

**Nov. 15, 1938.**

C. F. L. RØDER

**2,136,907**

MILL CONTROL

Filed May 17, 1937

2 Sheets-Sheet 1

Fig. 1,

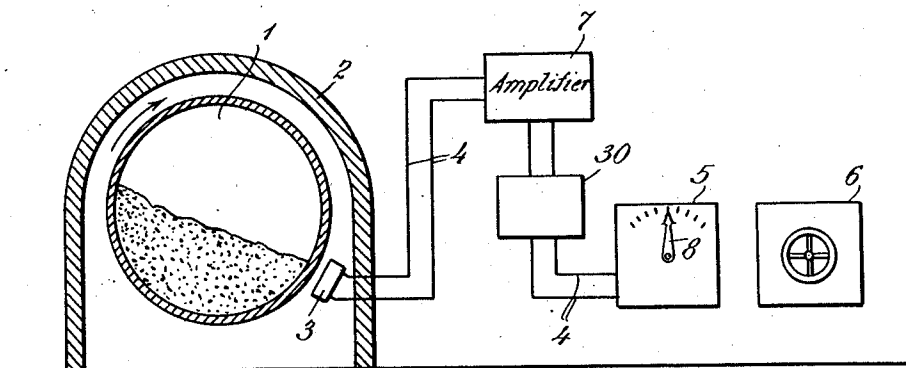
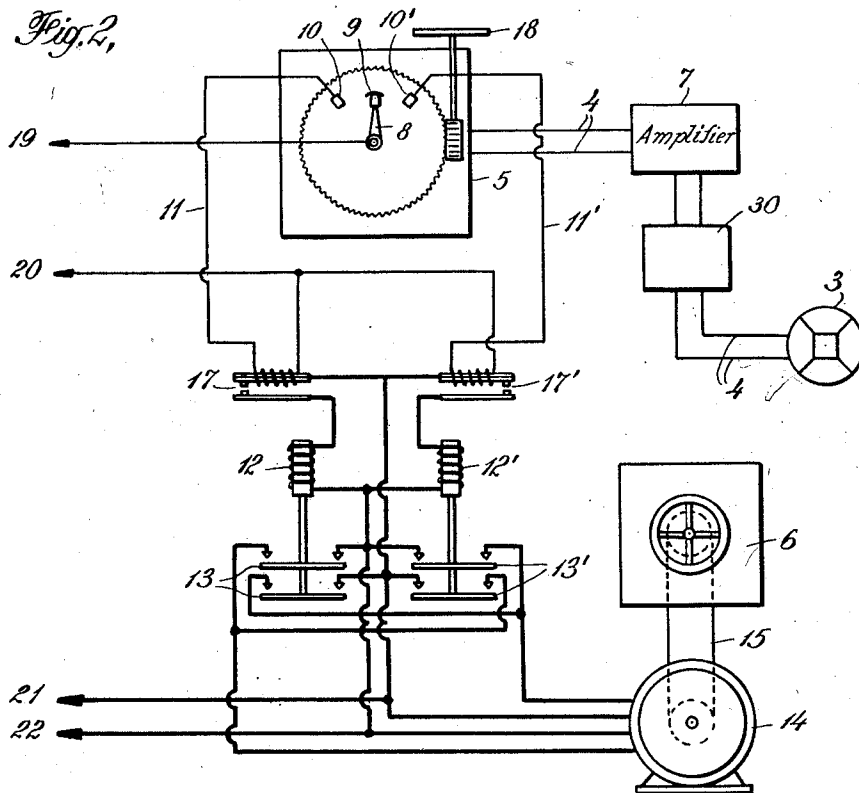


Fig. 2,



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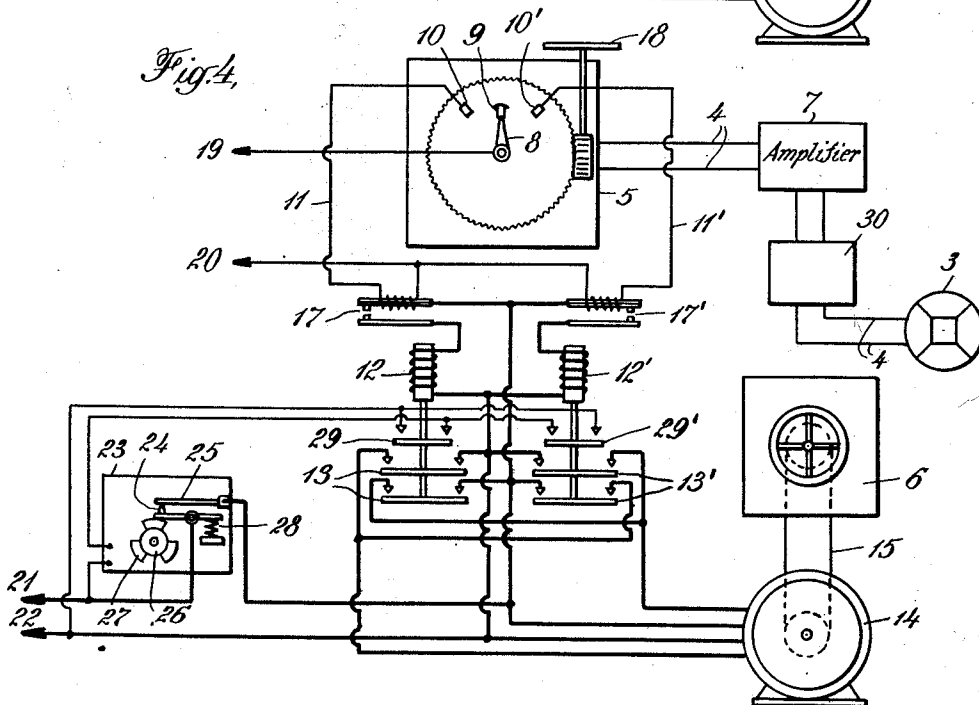
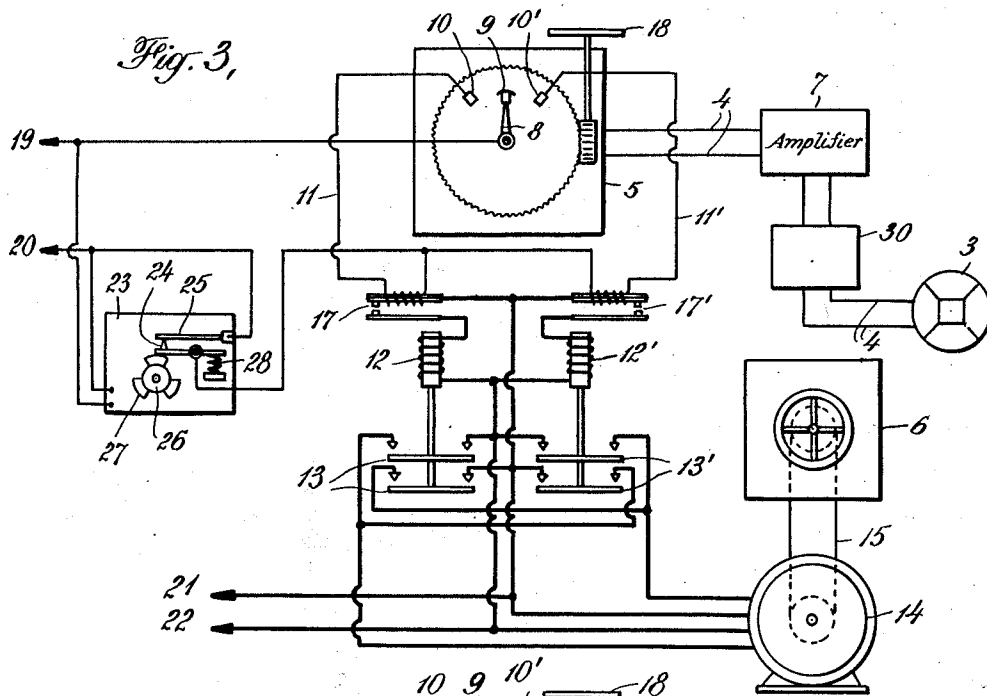
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## MILL CONTROL

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2 Sheets-Sheet 2



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## UNITED STATES PATENT OFFICE

2,136,907

## MILL CONTROL

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In Great Britain May 18, 1936

## 1 Claim. (Cl. 83—44)

This invention relates to grinding or crushing installations and is particularly applicable to tube mills and ball mills.

It is well-known that a grinding or crushing mill operates inefficiently and uneconomically if there is any departure from the operating conditions for which it was designed. In particular, if the material is fed to the mill at too high a rate the operation is inefficient, and if it is fed to the mill too slowly there is not sufficient material for the grinding elements to act upon and then a great deal of their work is converted into heat owing to impact and friction between the grinding elements themselves. Other factors which determine the output of the mill are the speed at which it is driven and the fineness of the material, but as a rule the quantity of material fed in a given time is the most important factor.

When the mill has been fed too quickly or too slowly for a certain time the fact can, of course, be ascertained, for example by examining the degree of fineness of the ground product leaving the mill. As however, this is not discovered until the grinding of the material has been finished, the feeding of the material to the mill and the operation of the mill have actually been irregular for some considerable time.

It is therefore a matter of great importance to be in a position to ascertain as quickly as possible whether the feeding of material to the mill has been irregular. It has been found by experience that skilled operatives who are accustomed to superintending the running of mills are able to decide to some extent from the sound of the mill in operation whether the mill is operating with too much or too little material, because a mill charged with too much material gives out a dull and somewhat muffled sound, while a mill which is fed too slowly makes more noise. Thus the attendant looking after the mill is able to adjust the feed device so as to maintain a constant feed of material to the mill at a rate which is, within limits, the most suitable for the mill.

According to the present invention, a device responsive to the noise caused by the grinding in a tube mill or ball mill is combined with the mill. The device either affords a direct indication of the noise so that the attendant can regulate manually another device by which the operation of the mill is influenced, or the device responsive to the noise is arranged automatically to control said other device. It is preferred that said other device should be a feed device, because in gen-

eral, for maximum efficiency of grinding, the mill should be run at a given speed and should be fed only with as much material as it can grind. However, a mill is able to increase its output when the speed of revolution is increased within certain limits. The efficiency of the mill may decrease when the mill speed is accelerated, as at the same time the power consumption will increase, but if the speed is not increased too much the output will increase. Thus the said other device may be a motor that drives the mill. When the mill motor thus is automatically controlled, any increase in the mill feed will result in the noise-meter indicating a less intense noise.

As stated above, the output of the mill is also determined by the fineness of the material, and small variations in the fineness will cause small variations in the output. If, therefore, the feed to the tube mill for some reason or other is increased the output may be increased accordingly if the material is removed from the mill in a somewhat coarser state. Such adjustment of the fineness of material can easily be effected in mills which are air-swept, i. e. mills in which the fine particles are picked up and carried out of the mill by an air stream. When the velocity of the air-stream is increased the particles which are removed by the stream are coarser and vice versa. Thus the said other device may also be a fan or the equivalent thereof by which the current of air is caused to flow through the mill.

In practicing the invention, the physical or electro-mechanical impulse or series of impulses caused by the noise of grinding is conveniently employed. Various forms of noise-meters are already known in which the noise to be measured is converted into physical impulse, the magnitude of which affords a measure of the intensity of the noise. For example, such an instrument may consist of a microphone with an amplifier (and, if desired, a detector) connected to a moving coil deflecting instrument in such a way that the deflection is proportional to the intensity of the sound received by the microphone. Such noise-meters can be designed to be sensitive to certain ranges of audio frequencies, and may preferably be arranged to operate upon the range of frequencies in which the greatest variations in noise level occur in each particular case. The use of such noise meter in combination with the mill makes it possible to adjust the operation of the mill, so that the noise remains constant, that is to say, of a predetermined average level or magnitude.

Instead of utilizing the physical impulse generated by the noise, for example an electro-mechanical impulse, to afford a measurement of the noise so that the attendant can adjust the operation of the mill accordingly, it may be arranged for the said impulse or series of impulses to cause automatic adjustment of the device controlling the mill operation, for example, by arranging for the electro-mechanical impulse to control the speed governor of the feed device.

In order that the invention may be clearly understood and readily carried into effect, some embodiments of the invention will now be described by way of example with reference to the accompanying drawings, in which

Fig. 1 shows diagrammatically a microphone with a noise-meter combined with a tube mill so as to provide an indication of the noise set up by the grinding in the mill for the guidance of the attendant;

Fig. 2 is a circuit diagram showing how the feed device of the mill may be adjusted automatically; and

Figs. 3 and 4 illustrate modifications of the system of Fig. 2, wherein arrangements are provided to prevent over-control or "hunting".

Fig. 1 illustrates a tube mill 1 enclosed in a casing 2 made of sound-insulating material. Enclosing each mill in a separate sound-insulating casing avoids or reduces the noise nuisance in mill installations. Additionally, the use of such stationary sound-insulating casings provides conditions in which the use of the present invention is particularly favorable, since the microphone 3 is mounted inside the casing 2 and consequently is not affected by the noise from other mills in the room. The microphone may be placed at a point where the noise is particularly intense, preferably close to the inlet end of the mill. The microphone 3 is connected by means of conductors 4 to a noise-meter 5, which may be of known construction. The regulator 6 for the feed device (not shown) of the mill is placed close to the noise-meter 5 so that the attendant may observe the dial of the noise-meter, and according to the reading of this instrument as indicated by the pointer 8 may regulate the feed of material to the mill by means of the manual regulator 6.

In the conductors 4 between the microphone 3 and the meter 5 there may be connected an amplifier 7 and a tone filter 30. The amplifier which is preferably of the vacuum tube type customarily employed for audio frequencies, raises the signal level sufficiently to enable the use of a less sensitive and more rugged meter 5. It is also especially desirable in connection with the automatic control later to be described. The tone filter 30 may comprise inductive, capacitive and resistive elements connected either as a band-pass filter or as a high-frequency or low-frequency filter or a combination thereof, the purpose being to select from the noise picked up by the microphone, and to pass to the control meter 5 only those frequencies most faithfully representing the conditions in the mill on which the feed rate must be based. To determine these frequencies empirically it is preferable that some of the filter elements be adjustable.

Although it is not illustrated in detail in the drawings, a detector or rectifier may be interposed between the tone filter, if any, and the meter 5. The box 30 may be considered to include the filter, the detector, or both. If the detector is included a direct-current instrument

may be employed of which the response is more nearly proportional to the sound intensity being measured.

A scheme for automatic adjustment of the feed device of the mill is illustrated diagrammatically in Fig. 2, in which the microphone 3 is again connected to the noise meter by means of conductors 4, in which an amplifier 7 and the tone filter 30, are interposed in the conductors as in Fig. 1. In this arrangement the noise-meter 5 of Fig. 1 is replaced by one in which the pointer 8 has a movable contact 9 mounted on it and is arranged to come into contact with one of two stationary contacts 10 and 10', when the noise made by the mill increases or decreases to a predetermined extent and thereby causes the pointer 8 to make a sufficient deflection. As a result, one or the other of two circuits is completed depending on which of the stationary contacts 10 or 10' is touched by the movable contact 9.

If the rate of feed to the mill exceeds a predetermined maximum, the mill makes less noise than normally. It may be assumed that the pointer 8 then turns to the left, bringing its contact 9 against the contact 10 and thus completing a circuit from the supply 19, 20, through the conductor 11. A time-lag relay 17 included in this circuit operates, when the circuit has remained closed for a preselected time, to close another circuit including the source of supply 21, 22 which is completed through a solenoid or electro-magnet 12 of a heavier relay. The armature or plunger of the latter relay is then drawn up and by means of its contact discs 13 completes a circuit from the power supply 21, 22, through the motor 14, which is thus started. In the drawings, the motor 14 is shown diagrammatically connected by a driving chain 15 to the regulator 6 for the feed device to the mill, and in this case, the regulator 6 is turned to the left, for example, to reduce the rate of feed of material to the mill. The charge of material in the mill is then quickly decreased so that the noise set up is increased and then the pointer 8 is restored again to a position in which the contact 9 lies between the fixed contact 10 and 10'. This results in stopping the motor 14 and the regulator 6.

If, on the other hand, the charge of material in the mill should be too small, the sound level from the mill is increased and the pointer 8 will then be deflected to the right making contact with the fixed contact 10' and completing a circuit from the supply 19, 20, through another time-lag relay 17'. Upon the closing of the contacts of the relay 17' a similar circuit from the supply 21, 22, is completed through another solenoid or electro-magnet 12', the contact discs 13' of which complete a circuit from the power supply 21, 22 with reversed polarity to the motor 14. The motor will therefore start, but this time in the opposite direction, so that the regulator 6 turns to the right increasing the speed of the feed device and thus the rate of feed of material to the mill.

The relays 17, 17' are time-lag relays in order to avoid operation of the regulating device 6 due to merely casual or temporary variations in the noise made by the mill. There are several known types of time-lag relays which would be suitable for this purpose, the relays illustrated being of the adjustable bi-metallic thermal type. As already mentioned, these relays 17, 17', prevent the motor from being started until a preselected time after the contact 9 has reached the contact 10 or 10' so that casual variations in the noise in-

tensity will not cause the regulator 6 to be shifted, for so long as the contact 10 or 10' remains closed.

An adjusting screw 18 is provided for rotating the disc carrying the contacts 10, 10', relatively to the contact 9 to enable the zero position of the noise-meter to be adjusted. This permits the noise intensity to which the feed to the mill is responsive to be adjustably predetermined.

Fig. 3 differs from Fig. 2 only in the addition of a device to prevent over-regulation and the setting up of a hunting effect. This device operates so that the electro-magnets 12, 12' when attracted will remain energized for only a relatively short time and will then fall back to the unattracted position. If, however, the contacts 9 and 10 or 10' continue to be closed the electro-magnets 12, 12' are again energized thereby giving a series of short regulating periods. More specifically, the device may comprise an "off-and-on" relay, well known in the art, such as is usually operated by a synchronous, alternating current clock motor. In Fig. 3 this relay is designated 23 and comprises a synchronous alternating current clock motor 26 which operates adjustable timing cams 27. These cams cooperate with contact lever 24 causing the lever to make contact with arm 25 thereby closing the circuit 19, 20. As each of the cams 27 passes beyond the end of the contact lever 24, spring 28 depresses the lever breaking the contact between the lever and contact arm 25 until the next cam cooperates with lever 24 as motor 26 continues to rotate. Thus, since the synchronous motor will be in constant operation, it will be seen that the electro-magnets 12, 12' will be periodically de-energized and reenergized as long as the contacts 9 and 10 or 10' are closed. The timing of such energizing and deenergizing by means of the off and on relay 23 must, of course, be properly regulated with respect to the duration of the hunting period which otherwise might be established. To this end the cams 27 are adjustable or interchangeable as to their length and spacing so that the off and on periods can be set as desired.

In Fig. 4 there is illustrated a further modification of the device just explained in connection with Fig. 3, for in this arrangement the synchronous motor 26 is in operation only when the contacts 9 and 10 or 10' are closed, and the current to operate it is taken from the circuit 21, 22 instead of from the circuit 19, 20, as in Fig. 3. In this embodiment the electro-magnets or solenoids 12, 12' have been provided with a third set of contact discs 29, 29' each of which serves to close the circuit controlling the operation of the synchronous motor 26. Thus when either one of the electro-magnets 12, 12' is energized the circuit of the motor 26 is completed through the contacts closed by disc 29 or 29' respectively, and the feed-regulating motor 14 will operate as long as contacts 24, 25 are closed. However, when a cam 27 passes beyond the end of contact lever 24 the circuit 21, 22 for the motor 14 is temporarily broken. When the next cam co-

operates with lever 24, thereby closing circuit 21, 22, the motor 14 will again operate provided the electro-magnets 12, 12' have not been de-energized through the opening of contacts 9 and 10 or 10'. It is evident that the current which must be broken by contacts 24, 25 will be greater in the arrangement of Fig. 4 than in that of Fig. 3. In either arrangement the tendency toward over-correction or hunting will be avoided because the breaking and making of the control circuit by the off-and-on relay device 23 is dependent solely upon the operation of the synchronous motor 26 and its cams 27 and not in turn upon any other variable factor in the control apparatus.

If the operation of the mill is to be controlled by the speed at which it is driven the only alteration necessary in the arrangements illustrated is to replace the regulator 6 of the driving motor of the feed device by a regulator for a motor which drives the mill. Similarly, if the operation of the mill is to be controlled by the speed of the air stream through it, the regulator 6 may be replaced by a regulator of an electric motor driving the fan, so that a reduction in the noise, i. e. an increase in the mill feed, brings about an increase in the fan speed.

Although it is convenient to drive the controlled device by an electric motor and to adjust a regulator for that motor in accordance with the noise, this is not essential. Thus the feed device may be driven from the mill through variable gearing that is adjusted in accordance with the noise.

I claim:

A crushing or grinding mill in which the level of noise emitted by the mill in operation is a function of the quantity of material therein, a device for automatically controlling the operation of said mill comprising a microphone located near the mill to pick up said noise and translate it into audiofrequency current, an amplifier connected to said microphone for increasing the level of said audio frequency current, a filter connected to the output of said amplifier, said filter being adjustable to select those frequencies indicative of the quantity of material in the mill, contact means adjustably operative in response to current of said selected frequencies to close one of two time-lag relays when said current reaches a preselected minimum or maximum value, respectively, means for adjusting said contact means to close at preselected minimum and maximum values of current, two power relays each controlled by one of said time-lag relays, a reversible motor-actuated controlling device for said mill, an electric power source, contacts connecting said power source to said motor upon operation of either of said power relays, the direction of rotation of said motor being dependent upon which of said power relays is operated, and an off-and-on relay device adjustably controlling the periods of operation of said motor independently of the other relays.

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