrying solids to said mill; an electric motor for furnishing motive power to said classifier; an electric motor for furnishing motive power to said mill; a transformer responsive to the current drawn by said

classifier motor; means responsive to the current drawn by said mill motor; means for causing successive reversals in small substantially equal increments of said reversible motor during normal operation of said mill and classifier; electrical means operable by current produced by said transformer for increasing the increments in one direction to effect an increase in the feed to said mill upon a decrease in current required by said classifier motor and for increasing the increments in the opposite direction to effect a decrease in the feed to said mill upon an increase in the current required by said classifier motor; and means controlled by said mill motor current responsive to means for stopping the feed of solids to said mill for a predetermined interval upon an overload on said mill.

11. Apparatus for controlling a grinding mill as defined in claim 9 wherein said responsive means is inclusive of a pair of rollers submerged in said liquid and movable toward and away from each other according to the size of particles passing between said rollers and wherein the means actuated by said responsive means is actuated according to the amount of separation between said rollers.

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