

March 25, 1941.

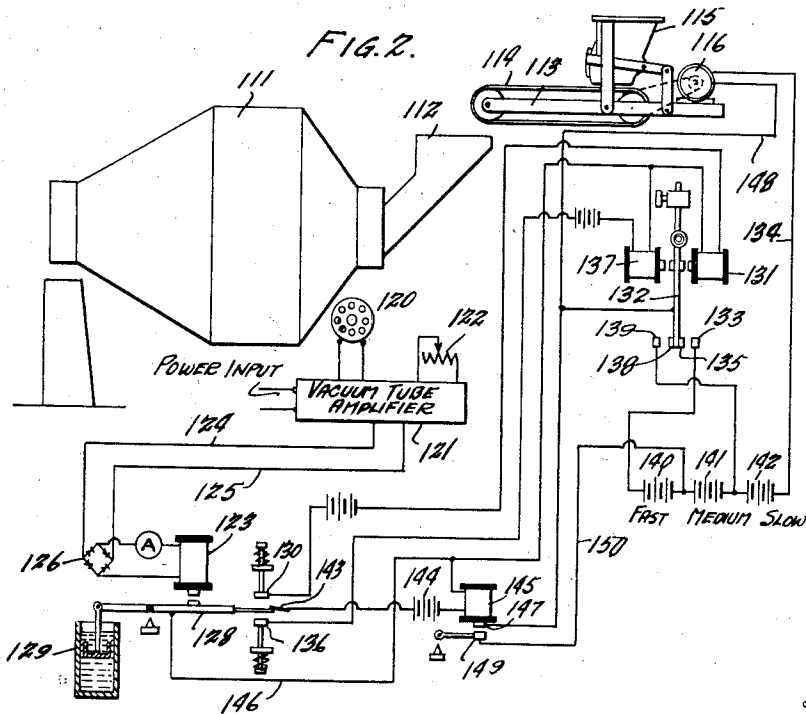
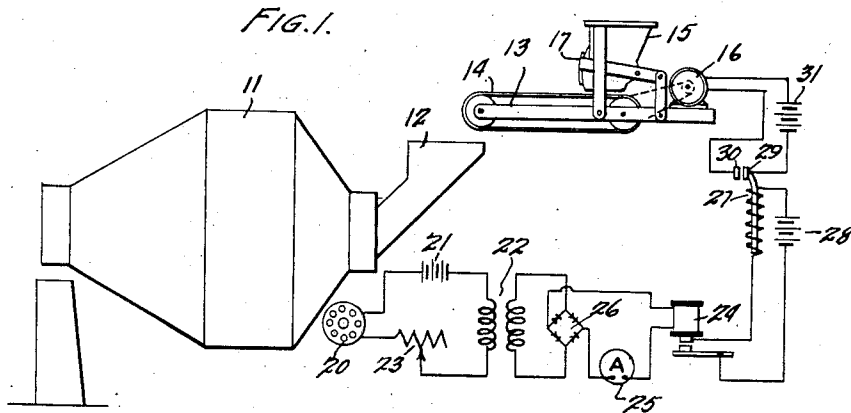
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2,235,928

APPARATUS AND METHOD FOR CONTROLLING GRINDING DEVICES

Filed Jan. 4, 1939

2 Sheets-Sheet 1



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2,235,928

APPARATUS AND METHOD FOR CONTROLLING GRINDING DEVICES

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2 Sheets-Sheet 2

FIG. 3.

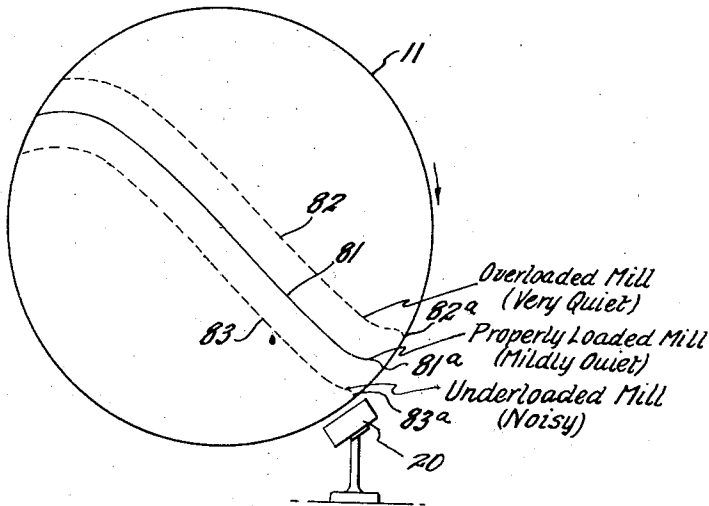


FIG. 4.

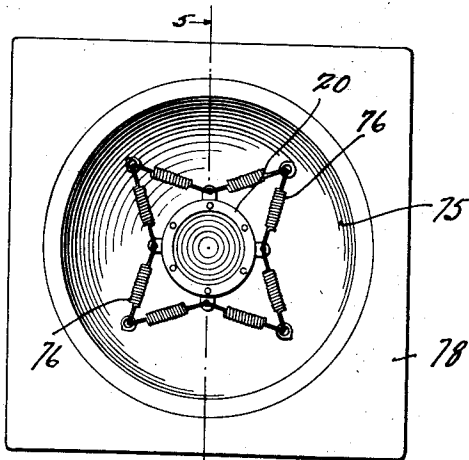
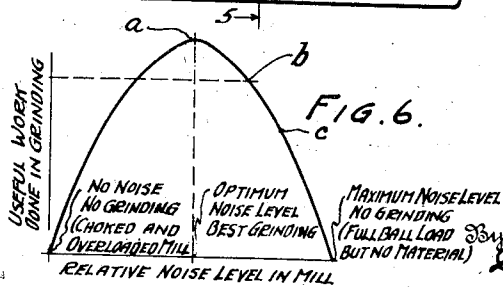
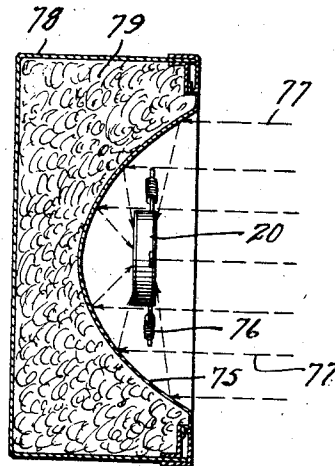


FIG. 5.



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UNITED STATES PATENT OFFICE

2,235,928

APPARATUS AND METHOD FOR CONTROLLING GRINDING DEVICES

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Application January 4, 1939, Serial No. 249,291

10 Claims. (Cl. 83—44)

This invention relates to controlling systems, and more particularly to controlling systems for power driven mechanisms. This is a continuation-in-part of my co-pending application Serial No. 110,207, filed November 11, 1936.

It is well known that in devices, such as grinding mills, crushers, dryers, mixers, and other apparatus, the operation is often regulated by an operator in accordance with the sound produced by such devices. For instance, an operator often regulates the operation of a ball mill by the sound produced by the balls. That is to say, in most cases, during normal operation of a ball mill, the noisier the mill is, the less it is being fed with fresh material. There is an optimum point of noise level where best grinding occurs. If a ball mill becomes too quiet, the balls are either coated or spaced apart and the capacity of the mill is reduced considerably. Conversely, where there is an excessive amount of noise in a ball mill, the mill is underloaded, the balls hit themselves and the lining of the mill, and create an excess sound.

Heretofore the operator of a mill, or other similar device, has endeavored to manually regulate the mill to secure the optimum noise level, as above indicated, where best grinding occurs. However, manual operation can only roughly approach such optimum point in view of the fact that slight deviations from the optimum sound level materially reduce the efficiency of the grinding, and the human ear is not sufficiently sensitive to detect such slight variances.

Even if such optimum noise level were secured, it would be impossible for an operator to manually maintain the mill running at a constant noise level, for noise meters will indicate relatively wide fluctuations in noise levels where even the most efficient operator believes that he is maintaining a constant level. Furthermore, these fluctuations are due to frequent changes in the feed size, grindability, moisture content, etc., from time to time, and, even if the operator were able to audibly detect such changes, it would be impossible to regulate the feed manually to follow all such changes as soon as they occur.

An object of the invention is to provide means for automatically controlling the rate of feed of material to a mechanism by the sound produced by the mechanism.

Another object of the invention is to provide a means for controlling a feeding device of a mechanism which is actuated by varying degrees in noise level produced by the mechanism, so

that substantially constant conditions are maintained by said mechanism.

Yet another object of my invention is to provide a feed control system for a grinding mill and the like, which includes means for regulating the sound level set up by the mill.

A further object of my invention is to provide a method and means for accurately determining and securing the optimum grinding conditions of a mill or the like, and for thereafter causing the mill to operate at such condition.

A still further object is to provide a sound sensitive device of improved construction for a control system of the above type and to so locate such device as to secure maximum sensitiveness.

With the foregoing and other objects and advantages in view, the invention consists in the construction and arrangement of the several parts which will be hereinafter more fully described and claimed.

In the accompanying drawings:

Figure 1 is a circuit diagram of a controlling device or system disclosing one embodiment of the invention, said device being shown in association with a well known type of ball mill.

Figure 2 is a view similar to Fig. 1, of another embodiment of the invention.

Figure 3 is a diagrammatic sketch showing the preferred location of the microphone with respect to the mill.

Figure 4 is a frontal elevational view of a microphone arranged within its housing.

Figure 5 is a view taken along the line 5—5 of Figure 4 looking in the direction of the arrows and showing diagrammatically the reception of noise waves and vibrations.

Figure 6 is a graph depicting the relationship existing between the noise level of an operating mill and the efficiency of its operations.

Referring to the drawings, and especially to Fig. 1, the ball mill 11 has a feed hopper 12 at one end, into which is delivered material to be ground in the mill, from a feeder 13 of well-known type.

The feeder 13 has an endless belt 14 which carries the material discharged from a hopper 15 to the hopper 12, said belt being driven by an electric motor 16.

The rate at which the material flows from the hopper 15 on to the belt 14 is controlled by a swinging gate 17 which is adapted to be adjusted to vary the size of the discharge opening of the hopper 15.

During operation, the ball mill 11 rotates at a predetermined speed and the feeder device 13

is adapted to supply the mill with fresh material at a rate equal substantially to the rate at which the ground or pulverized material leaves the mill, so that the mill will operate at maximum capacity. Specifically, the rate at which the feeder delivers material to the hopper 12 may be varied in several ways, depending upon the particular type of feeder and actuating means therefor. In Figure 1, I have shown a feeder in which, when regulated by my control system, the belt operates at a constant speed, and, with the gate 17 set for a given discharge opening, the quantity delivered to the hopper 12 is varied by intermittently operating the belt. Of course, the feed could be controlled by continuously operating the belt 14 at a constant rate and adjusting the gate 17 to control the amount of material deposited on the belt 14.

Since sounds are produced by a ball mill and the like, and since these sounds vary according to the manner in which the mill is operating, by this invention I propose to employ the sounds to control the operation of the mill, particularly the rate of feed to the mill. The mill or the like may also vibrate according to the manner it is operated and these vibrations may likewise be used for the same purpose.

Located adjacent to the mill 11 is a microphone 20. The microphone may be sensitive to vibrations, sound waves, or both, and adjusted to pick up and handle all character of conditions prevailing at the mill 11, such as vibrations produced by the mill, reacting on the foundations or other parts of the apparatus, which will cause a change in electric current, similar to that produced in a telephone or microphone pick-up of an amplifier or vibration sensitive device, along the same general principles.

In a simple form, the microphone circuit utilizes a source of electric current, such as a battery 21, the primary winding of a transformer 22, and a variable resistance 23.

The output side of the transformer 22 is in circuit with a relay 24 and an indicating device, such as an ammeter 25.

I have also shown a rectifier 26, so that direct current is supplied to the relay 24 and ammeter 25 to take advantage of better operating characteristics of the relay and ammeter where such a condition is desirable. The relay is adapted to operate at a definite energy level, and, while I have shown a conventional magnetic relay, it will be appreciated that a galvanometer relay, or any other type, may be used.

The actuating contacts of the relay 24 are in another circuit, in which is located a time delay resistance contactor 27, and a source of power such as a battery 28, or line current from a power line.

The contact points 29, 30, of the contactor 27 close the circuit in the control device or, as illustrated here, feeder motor 16, through a source of power, such as a battery 31.

If desired, the contactor 27 can operate other power relays or other control devices where the electric current is higher than the contact points 29, 30, are capable of handling properly, but for the purpose of illustration, the arrangement shown here is all that is necessary, as I have found by actual practice, when controlling a circuit including a small motor used to drive the feeder.

Since the noise of a ball mill or any similar device is somewhat irregular, there is quite a wide fluctuation in the instantaneous power in

the relay circuit. In order to prevent damaging of the feeder motor 16 and other parts of the power circuit, by a rapid succession of on and off positions until the system is definitely over on one side, or the other, the time delay resistance contactor device 27 having a thermal element is employed, so that while the relay 24 flutters constantly, the contactor 27 will not close the contacts 29, 30, until the contacts of the relay 24 are closed for a sufficient length of time to generate enough heat in the thermal element 27 to close the contacts 29, 30.

Thus, instead of having the power of the feeder motor 16 on and off many times a minute, depending upon the current in the relay 24, the time delay resistance contactor device 27 will smooth out this fluctuation to the desired point, so that the feeder 13 will be cut in and out over a much longer period of time, which can be adjusted by adjustment of the thermal element of the contactor 27.

I have found that satisfactory operation can be had if the thermal element of the contactor 27 is set so that it will function only after the circuit to it has been closed for a period of from a few seconds up to half a minute, although the time element in this case is not critical, so long as the power circuit is protected from too rapid make and break of contact. The time delay resistance contactor device 27 used is of standard design and construction well-known in the art.

Where more power to actuate the relay 24 and ammeter 25 is needed than is available from the circuit shown here, or a less sensitive relay is used, it may then be advantageous to use an amplifier between the microphone and relay circuit, which amplifier can be of the vacuum tube type, well-known in the art and need not be described here.

A complete cycle of operation of the mill, feeder, and control system will now be described. Assuming that the entire system is properly installed, and that the mill and feeder are not operating, the mill will initially be started and the feeder manually regulated to deliver the proper quantity of ore to the hopper 12, insofar as this quantity can be determined by the human ear. Examination of the mill operation in the conventional manner will determine whether such rate of feed is correct or whether variations in rate of feed should be made to improve mill conditions. As heretofore indicated, the gate 17 is adjustable, and therefore the regulation of the feed rate may be accomplished by running the belt 14 at a uniform speed and adjusting the gate 17, as is the preferable course, or a variation in feed may be accomplished by setting the gate 17 at a fixed point and varying the speed of the belt. A still further method is that accomplished by the present system—namely, setting the gate at a fixed point and intermittently operating the belt. However, the preferred form for manual operation is to operate the belt at a constant speed and regulate the gate 17 until the desired rate of feed is secured.

During this manual operation, the motor 16 is continuously operated by a source of current (not indicated in the drawings) independent of the control system, or, at any rate, the control system is not actually controlling the motor 16. However, even though the control system is not actually controlling the motor 16 as yet, the microphone and relay circuit, (and possibly time delay switch circuit) should be energized and

observations made for the subsequent operation of the feeder. The relay 24 is actuated when the current in the relay circuit is of some predetermined minimum intensity—say, 35 microamperes in the instant case. With the desired rate of feed attained manually as just described, it is therefore necessary to establish in the relay circuit a current of just 35 microamperes. However, the current which is established in the microphone circuit before adjustments are made will probably be somewhat different than the amount necessary to produce 35 microamperes in the relay circuit. The current in the relay 24 depends upon the resistance 23 in the primary circuit as well as the amount of noise picked up by the microphone 20, and therefore the resistance 23 will be adjusted to produce a current of 35 microamperes in the relay. The current passing through the relay 24 will be indicated by the ammeter 25, which has a graduated dial.

For instance, if the ammeter 25 indicates an average current in excess of 35 microamperes, with the desired conditions in the mill still being in effect and remaining constant for the time being, the resistance 23 in the microphone circuit must then be increased to decrease the current in the relay, and such resistance is gradually increased until an average current of 35 microamperes is established in the relay circuit. When the desired current is thus attained in the relay circuit, the control system is then cut into the motor 16, and the feeder 13 set so that, on constant operation, the amount of feed would be increased possibly 20% or more, or sufficient to insure a feed rate in excess of that the mill is capable of handling at any time due to variation in hardness, fineness, or other factors affecting mill operation.

This re-setting of the feeder is usually accomplished by increasing the gate opening or belt speed, and is necessary in view of the fact that, when automatically controlled, the feeder is intermittently operated. Consequently, it is necessary that, when the motor 16 is operating, the feeder must be delivering to the mill a quantity which, if the feeder were operating constantly, would be in excess of that desired for the operating conditions which had been manually established at the outset.

After the control system has been cut into the motor, the operating conditions which were initially established will be maintained within extremely narrow limits. In view of the fact that the feeder is now set to feed an excess quantity of ore, there is a tendency for the load in the mill to increase above the desired level, but the slightest deviation from such a level is reflected in the noise vibrations, and this tendency to increase the load and quiet down the mill is reflected by a drop in the sound energy picked up by the microphone, which in turn reduces the energy in the relay circuit causing the latter to open. When the time delay relay circuit is broken, the time delay relay 27 breaks the power circuit to the motor 16, thereby stopping the motor with consequent stoppage of feed. With this stoppage of feed, the noise level of the mill tends to increase, thereupon inducing greater energy in the microphone and relay circuit, and thus actuating the time delay relay 27 to start the motor 16 and re-commence the feed. In actual operation, it is found that the on-and-off periods of the feeder are of relatively short duration, due to the sensitivity of

the control system, and therefore uniform conditions within narrow limits are maintained.

An important feature of my invention resides in the fact that the control system not only normally maintains conditions within the mill constant, but also this system may be used to readily vary those conditions as may be necessary or desirable. Such a change in the operating conditions may be prompted by a difference in the type of feed, a difference in the product sought, wear of the grinding media, etc., but one of the most frequent reasons for changing the operating conditions is to secure precise optimum results. As mentioned above, the human ear is not sufficiently sensitive to determine what the precise optimum conditions are. As shown by Figure 6, which is a graph of an actual operation showing the relationship of the noise level in the mill to the useful work done in grinding, there is one best noise level for any given condition of feed, desired product, etc. This graph shows that the maximum noise level obtains when there is a full load of balls in the mill but no material, and consequently no grinding. At the other end of the curve it will be observed that there is no noise because the mill is choked and overloaded, and consequently no grinding takes place. From these two extremes, the curve ascends to a point *a*, which represents the optimum grinding for the conditions of feed, product, etc., which may be involved. It will be noted that this optimum noise level is a relatively sharp point, and can never be reached with certainty by the human ear when it is attempted to control the feed manually. As stated, Figure 6 represents an actual operation, in which case the point *b* was selected by the operator as the optimum noise level, and it was only after repeated trials and testing that the actual optimum level was plotted and found.

While I have referred to the point *a* as the optimum noise level, and while this does represent the noise level at which the maximum useful work is done, under some conditions it may be desired to operate the mill at a point other than *a*, for instance at some point such as is designated *c*. This, for example, might be the case where a change in fineness is desired at the sacrifice of capacity. It will, of course, be appreciated that this desired point then becomes, in effect, the optimum operating condition under such circumstances, and can be determined and maintained in the same way as above described with references to the point *a*.

In order to ascertain the optimum noise level, it is necessary to vary repeatedly the noise level which is initially established by manual control, and the present control system affords ready means for effecting such variations. For instance, if it is desired to operate the mill at a lower noise level, the resistance is decreased, which thereby increases the current in the microphone circuit and consequently in the relay 24. As a result of this, the relay 24 is actuated and this in turn closes the time delay switch 27 to actuate the motor. Due to the fact that the decreased resistance permits a greater current than before adjustment, the relay will consequently remain closed until the noise level of the mill is reduced to a point where it does not actuate the microphone sufficiently to generate a 35 microampere current in the relay circuit. As soon as this occurs, the relay 24 opens, opening the time delay relay 27 and cutting off the feed to the mill. The noise level of the mill then starts to rise.

As such rise continues, the microphone is sufficiently influenced to induce an excess of 35 microamperes in the relay circuit, whereupon the feed will be resumed.

5 The reverse of the operation just described takes place when it is desired to increase the noise level—namely, the resistance in rheostat 23 is increased, thus decreasing the energy in the relay circuit and opening the relay which stops
16 the feeder until such time as the noise level of the mill activates the microphone sufficiently to induce a 35 microampere current in relay 24.

It should be pointed out that, when the resistance is increased or decreased in order to
15 decrease or increase the noise level, the current in the relay will be initially varied accordingly, but when the new noise level is attained, the current will remain at about 35 microamperes. However, the resistance 23 is provided with an indicator that will show that a change in noise level
20 has taken place and can be used as a means of indicating the relative noise level of the mill by observing the position of the indicator.

While I have heretofore described a manual
25 regulation of the feed independently of the control system, the control system itself may be used to manually regulate the feed initially. When this is desired, the mill and feeder are started, and with the control system operatively
30 connected to the feeder, the operator then manipulates the resistance 23 over relatively wide ranges until he determines by the sound of the mill or the character of the product what he believes to be the optimum operating conditions.
35 From this point on, by "inching" the resistance, as just described, he can then determine the exact noise level for optimum operating conditions. When the manual control of the feeder is initially effected by use of the control system, as
40 just indicated, it is still necessary to adjust the gate 17 so that, upon constant operation of the belt, the mill would receive in excess of the amount of feed that would be needed at any time at the given setting of the control system.

45 Another alternate arrangement of a more complicated nature for obtaining intermediate control of operation, rather than simple on and off control of the feeder, is that shown in Fig. 2, in which the ball mill 111 and feeder 113 are of
50 the same general type as that shown in Fig. 1, the feeder being operated by an electric motor 116.

As shown in Fig. 2, a microphone 120, located near the mill 111 picks up noises which are amplified by a vacuum tube amplifier 121, having
55 suitable output control indicated at 122. The amplifier may be of standard construction and it is connected to a relay 123 by conductors 124 and 125. If the relay 123 requires D. C. current, a suitable rectifier 126 is connected to the circuit between the amplifier 121 and the relay 123, in the manner shown.

The relay 123 is adapted to control the operation of a galvanometer 128 of any approved
65 type.

As the noises will have sharp variations in intensity for any given average intensity, a dash pot 129 or some dampening device is employed to smooth out the peaks, or wide fluctuations in
70 current which occur, as previously described.

As the average intensity of noise increases, the galvanometer needle swings over until the upper contact 130 is reached. In this way the circuit of a relay 131 is closed and the relay magnet
75 pulls an overbalanced lever 132 to the right hand

contact 133, which closes the feeder motor circuit 134, and operates the feeder at the highest speed, since the maximum power is connected into the circuit, utilizing all three batteries, 140, 141, and 142, or other source of energy.

Since lever 132 is overbalanced, the contact 135 of said lever will remain over against contact 133, thereby keeping the feeder circuit 134 closed, even after the galvanometer circuit has been opened by lowering of the galvanometer needle 128 away from contact 130.

If so desired, the feeder circuit can be opened as soon as the relay circuit is opened, if the lever 132 is the type which will swing back to normal position, as shown in Fig. 2, as soon as the current ceases to flow in the magnet of relay 131. Such a lever is of the pendulum and not overbalanced type.

When the noise is low and galvanometer current low, the galvanometer needle will swing down and make contact with contact point 136. In this case, relay 137 will pull the lever 132 towards the left, so that contact 138 engages contact 139, thereby closing the feeder motor circuit, which includes battery 142 only. This
25 causes the feeder to run at a slow speed. This circuit will remain closed until the needle of the galvanometer 128 swings upwardly and away from contact 136.

It will also be understood that the relay circuit may sound an alarm, or make contact with other equipment effected by such changes in the operation of the mill 111.

As shown in Fig. 2, the galvanometer needle is in contact with a spring finger contactor 143, which is connected to a source of power such as a battery 144, said battery in turn having one terminal connected to a terminal of relay 145. The other terminal of battery 145 is connected to conductor 146, which connects the galvanometer
40 128 with terminals of the relays 131 and 137, respectively. Contact 147 of relay 145 is connected to one terminal of feeder motor 116 by conductor 148.

With finger contactor 143 engaging the galvanometer needle the contact point 147 of relay 145 engages contact 149, which is connected to one terminal of battery 141 by conductor 150, so that the feeder motor circuit 134 is closed
50 through batteries 141 and 142, and the feeder is then operated at its medium or normal rate.

In this way it will be noted that the operation of the feeder 113 can be so controlled that the feeder will operate at varying speeds in accordance with variations in amount of noise emanating from the mill as picked up by the microphone 120, and should the mill become overloaded, the feeder will operate at low speed, or if the mill should become underloaded, the feeder will be
60 speeded up to increase the feed to the mill.

It will be understood that the dash pot 129 takes the place of the time delay resistance contactor 27, previously described, so that the power circuit is protected from too rapid make and
65 break of contact.

In Figures 1 and 2, I have merely shown the microphone 20 and 120 diagrammatically. While my invention may be practiced with a microphone of any desired construction and placed at any
70 convenient location with respect to the mill, I have found that decidedly improved results may be obtained when the microphone is provided with a shield to prevent extraneous noises registering on the microphone, and where the micro- 75

phone is positioned adjacent the mill and below the point of maximum impact for any loading.

As best shown in Figures 4 and 5, I prefer to suspend the microphone designated 20 at the focal point of a parabolic reflector 75. Suitable springs 76 may serve as suspending means, and as best shown in Figure 5, the specific location of the microphone with respect to the reflector is at the focal point of the latter, as indicated by the arrows 77 representing the incoming sound or vibration waves. It will be appreciated that the provision of such parabolic reflector, and the position of the microphone at its focal point, insures the maximum reception of sound vibrations which emanate directly in front of the microphone.

To prevent the reception of any extraneous vibrations, or noises, such as from adjoining mills, or other equipment, I provide a dust-proof and water-proof shield for the microphone and reflector. This shield is composed of a casing 78 and insulating material 79 intermediate such casing and the parabolic reflector 75. This insulating material 79 serves to prevent any vibrations, except those emanating directly in front of the microphone, from reaching the microphone. In addition to the protection afforded by this shield around the microphone, a covering or fabric or other material permitting the passage of sound therethrough may be placed over the front of the shield to protect the microphone from dust, moisture, or other injury.

With regard to the relative location of the microphone and mill, I have found that improved results are obtained when the microphone is located on that side of the mill toward which the ore and balls drop, and below the point at which the mass impacts the mill when the mill is operating with the smallest load that would be encountered.

In Figure 3, I have diagrammatically shown a mill and a microphone so arranged. In this figure the mill is designated generally by 11 and the microphone by the numeral 20. The solid line 81 represents the outline of the charge and grinding media when the mill is rotating in a clockwise direction and is properly loaded. The dotted line 82 represents such outline of an overloaded mill, and the dotted line 83 represents the outline of the contents of an underloaded mill. The respective points of impact of the falling masses are at 81a, 82a and 83a.

It will be noted that the microphone 20 is positioned below the zone of impact of an underloaded mill, and is so positioned for the following reasons: The activation of the microphone is a function of the noise generated by the mill and also the position of the microphone with respect to such noise. In turn, the noise generated by the mill is a function of the degree to which the mill is loaded.

As heretofore pointed out, in general, the noise of a mill decreases as the load is increased, and, conversely, the noise increases as the load is decreased. If the microphone were positioned above the zone of impact when the mill is running with its minimum load, then, as the load is increased, the general noise level of the mill is decreased, but the diminished reaction of the microphone thus caused by the increased noise level tends to be offset by the fact that the zone of noise, though decreased, is brought nearer to the microphone. This is due to the fact that with an increase in the load of the mill the volume of the contents increases, as indicated by the

lines 83, 81 and 82, and the zone of impact rises on the periphery of the mill, which, with the microphone so positioned, approaches the microphone.

In such a situation the approach of the zone of impact toward the microphone works against the decrease in general noise level, and the net result would be a sluggish activation of the microphone or even erroneous results within certain limits, and in general a much greater change in noise level, or loading of the mill, would be necessary in order to produce a different effect on the microphone.

However, as opposed to the above, when the microphone is located further down the mill shell so that the zone of impact is always above the microphone, as shown in Fig. 3 to be below the point 83a, the point of maximum noise on the shell moves away from the focal point of the microphone when the mill starts to load up and thereby decreases the noise level, thus insuring a dual action which increases the effective sensitivity of the microphone and consequent improvement of operation of the entire control system.

While I have described above the preferred location of the microphone, whereby it is positioned immediately below the zone of maximum impact of an underloaded mill, mention might be made of the fact that, if the microphone is positioned at any point along the arc that is defined by the contents of an unloaded mill, better results are secured than if located elsewhere.

In the previous description I have used the operation of a ball mill to show how my invention functions in one of its many forms. It will be noted that an increase in the noise in a ball mill is the indication of an underfed or underloaded machine. The reverse may be true if my invention is used in connection with some other machine, such as a jaw crusher, for example, since in this case the vibrations or sound emanating from a crusher increase as the feed increases within certain limits, then by reversing the operation of my control device the desired results can be secured, that is, the feeder control will shut off the feeder or reduce the feeder speed, when the sound vibrations increase beyond a predetermined point and conversely the feeder control will increase the feeder speed when the sound vibrations decrease a predetermined amount. One way to accomplish this result is to use relays which will open the power circuit. This is just the reverse action of the relays for the ball mill feeder control circuit.

There are many other machines for a great variety of uses whose operation is accompanied by sound or vibration. It is the control of such machines, as well as the machines herein described, that I wish it understood be included in the general scope of this invention.

I claim:

1. In a control system for a mill in which vibrations set up by the mill are a function of the operating condition of the mill, a feeder for delivering material to said mill, means for actuating said feeder, a microphone positioned with respect to said mill for picking up the vibrations emanating therefrom, means responsive to the vibrations picked up by said microphone for controlling the feeder actuating means, and separate means for varying the degree of reaction of the vibration responsive means whereby the system may be balanced with respect to a desired vibration level and to thereby maintain such level

substantially constant, and which separate means may also be adjusted to establish any desired operating condition of the mill with its corresponding vibration level.

2. A control system as defined in claim 1, in which an electrical circuit is included, and in which the means for varying the degree of reaction of the vibration responsive means consists of a device for varying the amplitude of power in said circuit.

3. A control system as defined in claim 1, in which the means for controlling the feeder actuating means includes an electrical circuit and a relay, and in which the means for varying the degree of reaction of the vibration responsive means is a rheostat.

4. A control system as defined in claim 1, in which the means for controlling the feeder actuating means includes an electrical circuit, a relay, means for quantitatively indicating the energy in said circuit, and a time delay contactor, and in which system the means for varying the degree of reaction of the vibration responsive means is a rheostat.

5. A control system as defined in claim 1, in which the means for controlling the feeder actuating means includes an electrical circuit and a relay therein operable at a definite electrical power level, and in which system the means for varying the degree of reaction of the vibration responsive means consists in a device for regulating the amount of electrical power which actuates the relay.

6. For a drum type mill, a control system as defined in claim 1, in which the microphone is located opposite the arc of the drum defined by the load in the mill.

7. Apparatus for controlling the operation of a machine for handling material in which vibrations set up by the machine are a function of the operation of the machine and including a motivating element, a microphone positioned with respect to said machine for picking up vibrations emanating from the machine to estab-

lish an electric circuit, an amplifier for amplifying the electric current responsive to said vibrations, a rectifier in said last-mentioned circuit, and a time delay relay, said time delay relay adapted to alternately establish three circuits depending upon the actuation of said relay, each of which circuits includes a relay, and each of which last-mentioned relays upon actuation is adapted to establish an independent circuit of a predetermined intensity, and all of which last-mentioned circuits include said motivating element.

8. A method of regulating the feed to a mill in which vibrations set up by the mill are a function of the operating condition of the mill and in which provision is made for actuating a feeding device by means of an electrical circuit, comprising the steps of feeding material to the mill at a given rate and thereby establishing a certain operating condition in the mill having a corresponding vibration amplitude, translating the acoustic energy of the vibrations into electric energy in said circuit so that variations in the acoustic energy effect corresponding variations in the electric energy so as to secure a rate of feed for maintaining a definite and substantially constant operating condition in the mill, and varying the operating condition in the mill, and may be desired, by changing the ratio of translation of acoustic energy into electric energy.

9. A process as defined in claim 8, in which, in order to maintain the definite operating condition in the mill, the electric circuit effects an intermittent feed of the material to the mill at such a rate per increment of time and for such periods of time as to maintain a substantially constant operating condition.

10. A process as defined in claim 8, in which the rate of feed is changed a sufficient number of times, and the respective operating conditions resulting therefrom noted, in order to definitely ascertain the optimum operating condition.

HARLOWE HARDINGE.

CERTIFICATE OF CORRECTION.

Patent No. 2,235,928.

March 25, 1941.

HARLOWE HARDINGE.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 5, first column, line 29, for the word "or" before "fabric" read --of--; page 6, second column, line 28, claim 8, for "and" read --as--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 24th day of June, A. D. 1941.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.

CERTIFICATE OF CORRECTION.

Patent No. 2,235,928.

March 25, 1941.

HARLOWE HARDINGE.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 5, first column, line 29, for the word "or" before "fabric" read --of--; page 6, second column, line 28, claim 8, for "and" read --as--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

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