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APPARATUS FOR CONTROLLING THE FEED
TO A MILL IN A GRINDING CIRCUIT

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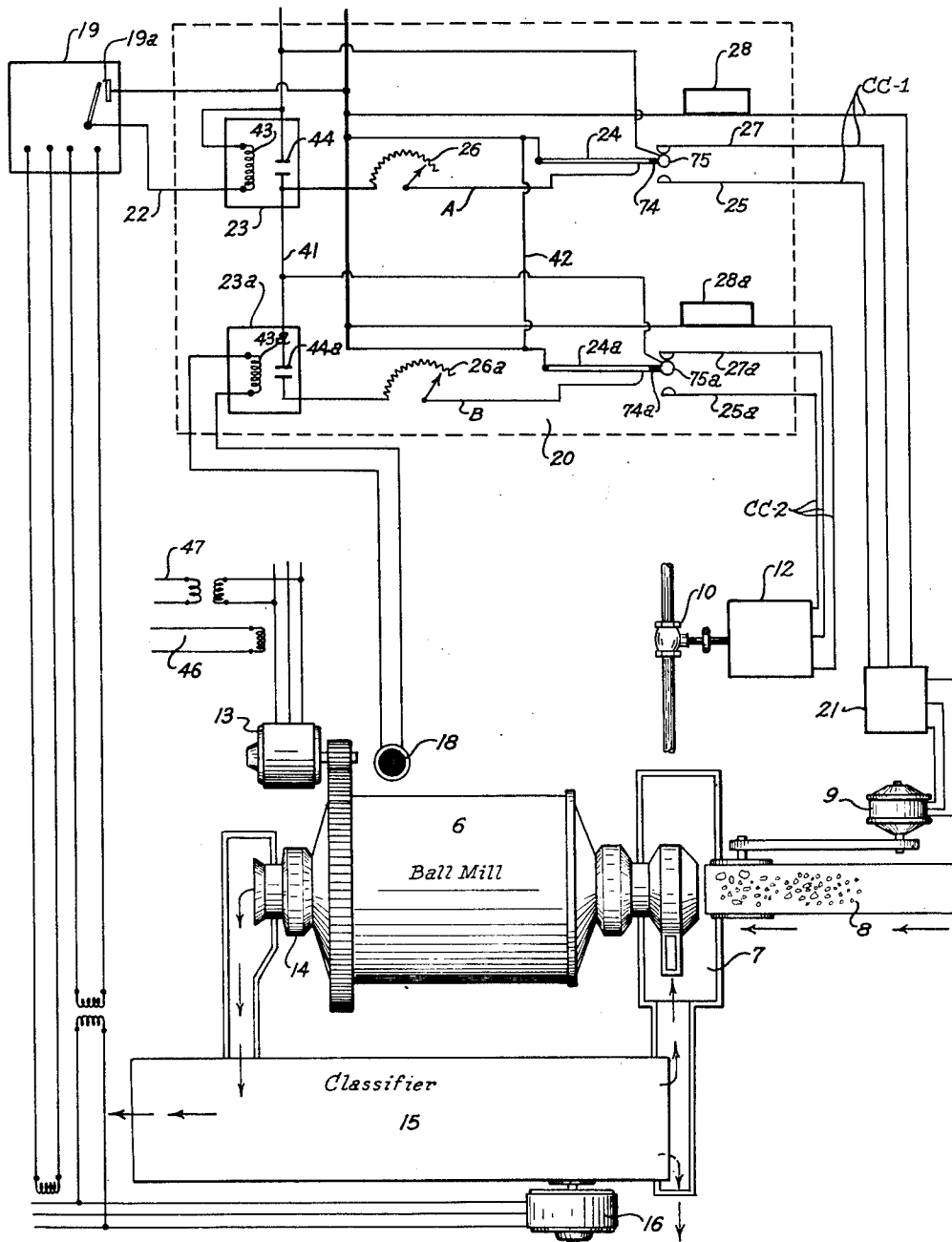


Fig. 4

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APPARATUS FOR CONTROLLING THE FEED
TO A MILL IN A GRINDING CIRCUITJames A. Adams, Denver, Colo., assignor to The
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1

This invention relates to the control of grinding circuits and the like, and more particularly relates to an automatic control for determining the amount of feed required in a mill and for supplying the determined amount thereto.

The present invention is related to and is an improvement upon the invention described and claimed in my U. S. Patent Number 2,240,822, and utilizes the same principle of determining mill requirements. This invention also regulates water supply and ore or solids feed to the mill, but the means of determining requirements and of operating controls have been simplified and improved.

In ore dressing operations, the mine ore is crushed and then introduced into a grinding circuit where it is reduced to a sufficient degree of fineness to unlock the valuable constituents of the ore from the waste rock or other gangue matter with which they have been associated in its natural formation. Frequently, such reductions include the unlocking of one mineral from another, as well.

These separations and similar grinding treatments often require a reduction to a very fine state, such as a —200 mesh product, for example. In order to prevent excessive slime formation and to obtain more efficient grinding such operations frequently are performed in closed circuit with a classifier. The ore or other solids reaching a suitable state of fineness is passed from the circuit, while the oversize is recirculated through the grinding stage until a satisfactory reduction is obtained.

In such operations it is necessary to regulate the amount of new ore feed to the requirements of the grinding circuit, as well as maintaining a desired water to solids ratio. Ores vary widely in hardness and coarseness even when obtained from the same mine or the same area of a mine, and when custom work is done an even wider variation in these factors will occur in the ores from different mines.

The amount of ore that the mill can grind depends on the hardness and coarseness of its feed and the fineness of the finished product. The grinding capacity of the mill changes with variations in these factors. When the mills are manually controlled, the operator watches the mill power meter and listens to the sound of the mill,

2

and he bases his adjustments on these two factors.

If the mill power is high and the mill is noisy, he increases the ore feed, and perhaps the water as well. If mill power is low and the mill is relatively quiet, he reduces the feed rate. When the mill is noisy and power is low, the operator knows there is too much water and not enough ore in the mill, while a relatively quiet mill with high power consumption indicates a need for more water and less ore.

The operator also watches the amount of oversize being raked back by the classifier for regrinding. If the amount of oversize appears to be more than the rakes can effectively handle, the operator reduces feed to the mill and in this way lessens the amount of unfinished product fed to the classifier by the mill.

It is an object of the present invention to provide simple, durable and efficient mechanism for detecting variations from optimum condition within a mill and restoring the mill operation to said optimum condition.

Another object of the invention is to provide an automatic mill control which remains inactive so long as operating conditions are maintained within a predetermined efficiency range, and which operates instantly whenever variations outside said range occur to restore the operation within said range.

Other objects reside in novel details of construction and novel combinations and arrangements of parts, all of which will be described in the course of the following description.

The accompanying drawings illustrate typical installations embodying features of the present invention, and in the drawings in the several views of which like parts have been designated similarly,

Figure 1 is a diagrammatic view of one control circuit used in the practice of the present invention;

Figure 2 is another diagrammatic view illustrating another circuit, which may be used in conjunction with or independently of the circuit of Figure 1;

Figure 3 is a diagrammatic view of still another circuit used in the practice of the present invention;

Figure 4 is a flow sheet representation of a

3

closed circuit grinding operation to which the present invention has been applied, and

Figure 5 is another flow sheet illustrating another type of grinding circuit to which the present invention has been applied.

This present invention includes a number of distinct operating procedures and different arrangements of equipment for performing such operations. Despite this variety of arrangement, essential features of the functioning of the system are common to all forms.

Each of the controls requires that the solids feed to the mill be varied in accordance with changing conditions in the mill, and preferably involves changes in the water supply corresponding to the changes in solids feed. To attain such correction, some factor indicating mill output is measured for the purpose of initiating the operation of the control.

In addition to the regulation employed in my Patent No. 2,240,822, the present system includes: (1) factors for accelerating the control rate (up and down) when the mill operation is beyond the normal range; and (2) also includes the classifier motor power demand as an additional control factor, which may be used instead of the mill motor power demand if the mill operation is improved thereby.

In some plants, variations in the character of the material fed to the mill, occur so quickly that an overloaded mill condition may result, even though the controller is slowly reducing the amount going into the mill. Consequently, it will be desirable to stop the feed completely for a relatively short time to permit the mill to work out of the overloaded condition. Most of the time, however, a gradual controlled variation in the feed will take care of the mill's requirements. The present invention provides both gradual control and "off and on" control.

The thermal switch provides an effective means of obtaining the desired regulation, for it must heat or cool for a substantial interval before regulation begins. Other devices may be utilized to perform an equivalent function, such as a time delay relay, or even hydraulic or pneumatic control systems. However, the simplicity and efficiency of the thermal switch constitutes it a preferred unit under present conditions, for which reason other types of devices or systems have not been shown in the drawings.

With this understanding of the scope and purpose of the present invention, the arrangement of equipment illustrated in the drawings will be described now. Referring first to the flow sheet arrangement shown in Figure 4, a ball mill 6 of any suitable design is provided with a scoop 7 for the intake of crushed ore delivered by an endless conveyor 8 driven by a motor 9 preferably of the variable speed type. Water or other liquids used as a suspension medium for ore particles is delivered to mill 6 by a valve-controlled conduit 10, the valve of said conduit being controlled by a motor 12.

Mill 6 is driven by a motor 13 and the ground product of the mill passes from a trunnion discharge 14 into a classifier 15. The finished product overflows the classifier and is removed from the circuit, while raking mechanism (not shown) of any suitable type and driven by a motor 16 moves the oversize to an elevated point of discharge from which it passes into a launder 17 or other suitable conveyor for return to the mill 6.

The control mechanism of the present invention is connected in this grinding circuit to measure

4

either mill power demand, or classifier power demand, or both, as one factor indicating conditions in the mill, and mill sound as a second factor to be measured. To this end an acoustic switch or microphone 18 is employed to furnish an accurate record of mill sound and one or more power-responsive meters 19 measure the power demands of mill motor 13 or classifier motor 16, or both.

A control box 20 is placed in a convenient location adjacent mill 6 and is connected in circuit with the acoustic switch 18 and meter or meters 19, and also connects through control circuits CC2 and CC1 respectively, with the water-control motor 12 controlling the water supply and another control motor 21 regulating the solids feed, either by actuating the control mechanism of the variable-speed motor 9, or by raising and lowering a gate controlling the feed delivery. Motor 21 is reversible and is adapted to increase or decrease the rate of feed of ore to the mill by speeding up or slowing down mill feed motor 9.

Having thus described the arrangement of equipment, the circuit controlling these operations will be described now. As shown in Figure 1 the motor 13 is connected in circuit with a wattmeter 19 in the manner shown. Wattmeter 19 may be connected with motor 16 to Fig. 5 in the same manner. Whenever a decreased power demand indicating an overloaded condition is registered by the meter 19, the contacts 19a close so that control circuit 22 is closed and in turn closes relay 23 sending a current through a thermal switch 24, which is stronger than the current passing through the coil of relay 23 and the meter contacts. The latter current is relatively weak because of the high impedance of the coil of relay 23. This is desirable because the contacts 19a of watt meter 19 tend to open and close relatively slowly, so that a heavy current would tend to produce undue arcing and burning of contacts, together with chattering of relay 23.

When continued for a sufficient period of time or over a sufficient portion of time, such current causes the thermal switch 24 to bend until contact 75, which is insulated from thermal switch 24 by insulation material 74, comes into contact with the terminal of a wire 25 in a control circuit CC1. Contact 75 is connected to an external power source and wire 25 is connected to the reverse windings of motor 21, therefore, this closing of the circuit causes the motor 21 to turn in a reverse direction thereby causing mill feed motor 9 to slow down decreasing the rate of ore feed to the mill. Preferably a rheostat 26 is placed in series with the thermal switch to provide an adjustment for varying the current passing through thermal switch 24. A second wire 27 in control circuit CC1 is also connected through thermal switch 24, but to the opposite contact, and also connected with the forward windings of motor 21. The third wire of circuit CC1 is, of course, a common lead to both the forward and reverse windings of motor 21. When current passes through wire 27, the motor 21 turns in the forward direction to cause motor 9 to speed up, thereby increasing the rate of ore feed to the mill. The circuit through wire 27 thereby performs the reverse action of the circuit through wire 25.

The thermal switch 24 is a bi-metal strip which heats up and bends when sufficient current passes through it, and also bends in the opposite direction when no current passes through it and it cools. Therefore, any substantial variation from optimum conditions will actuate switch 24 to close the circuit through wire 25 or 27, but minor

5

fluctuations and substantial variations of short duration only, do not have sufficient effect on switch 24 to heat or cool the bi-metal strip sufficiently to induce movement to a circuit-closing position. Thermal switch 24a is similar to switch 24, bending in one direction to close the corresponding contacts, thereby closing the circuit through wire 25a upon heating. Similarly a timer control 28a is provided in this circuit, and this timer control 28a and wires 25a and 27a are included in a control circuit CC2 which is similar to control circuit CC1 of Fig. 1.

A second type of circuit has been illustrated in Figure 2. This circuit includes an acoustic switch or microphone 18 which picks up the sound of the mill and operates a relay 23a in accordance with sound variations of the mill. For example, a noisy mill will cause relay 23a to close and send a current through thermal switch 24a. Thermal switch 24a is similar to switch 24, bending in one direction to close the corresponding contact and close the circuit through wire 25a upon heating due to a larger current passing therethrough. Conversely, a smaller current passing through switch 24a will cause the switch to close the opposite contact, thus closing the circuit through wire 27a. Wires 25a and 27a are included in a control circuit CC2 which is similar to control circuit CC1 of Fig. 1, while rheostat 26a is utilized in the same manner as rheostat 26.

Under some conditions, it may be preferable to measure mill or classifier power demand alone, without including mill sound, in regulating mill feed. In such instances, the circuits of wires 25 and 27 are used to lower or raise the feed as dictated by the power demand by either the mill or classifier motors. The mill motor power demand rises as the mill becomes underloaded, up to a certain limit, and conversely the power demand falls as the mill approaches an overloaded condition. With the classifier the reverse is true. Leads 25 and 27 may be reversed to suit either the mill power demand or the classifier power demand.

However, for most purposes, it will be desirable to measure both mill sound and mill power demand or classifier power demand, and in such operations the circuits of Figures 1 and 2 will be combined as a unit, with the current passing through switch 24 governed by mill sound and power demand. These control elements may be correlated in a number of ways.

One method of control involves the use of circuit A as responsive to mill motor power demand controlling ore feed, while a second circuit B controls mill water feed. When the power demand is high, in this arrangement, contact points 19a of watt meter 19 will be opened and switch 24 will return to a position of contact with circuit 27 to raise the ore feed.

If the mill is noisy at the same time, the acoustic switch will send a current through circuit B including thermal switch 24a, which closes the circuit through wire 27a to decrease the water supply for a short time, or until the increasing feed quiets the mill to a point where the controller will increase the water. Each of the controls acts independently of the other in this arrangement, the one circuit controlling one feed element and the other controlling the other feed element.

Another method of controlling the system is shown in Fig. 4 in which the rate of feed to ball mill 6 and classifier 15 are regulated in accordance with the classifier power demand and the noise level of the ball mill. The circuit as here

6

represented is in general a combination of the circuits shown in Figs. 1 and 2 and incorporates the use of additional lines as necessary to accomplish the inner working of these previously described circuits. As shown in Fig. 4 the relays 23 and 23a are connected together by a line 41 and the heater circuits A and B controlled by rheostats 26 and 26a are interconnected by a second line 42. With these connections, the circuits previously described in connection with Figs. 1 and 2 will operate as follows:

Assuming that the feed to the ball mill 6 has been such that the classifier 15 becomes overloaded, the power demand of classifier motor 15 will be increased. This increased power demand will cause the contact points 19a of watt meter 19 to close, thereby energizing the coil 43 of relay 23. As the coil 43 is energized, relay contact points 44 will close and current will pass through heater circuit A causing thermal switch 24 to move downwardly into contact with the line 25. In this manner control motor 21 and feed motor 9 will be reversed and the feed to the ball mill 6 will thus be cut off whenever the power demand of the classifier 15 is increased. After the feed has been cut off, ball mill 6 will tend to unload.

When ball mill 6 has unloaded to the point where the noise level is substantially increased, the current in microphone 18 will energize the coil 43a of relays 23a, thereby closing contact points 44a. When contact points 44a are closed heater circuit B will be energized and line-current will pass through a secondary circuit inclusive of thermal switch 24a, line 42, and thermal switch 24. If the respective resistances of rheostats 26 and 26a are correctly adjusted this will cause the switch 24 to cool and thus return to its position of contact with line 27. When the contact point of thermal switch 24 is in contact with line 27, control motor 21 and thereby feed motor 9 will be re-energized to deliver material to ball mill 6.

It will thus be seen that when the circuits of Figs. 1 and 2 are interconnected as herein indicated by lines 41 and 42, a method of controlling a grinding circuit in accordance with classifier power and mill sound is provided.

If it is desired to control the grinding circuit in accordance with the mill power demand and mill sound, the current responsive circuit 46 and the voltage responsive circuit 47 will be connected into the watt meter 19. However it is to be understood that an increase in mill power demand should cause the contact points of watt meter 19 to open rather than close inasmuch as an increase in mill power demand is an indication of an underloading of the ball mill 6.

Figure 3 illustrates a circuit, inclusive of an alarm, which preferably is used in conjunction with the control circuits hereinbefore described. This emergency control circuit recognizes any abnormality in the mill power demand or mill sound and corrects to within a safe operating range, where gradual regulation can be made to approach optimum mill operating conditions.

Any abnormal change in mill sound or power demand sufficient to actuate the thermal switches 24 or 24a will also actuate another thermal switch 24x to close one or the other of two circuits 32 and 33 to operate an alarm 34a or 34b. At the same time the alarm 34a is operated, the closing of circuit 32 passes current through a relay 30 to break the circuit to the conveyor drive motor 9 stopping the feed completely. Similarly, closing of circuit 33 which includes alarm 34b will by-pass the timing device 28 to accelerate the rate of

change in feed to mill 6. The function of the timing device in this circuit is to control the rate of change in feed. However, when a substantial variation from the optimum condition range in the mill is detected by the mechanism, which condition actuates the alarm, then the timing device is by-passed, as aforesaid, to permit rapid regulation to correct the changed condition in the mill.

The mill sound in the above case acts as a regulator of the control rate, increasing or decreasing the rate at which the feed rate is changed. The power responsive control element effects either an increase or decrease, but the sound responsive element indicates how much.

The circuit of Figure 3 also may be adapted to utilize the aforementioned cumulative effect on the control. While it has been illustrated as a separate circuit for clarity of description, in actual practice it would be combined with the circuit of Figure 1 and the thermal switches 24 and 24x of the respective circuits would be replaced by a single thermal switch 24.

With such an arrangement, when the thermal switch 24 is cold, it indicates that mill power is down and the mill is overloaded, while a quiet mill represents an overloaded condition. With both the factors of power demand and mill sound indicating an overloaded mill, circuit 32 will close and ring an alarm 34a and also open the circuit connected to the motor driving the conveyor belt 8.

This operation stops the feed entirely and permits the mill to unload in the shortest possible time. Conversely, if mill power is up and the mill is very noisy, circuit 33 will be energized, which also rings an alarm and by-passes a timer to increase the feed rate continuously until such time as the mill is fairly quiet again and within the normal operating range. At such time, the feed rate is slowed by the timer 28, and in effect, the feed rate not only is changed, but the amount of change is under control.

Still another arrangement of the circuits permits the "sound" circuit of Figure 2 to be used alone in the regulation of the water supply. In this circuit, changes in mill sound are registered through switch 24a, and the circuits of wires 27a and 25a are used to decrease or increase the water supply in accordance with the measured changes.

Another type of grinding circuit in which the control of the present invention may be utilized has been illustrated in Figure 5. In this arrangement, classifier power demand is the sole factor measured to regulate mill feed. A ball mill 6, driven by motor 13 is arranged to deliver ground ore to a classifier 15 and the overflow from the classifier passes from the circuit.

The raked product of the classifier is conducted to a tube mill 31 for further reduction. The classifier power demand is registered by a meter 19 in circuit with a control box 20 and a variable-speed motor 9 driving the ore feeder 8 which supplies mill 6.

The control circuit in this arrangement is essentially the same as shown in Figure 1 and regulates ore and water input to mill 6 in accordance with variations in the classifier power demand. As an optional arrangement, a portion of the raked product of the classifier may be recirculated through mill 6 as indicated by the dotted line representations.

From the foregoing examples, it can be seen that the controller system is flexible and uses sound and power together to produce certain con-

trol effects or they may be used independently to achieve control, one working on mill water and the other on the ore. Or it is also possible to achieve limited control by using the power demand of the classifier motor to control the mill feed. This power demand rises or falls depending on the amount of unfinished product the classifier returns for regrinding. An excessive return indicating the approach of an overloaded mill condition or conversely, a small return indicates that the mill is not being fed sufficient ore, and that it is operating under capacity.

Summarized then, it is possible, by the use of the controller described, which is responsive to the sound of a mill, the power demand of a mill, or the power demand of its classifier, to control the ore feed and water feed to the mill from a common control which regulates both the ore and water at the same time and in the same direction, or to use one factor to control the water, and the other control the ore feed. Or, if found desirable, one factor only may be used to control both ore feed and water feed.

It has been found in practice that when both ore feed and water feed are automatically raised or lowered simultaneously, the proportion of water to ore may not be correct at the various rates. Consequently, some time must be spent experimenting with the grinding circuit to obtain the correct ore-water ratio for the various feed rates. In an effort to reduce the time necessary to adjust the controller to the circuit, it is advisable to design the controller circuits so that the sound responsive circuit would control the water, and the power responsive circuit control the ore. Using this method, it is much simpler to adjust the controller to the grinding circuit.

For example, a noisy mill operation will always be improved by reduction in the water feed, notwithstanding the fact that the power control circuit may be increasing the ore feed, which will in itself have the effect of quieting down the mill by thickening up the ore-water mixtures. When the increased ore feed rate quiets the mill beyond a certain point, the water will then increase again until the proper sound level is reached.

From the description, it can be seen that sometimes both water and ore feed rates will increase together, while at other times they may temporarily move in opposite directions. It should be noted, that in this type of control the power control circuit is the dominant one, raising or lowering the ore feed rate. The sound control circuit then follows with water control to suit the ore feed requirements, since the noise emanating from the mill depends to a great deal on the consistency of the pulp in the mill. This method then has the added function of automatic proportioning of the two feed elements, water and ore.

While the invention has been described with particular reference to ore treatments, it has application to other grinding circuits treating materials other than ores, such as cement plant operations, for example. Also, while illustrated as applied to wet grinding treatments, the circuit may be used with mills employed in dry grinding treatments. In such a case, the ore feed will be regulated in the manner hereinbefore described.

The present arrangement of equipment is particularly valuable in that the control does not correct for minor fluctuations from the optimum condition within the mill, but whenever a substantial change occurs which would impair mill efficiency, the control operates to restore the mill conditions

within the prescribed range. In this way efficient operation is maintained throughout a continuous treatment period.

The arrangements of equipment illustrated in the drawings are intended as typical examples and changes and modifications may be availed of within the scope of the hereunto appended claims.

What I claim and desire to secure by Letters Patent is:

1. In an automatically controlled grinding circuit, inclusive of a grinding mill and an element associated with the mill and arranged to indicate variations in the output of said mill, a classifier in circuit with the mill and an element associated therewith and arranged to indicate variations in the classifier power demand, means for supplying solids to be reduced to the mill, a control member for increasing the rate of feed to the mill, a second control member for decreasing the rate of feed to the mill, a microphone associated with the mill and adapted to register changes in mill sound, an electric circuit including the indicating elements, the microphone and said control members, a thermal switch in said electric circuit responsive to the indicated variations in classifier power demand and mill sound and arranged to change the rate of or stop the feed to the mill by one or the other of said control members, and a regulating mechanism associated with the thermal switch in said circuit to control the stopping or amount of said change in the rate of feed.

2. In an automatically controlled grinding circuit, inclusive of a grinding mill and an element associated with the mill and arranged to indicate variations in the output of said mill, a classifier in circuit with the mill and an element associated therewith and arranged to indicate variations in the classifier power demand, means for supplying solids to be reduced to the mill, a control member for increasing the rate of feed to the mill, a second control member for decreasing the rate of feed to the mill, a microphone associated with the mill and adapted to register changes in mill sound, an electric circuit including the indicating elements, the microphone, and said control members, a thermal switch in said electric circuit responsive to the indicated variations in classifier power demand and mill sound and arranged to change the rate of or stop the feed to the mill by one or the other of said control members, and a regulating mechanism including a signaling device associated with the thermal switch in said circuit to control the amount of said change in the rate of feed.

3. In an automatically controlled grinding circuit, inclusive of a grinding mill and an element associated with the mill and arranged to indicate variations in the output of said mill, a classifier in circuit with the mill and an element associated therewith and arranged to indicate variations in the classifier power demand, means for supplying solids to be reduced to the mill, a control member for increasing the rate of feed to the mill, a second control member for decreasing the rate of feed to the mill, a microphone associated with the mill and adapted to register changes in mill sound, an electric circuit including the indicating elements, the microphone, and said control members, a thermal switch in said electric circuit responsive to the indicated variations in classifier power demand and mill sound and arranged to change the rate of feed to the mill by one or the other of said control members, and a regulating mechanism associated with the ther-

mal switch in said circuit and arranged to stop the feed to the mill by said supply means when the mill is overloaded.

4. In an automatically controlled grinding circuit, inclusive of a grinding mill and an element associated with the mill and arranged to indicate variations in the output of said mill, a classifier in circuit with the mill and an element associated therewith and arranged to indicate variations in the classifier power demand, means for supplying solids to be reduced to the mill, a control member for increasing the rate of feed to the mill, a second control member for decreasing the rate of feed to the mill, a microphone associated with the mill and adapted to register changes in mill sound, an electric circuit including the indicating elements, the microphone, and said control members, a thermal switch in said electric circuit responsive to the indicated variations in classifier power demand and mill sound and arranged to change the rate of feed to the mill by one or the other of said control members, and a regulating mechanism associated with the thermal switch in said circuit and arranged to stop the feed to the mill by said supply means when the mill is overloaded and to resume the feed by said supply means thereafter in accordance with the resulting change in conditions in the mill.

5. A grinding circuit comprising a rotary grinding mill, a classifier in the grinding circuit disposed to receive the output of the mill, an electric motor in driving connection with the classifier, conveyor means for delivering a solids feed to the mill, valve-controlled conductive means for delivering a liquid to said mill, a variable speed motor in driving connection with said conveying means, a reversing motor in actuating relation to the valve in said conductive means, means responsive to changes in classifier power demand, means responsive to changes in mill sound, an electric circuit connecting said means responsive to the classifier power demand, said means responsive to the mill sound, the variable speed motor and the reversing motor, and thermal switch means in said electric circuit connected to said means responsive to changes in classifier power demand and said means responsive to mill sound to thereby vary and stop the solids feed and the liquid input to said mill.

6. In an automatically controlled grinding circuit, inclusive of a grinding mill and a classifier in circuit therewith, means for supplying solids to be reduced to the mill, means for supplying a fluid suspension medium to the mill, means responsive to the power demand of said mill, means responsive to the power demand of said classifier, acoustic means responsive to the sound of said mill, thermal switch means, an electric circuit selectively connecting said means responsive to the power demands of the mill and classifier and said means responsive to the sound of the mill to said thermal switch means, said switch means being actuated by said means responsive to the power demands of the mill and classifier and the sound of the mill, and means in said circuit arranged to selectively control the rate of the solids supply to the mill in response to actuation of said thermal switch by changes in mill or classifier power demands or mill sound.

7. In an automatically controlled grinding circuit, inclusive of a grinding mill, and a classifier arranged in circuit therewith, means for supplying solids to be reduced to the mill, means for supplying a fluid suspension medium to the mill, means responsive to the classifier power demand,

11

acoustic means responsive to the mill sound, thermal switch means, an electric circuit selectively connecting said means responsive to the classifier power demand and said means responsive to the sound of the mill to said thermal switch means, said switch means being actuated by said means responsive to the classifier power demand and the sound of the mill, and means in said circuit arranged to selectively control the rate of solids supply and fluid supply to the mill in response to actuation of said thermal switch means by changes in classifier power demand and mill sound.

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