

[54] APPARATUS FOR AND METHOD OF
CONTROLLING FEED OF GRINDING
MEDIA TO A GRINDING MILL

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[58] Field of Search 241/30, 33, 34, 35,
241/36

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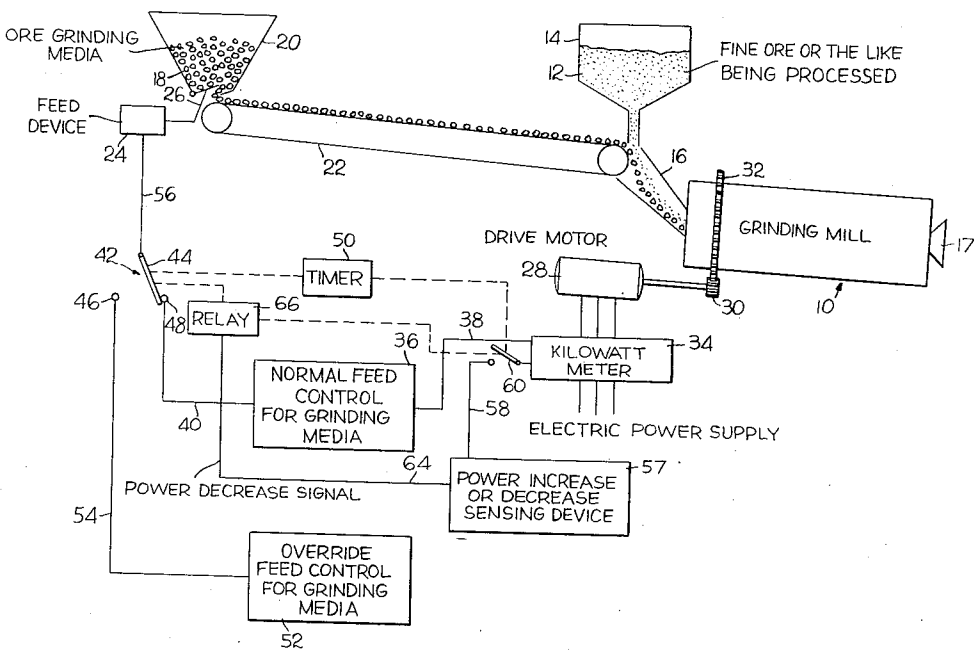
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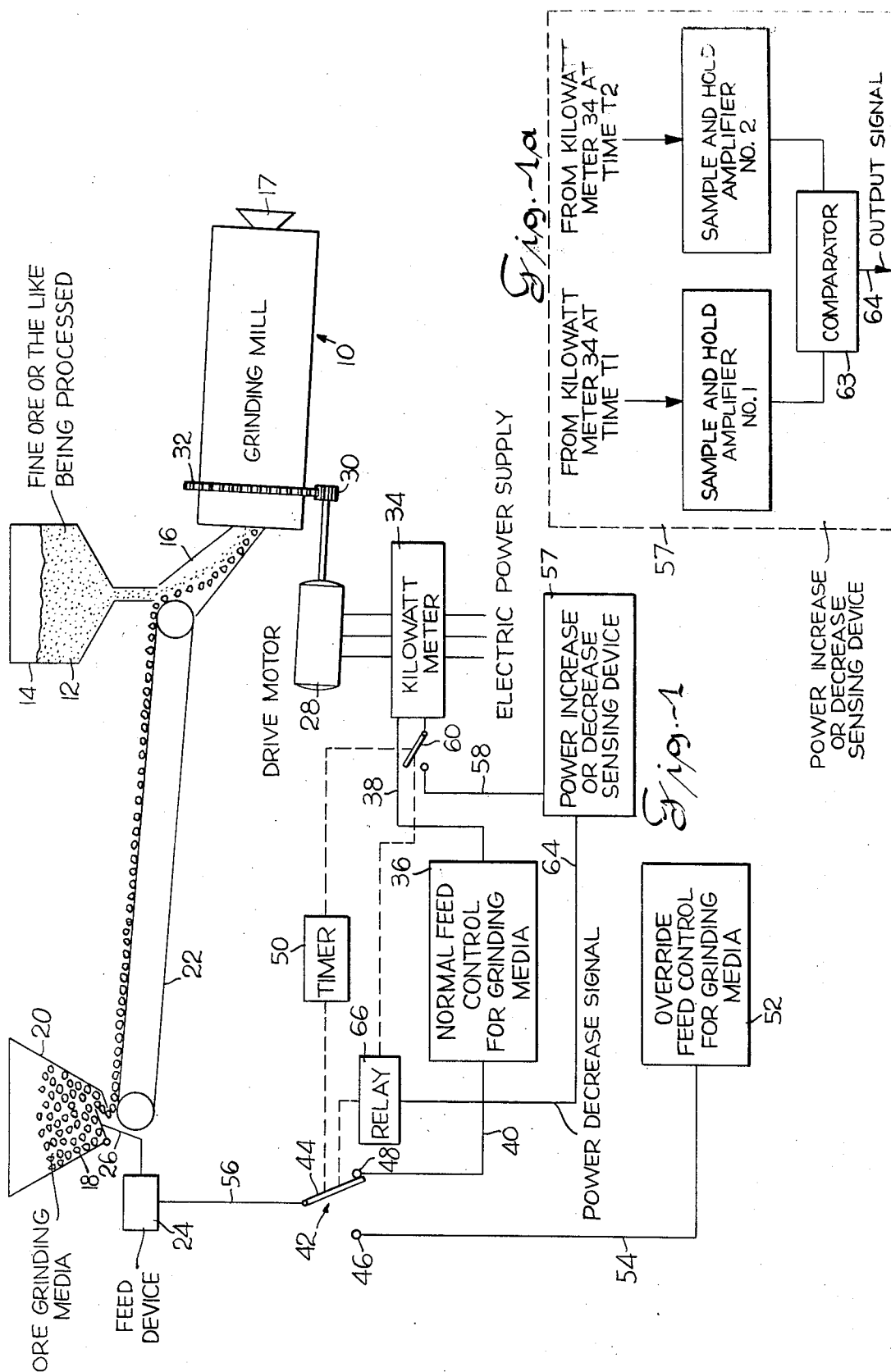
[57] ABSTRACT

An apparatus for and a method of controlling the feed rate of grinding media to a grinding mill of the type which operates at a power draft in the vicinity of the critical peak power draft of the grinding mill. In the described embodiment, the ore grinding media feed rate to a secondary autogenous grinding mill is controlled. In the described embodiment the ore grinding media feed rate is normally automatically controlled in response to the electrical power demand of the grinding mill by control means whose function is to

maintain the power draft of the mill at a predetermined set point. At suitable time intervals, such as once every sixty minutes, the normal automatic feed control for the ore grinding media is interrupted or deactivated and an override feed control for the ore grinding media is substituted in place of the normal feed control. The override feed control acts to substantially decrease the rate of feed of the ore grinding media to the mill sufficiently to cause a measurable effect on the power draft of the mill. During the period when the override control is in effect, the feed of ore grinding media to the mill may even be stopped completely. A sensing device responsive to power increase or decrease detects whether the power input to the mill decreases or increases when the override feed control is in control, thereby indicating whether the mill is loaded below or above the grinding media charge or loading corresponding to the critical peak power draft of the mill. If the sensing device detects a decrease in power input to the mill during the override period, the override ore grinding media feed control is disconnected or otherwise deactivated and the normal ore grinding media feed control is reconnected or otherwise reactivated. If the sensing device detects an increase in power input to the mill during the override period, the override feed control remains connected to provide a decreased rate of feed of ore grinding media, which may even include a complete stoppage of feed of ore grinding media, until the sensing device detects a decrease in power input to the mill, at which time the override ore grinding media feed control is disconnected and the normal ore grinding media feed control is reconnected.

8 Claims, 5 Drawing Figures





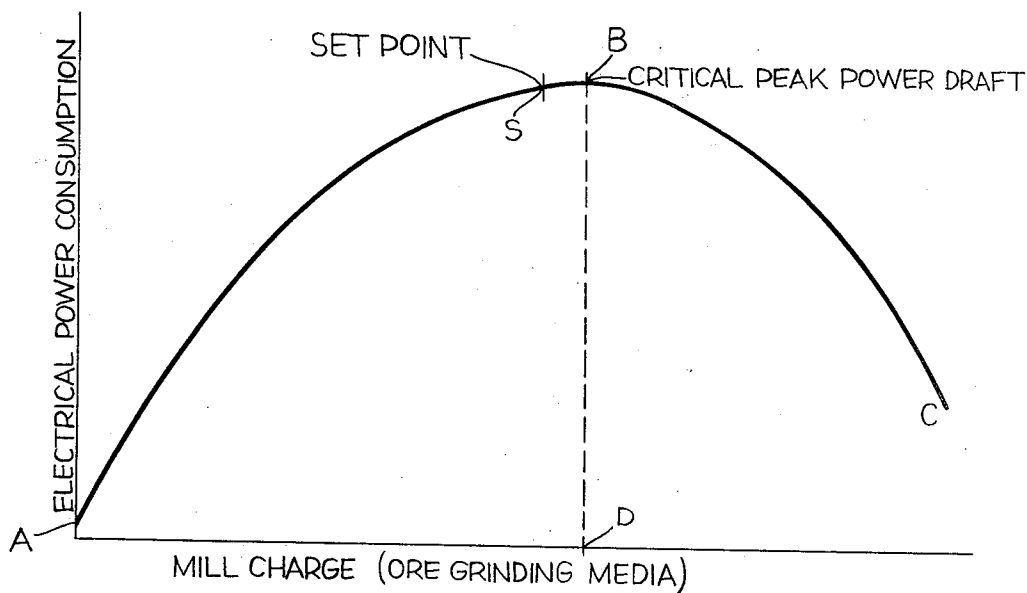


Fig. 2

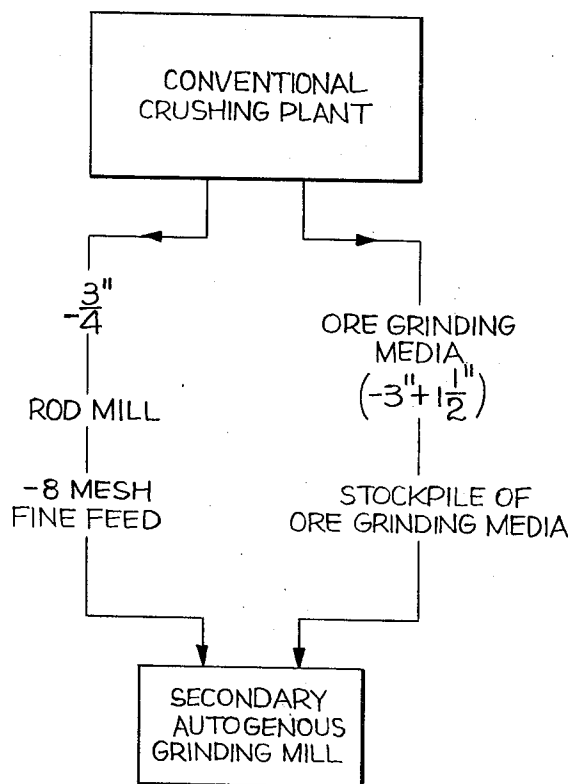


Fig. 3

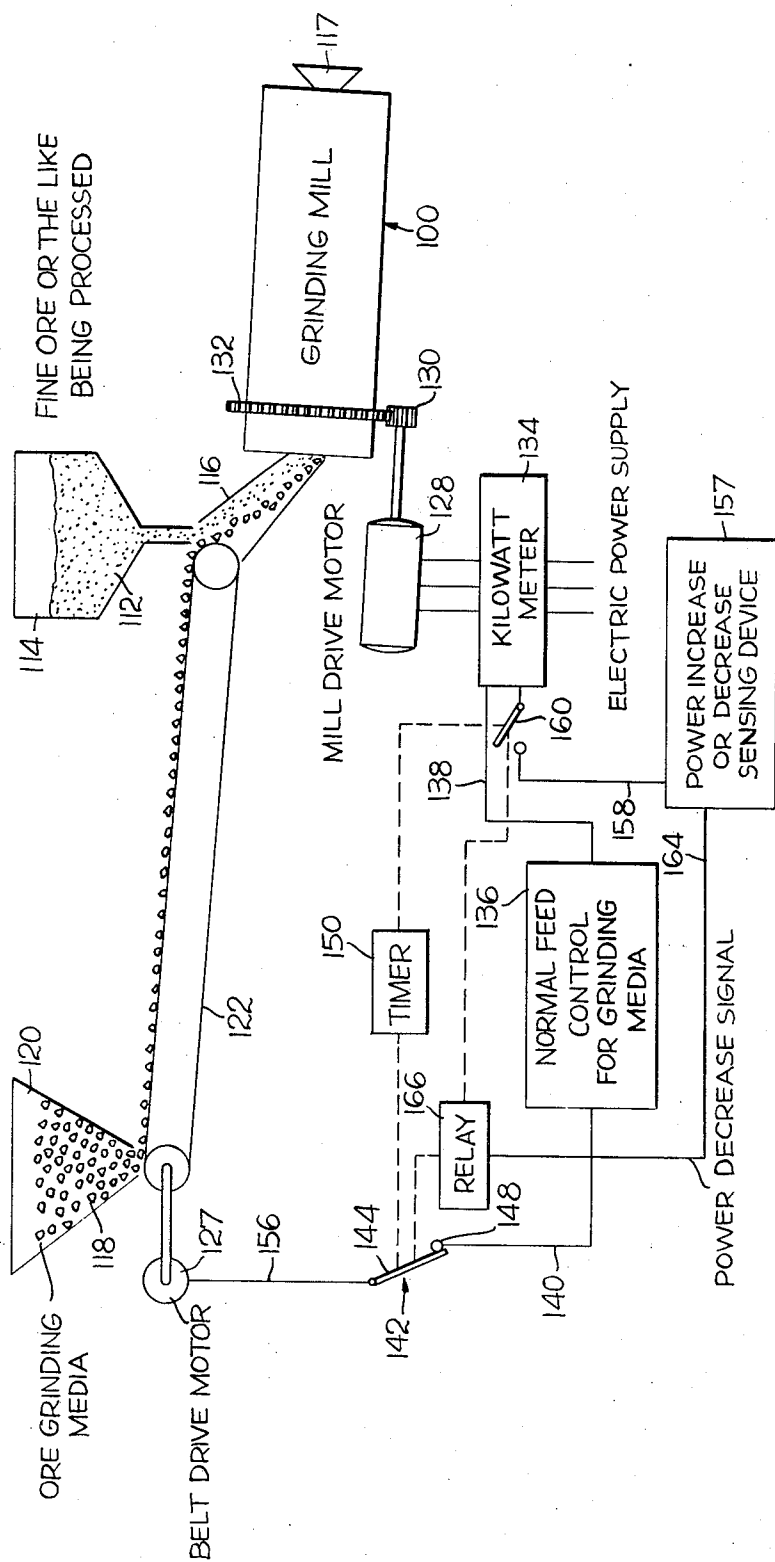


Fig. 4

APPARATUS FOR AND METHOD OF CONTROLLING FEED OF GRINDING MEDIA TO A GRINDING MILL

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an apparatus for and a method of grinding mineral ore and more particularly to an apparatus for and a method of controlling the feed of grinding media for use with grinding mills of the type which operate at a power draft in the vicinity of the critical peak power draft of the grinding mill.

The invention is of particular utility in controlling the feed of the "ore grinding media" to a secondary autogenous grinding mill of the type in which the ore grinding media, which may be, for example, ore having a mesh of from -3 inches to +1-1/2 inches, is fed to the secondary autogenous mill to serve as a grinding media for the fine feed ore which may, for example, be of -8 mesh. However, in its broader sense, the invention is applicable to controlling the input feed of grinding media to any grinding mill of a type which is capable of operating in the region of its critical peak power draft beyond which an increase in the total grinding media in the mill will cause the power draft of the mill to diminish. Thus, if applied to a ball or tube mill, the feed of metal or nonmetal grinding balls or other shapes used for grinding would be controlled by the present invention; and if applied to a primary autogenous or to a semi-autogenous grinding mill, the entire feed of material to the mill would be controlled. The term "grinding media" as used in the specification and claims is intended to be generic to the "ore grinding media" which is fed to a secondary autogenous grinding mill, to the metal or nonmetal balls or other shapes used for grinding in a ball or tube mill, and to the entire feed of material to a primary autogenous or to a semi-autogenous grinding mill.

2. Description of the Prior Art

Grinding mills of the secondary autogenous type using ore or rock as the grinding media (hereinafter referred to as "ore grinding media") are usually provided with an automatic control on the rate of the ore grinding media feed which is varied automatically so as to seek to maintain a constant set power draft by the grinding mill. In addition to the "ore grinding media" which serves as the grinding medium, the mill is also supplied with what is known in the art as "fine feed" ore which may, for example, be the output product of a rod mill having, for example, a -8 mesh grind. The feed rate of the "fine feed" ore to the grinding mill in the prior art and also in the environment of the present invention is responsive to control means which are separate and distinct from the feed control means for the "ore grinding media," the control means for the "fine feed" ore forming no part of the present invention. Furthermore, variations in the rate of feed of the "fine feed" ore affect the power draft of the grinding mill only slightly.

In the prior art secondary autogenous mill control arrangements the input power set point is commonly set appreciably less than the critical peak power which the mill would draw with a full charge of ore grinding media. For example, in the prior art, the power set point may be set at perhaps 90 percent or 85 percent of the critical peak power. If the mill power draft (demand) rises above the set point, the ore grinding media feed

in the prior art secondary autogenous grinding mill control systems is automatically reduced, and if the power draft by the mill falls below the set point, the ore grinding media feed rate is automatically increased, so as to seek to maintain the average power drawn by the mill at the set point.

In the prior art control systems for secondary autogenous grinding mills, the set point must be appreciably lower than the critical peak power of the grinding mill in order to safely avoid "overshooting" which would increase the amount of the total ore grinding media charge in the mill beyond that requiring the critical peak power draft or demand. If the total ore grinding media charge (i.e., the total amount of ore grinding media present in the mill at a given moment) exceeds that requiring the critical peak power, the power draft will decrease (see FIG. 2 of the drawing). The prior art control systems for controlling the feed of ore grinding media in a secondary autogenous grinding mill of which I am aware, are unable to discriminate as to whether the mill is operating on the "right" or "wrong" side of the critical peak power draft on the curve of power draft vs. mill charge of ore grinding media. Once the mill power draft is beyond the critical peak power point beyond which the input power to the mill decreases with increase in ore grinding media charge, most prior art mill feed control systems are ineffective since a decrease in power draft calls for an increase in ore grinding media feed rate which still further overloads the mill beyond the grinding capacity of the mill, causing a still further decrease in input power to the mill. When this happens, the only alternative in the prior art feed control system is for the operator to manually cut off the ore grinding media feed and permit the excess charge in the mill to be ground out before automatic feed control is resumed. This can result in serious loss in grinding capacity of the mill.

STATEMENT OF THE INVENTION

Accordingly, it is an object of the present invention to provide an apparatus for and a method of controlling the feed of grinding media to a grinding mill which is particularly adapted for use with grinding mills of the type which are capable of being loaded to a power draft set point in the vicinity of, but less than, the critical peak power draft of the mill and in accordance with which the grinding mill may be operated closer to the critical peak power draft point than in the prior art apparatus and methods.

It is a further object of the invention to provide an apparatus for, and method of controlling the feed of grinding media to a grinding mill in accordance with which a given grinding mill may operate closer to its peak grinding capacity than in prior art apparatus and methods.

It is another object of the invention to provide an apparatus for and a method of controlling the feed of grinding media to a grinding mill which is particularly suitable for, but not restricted to, use in connection with secondary autogenous grinding mills and which permits the secondary autogenous grinding mill to operate closer to its critical peak power draft than in the prior art, thereby increasing the overall capacity of the given grinding mill.

It is a further object of the invention to provide an apparatus for and a method of operating a grinding mill at a power draft only slightly below the critical peak

power draft of the given mill, while at the same time preventing the buildup of an excess charge of grinding media in the mill.

It is still another object of the invention to provide an apparatus for and method of controlling the feed of grinding media which can discriminate as to whether the mill is operating on the "right" or on the "wrong" side of the critical peak power draft on the curve of power draft vs. charge of grinding media for the mill and which can make appropriate corrections in the loading of grinding media if it is determined that the mill is operating on the "wrong" side of the critical peak power draft.

In achievement of these objectives, there is provided in accordance with an embodiment of this invention an apparatus for and a method of controlling the feed rate of grinding media to a grinding mill of the type which operates at a power draft in the vicinity of the critical peak power draft of the grinding mill. In the described embodiment, the ore grinding media feed rate to a secondary autogenous grinding mill is controlled. In the described embodiment, the ore grinding media feed rate is normally automatically controlled in response to the electrical power demand of the grinding mill by control means whose function is to maintain the power draft of the mill at a predetermined set point. At suitable time intervals, such as once every 60 minutes, the normal automatic feed control of the ore grinding media is interrupted or deactivated and an override feed control for the ore grinding media is substituted in place of the normal feed control. The override feed control acts to substantially decrease the rate of feed of the ore grinding media to the mill sufficiently to cause a measurable effect on the power draft of the mill. During the period when the override control is in effect, the feed of ore grinding media to the mill may even be stopped completely. A sensing device responsive to power increase or decrease detects whether the power input to the mill decreases or increases when the override feed control is in control, thereby indicating whether the mill is loaded below or above the ore grinding media charge corresponding to the critical peak power draft of the mill. If the sensing device detects a decrease in power input to the mill during the override period, the override ore grinding media feed control is disconnected or otherwise deactivated and the normal ore grinding media feed control is reconnected or otherwise reactivated. If the sensing device detects an increase in power input to the mill during the override period, the override feed control remains connected to provide a decreased rate of feed of ore grinding media (which may even include a complete stoppage of feed of ore grinding media), until the sensing device detects a decrease in power input to the mill, at which time the override ore grinding media feed control is disconnected and the normal ore grinding media feed control is reconnected.

BRIEF DESCRIPTION OF THE DRAWINGS

Further objects and advantages of the invention will become apparant from the following description taken in conjunction with the accompanying drawing in which:

FIG. 1 is a schematic diagram illustrating the relationship of the various parts of the apparatus of the invention;

FIG. 1A is a schematic diagram showing the components of a "power increase or decrease" sensing device which may be used;

FIG. 2 is a graph showing the relationship between electrical power consumption by the grinding mill and the charge of ore grinding media in the mill;

FIG. 3 is a schematic diagram showing the material which is fed into a secondary autogenous grinding mill; and

FIG. 4 is a schematic diagram of a modified control arrangement in accordance with the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawing and more particularly to FIG. 1, there is shown a grinding mill, generally indicated at 10, of the secondary autogenous type. Mill 10 receives a fine feed ore 12 which may be, for example, -8 mesh, from a hopper generally indicated at 14 which dispenses fine feed ore 12 in the form of a slurry into inlet end 16 of the grinding mill. As best seen in the schematic diagram of FIG. 3, fine feed ore 12 may be the output of a rod mill which in turn is fed at the input end thereof by the -¾ inch mesh, for example, output of a conventional crushing plant. The rate of feed of the fine feed ore 12 to mill 10 is separately controlled by means which form no part of this invention.

The "ore grinding media" which serves as the grinding media in mill 10 is indicated at 18 and is dispensed from a hopper 20 onto a moving conveyor belt 22 which delivers the ore grinding media to the input spout or the like 16 of the grinding mill 10, ore grinding media 18 becoming mixed with fine feed ore 12 inside the grinding mill. As seen in the schematic diagram of FIG. 3, the ore grinding media may be of a mesh size -3 to +1-½ inches and is derived from a stockpile which is supplied by the conventional crushing plant shown in FIG. 3. In other words, the fine feed ore (for example, -8 mesh) and the ore grinding media 18 (for example, -3 inches to +1-½ inches mesh) are derived from the same source of ore. The ore grinding media 18 serves as the grinding medium for the fine feed ore 12 and eventually is reduced in size itself within mill 10 to become part of the output product of grinding mill 10 which is discharged continuously through discharge outlet 17 as the mill rotates.

The feed device 24 controls the position of a variable adjustment gate 26 on hopper 20 whereby to control the rate of feed of the ore grinding media 18 onto the moving conveyor belt 22. It is obvious that the rate of feed of the ore grinding media could also be controlled by controlling the rate of movement of conveyor belt 22.

An electric drive motor 28 rotatably drives the grinding mill 10 through a pinion 30 which engages a ring gear 32 on the outer periphery of grinding mill 10, as is conventional in the art.

A kilowatt meter or kilowatt-hour meter 34 measures the electrical power input to drive motor 28.

Referring now to FIG. 2 which shows the relationship between the charge of ore grinding media in grinding mill 10 and the electrical power consumption of grinding mill 10 as measured on the kilowatt meter 34, it will be noted that as the charge of the ore grinding media 18 in the mill 10 increases, the electrical power consumption of the grinding mill 10, as measured by the kilowatt meter 34, also increases along the portion of

the curve indicated at A-B in FIG. 2. Point B of the curve in FIG. 2 represents the critical peak power consumption by grinding mill 10. If the charge of ore grinding media in the mill is increased beyond the value D which corresponds to the critical peak power point B on the curve of FIG. 2, the power drawn by the mill will decrease even though the total charge of ore grinding media in the mill is increased. Thus the portion B-C of the power curve of FIG. 2 shows a decline in power drawn by the mill even though the abscissa of the graph (total charge of ore grinding media in the mill) is greater in portion B-C of the curve than in the portion A-B of the curve.

When the power draft of the mill passes beyond the critical peak power point B, the mill becomes ineffective as a grinding mill and in substance becomes a rotating flywheel which is no longer effectively grinding the charge in the mill.

As seen in the diagrammatic view in FIG. 1, the normal feed control means for the ore grinding media 18 is indicated at 36. The normal feed control 36 controls the rate of ore grinding media feed as a function of the power demand by grinding mill 10. Normal feed control 36 is connected by the conductor means 38 to kilowatt meter or kilowatt-hour meter 34 and by conductor means 40 to one terminal 48 of a two-way switch generally indicated at 42. Two-way switch 42 includes a movable switch contact 44 which normally engages switch terminal 48. An override feed control means arranged to either decrease the rate of feed of ore grinding media 18 as compared to the rate of feed of ore grinding media provided by the normal feed control 36, or, alternatively, to entirely stop the feed of ore grinding media 18 to mill 10, is indicated at 52. Override feed control 52 is connected by conductor means 54 to terminal 46 of two-way switch 42. Timer 50 is mechanically connected to movable switch contact 44 in such manner that at suitable predetermined time intervals, such as, for example, once every sixty minutes, time 50 will move movable switch contact 44 out of engagement with fixed terminal 48 in which movable contact 44 is connected to the normal feed control 36, and into contact with the fixed terminal 46 in which movable contact 44 is connected to override feed control 52. The fixed end of movable contact 44 is connected by conductor means 56 to feed device 24. It will thus be seen that when the movable contact 44 of switch 42 is in engagement with the fixed terminal 48, feed device 24 is electrically connected to the normal feed control 36; and when movable contact 44 of switch 42 is in engagement with fixed terminal 46, feed device 24 is connected to override feed control 52.

A power increase or decrease sensing device 57 which is capable of sensing either an increase or a decrease in power input to grinding mill 10 is connected by electrical conductor means 58 to the kilowatt meter 34 in series with a normally open contact 60 which is closed by timer 50 when movable contact 44 is moved into engagement with fixed terminal 46. Conductor means 64 transmits a "power decrease" signal (assuming that there is a "power decrease" signal) from sensing device 57 to relay 66 which when energized or triggered by the "power decrease" signal, returns movable contact 44 into engagement with fixed terminal 48 to thereby disconnect override feed control 52 from feed device 24 and to reconnect normal feed control 36 to feed device 24. Relay 66 when energized or triggered

by the "power decrease" signal also opens contact 60 and thus disconnects the sensing device 57 from kilowatt meter 34. Override feed control 52 remains connected in controlling relation to feed device 24 until relay 66 is triggered by a "power decrease" signal as just described.

Instead of utilizing the "power decrease" output signal from device 57 to trigger relay 66 in response to a decrease in power consumption by mill 10 during the override period, as just described, a "power increase" signal indicative of an increase in power consumption by mill 10 during the override period may be transmitted by conductor means 64 to relay 66. In this latter case, as long as a "power increase" signal is transmitted to relay 66 from device 57, relay 66 will remain in a condition in which override feed control 52 is connected to feed device 24 and normal feed control 36 is disconnected. However, in the absence of a "power increase" signal transmitted from device 57 to relay 66, relay 66 will be actuated to disconnect override feed control 52 and to reconnect normal feed control 36 to feed device 24.

Normal feed control 36 may be an analog controller such as Foxboro Model 67HSTGZ-E, made by Foxboro Co., Foxboro, Mass., as described in Foxboro Bulletin No. GS2A-4D1B, July, 1966, or instead may be a digital computer, such as Model TCT88, made by Foxboro Co., of Foxboro, Mass., described in Foxboro Bulletin L-19, November, 1965.

The override feed control 52 may be an electrical power supply and a potentiometer connected to the power supply and adjusted to provide a signal current through conductor means 54, 56 which causes the feed device 24 to feed the ore grinding media at a desired reduced rate. If it is desired to have a progressive decrease in feed rate provided by override control 52, such progressive decrease may be provided by means of a suitable timer or clock control mechanism for providing a progressive variable adjustment of the potentiometer.

The power increase or decrease sensing device 57 may comprise the elements schematically shown in FIG. 1A. As shown, device 57 includes a "Sample and Hold Amplifier No. 1" connected to kilowatt meter 34 to receive a signal representative of the electrical power demand of grinding mill 10 at a time T_1 corresponding substantially to the moment when the override period first begins and before the override feed control 52 has had any effect on the electrical power demand by mill 10. Device 57 also includes a "Sample and Hold Amplifier No. 2" connected to kilowatt meter 34 to receive a signal representative of the electrical power demand of grinding mill 10 at a time T_2 sufficiently after the commencement of the override period for the override control to have had a measurable effect on the electrical power demand by mill 10. The signals which have been sampled by the respective "Sample and Hold Amplifiers No. 1 and No. 2" are fed into a comparator 63 which compares the signals from amplifiers No. 1 and No. 2 to determine whether the power demand by mill 10 at time T_2 is "less than" or "greater than" the power demand by mill 10 at time T_1 . Preferably only the comparator output signal corresponding to one of these conditions just mentioned, such as the "less than" signal corresponding to a decrease in power consumption by mill 10 at time T_2 is

fed over conductor means 64 to the utilization device such as relay 66.

The "Sample and Hold Amplifiers No. 1 and No. 2" of FIG. 1A may be the sample-hold module Model FS201 or FS202, manufactured by Intronic, Incorporated, 57 Chapel St., Newton, Mass. 02158, as described in the 1971-1972 *Electronic Engineers Master Catalog*, Vol. 2, page 1288, published by United Technical Publications, Inc., 645 Stewart Ave., Garden City, N. Y. 11530.

The comparator 63 of FIG. 1A may be "Volsensors" Model 552, precision solid state voltage comparator, manufactured by California Electronics Mfg. Co., Inc., P.O. Box 555, Alamo, Calif. 94507, as described in the aforementioned 1971-1972 *Electronic Engineers Master Catalog*, Vol. 2, pages 1315.

While the normal feed control 36 and the override feed control 52 have been shown and described as controlling the feed device 24 which controls the position of gate 26, it is obvious that the controls 36 and 52 could instead be used for controlling the speed of the belt conveyor 22, thereby controlling the rate of feed of the ore grinding media to mill 10.

Summary of Operation

In operating in accordance with the apparatus and method of the embodiment of the invention, shown in FIG. 1, the feed device 24 which actuates the gate 26 to control dispensing of the ore grinding media 18 onto conveyor belt 22, is normally automatically controlled in accordance with the power draft of drive motor 28, as indicated on kilowatt meter 34. Thus, in normal operation, feed device 24 is electrically connected to normal feed control 36, which is responsive to the reading of kilowatt meter 34, through the connection of movable contact 44 of two-way switch 42 to terminal 48 whereby the normal feed control device 36 is connected through switch 42 to feed device 24. When the kilowatt meter 34 indicates that the power drawn by the mill is below the set point S (FIG. 2) the normal feed control 36 acts to cause the feed device 24 to increase the feed rate of the ore grinding media 18; and, conversely, when kilowatt meter 34 indicates that the mill is drawing power above the set point S, the normal feed control 36 acts to cause feed device 24 to diminish the rate of feed of ore grinding media 18 to conveyor 22, thus tending to reduce the power draft of the grinding mill back to the set point S.

At suitable time intervals, say once in every sixty minutes, for example, timer 50 moves movable contact 44 of two-way switch 42 into engagement with fixed terminal 46 to thereby disconnect normal feed control 36 from feed device 24 and to connect the override feed control 52 to feed device 24. At the same time, timer 50 acts to close contact 60 to thereby connect power increase or decrease sensing device 57 to kilowatt meter 34.

The override feed control 52 is so adjusted as to reduce the rate of feed of ore grinding media by feeding device 24 to mill 10 considerably below the level at which it operated when subject to the normal feed control 36. Override feed control 52 may even be so adjusted as to cause the complete stopping of the feed of ore grinding media to mill 10.

Since the reduction in rate of feed of ore grinding media provided by the override feed control 52 is such as to cause a measurable effect on electrical power

consumption by mill 10 within a few minutes, power increase or decrease sensing device 57 will detect a change in power consumption within a short time after the override feed control 52 is connected in controlling relation to feed device 24.

If, during the period that the override feed control 52 is connected to feed device 24, the mill 10 is operating on portion A-B of the power input curve, it can be seen from an inspection of FIG. 2 that a decrease in the total charge of ore grinding media in the mill as caused by the effect of the override feed control 52 with its lesser rate of feed or alternatively, its entire stoppage of feed, will cause a decrease in the power consumption by the grinding mill. Hence, if during the period when the override feed control 52 is connected to feed device 24, the mill is operating on portion A-B of the curve, the power increase or decrease sensing device 57 will sense a decrease in power consumption due to the decrease in mill loading caused by override feed control 52. In this case, a power decrease signal will be transmitted by device 57 over conductor means 64 to relay 66 causing relay 66 to return movable contact 44 into engagement with fixed terminal 48, thereby disconnecting the override feed control 52 from feed device 24 and reconnecting normal feed control 36 to feed device 24. When energized or triggered by the "power decrease signal," relay 66 will also open contact 60, thereby disconnecting sensing device 57 from kilowatt meter 34. The normal feed control 36 when reconnected will act to increase the feed rate of ore grinding media to mill 10 to again reach set point S on the curve of FIG. 2. The normal feed control 36 will remain connected to feed device 24 until the next override period occurs as determined by timer 50.

However, if, during the period when override feed control 52 is connected to feed device 24, the power increase or decrease sensing device 57 detects an increase in power consumption despite the decrease in mill charge of ore grinding media caused by the operation of override feed control 52, this will indicate that the grinding mill is operating on portion B-C of the power curve of FIG. 2 and thus is operating beyond the critical peak power draft of the grinding mill. If this condition prevails, a "power decrease" signal will not be transmitted over conductor means 64 to relay 66 and relay 66 will remain in a position in which override feed control 52 remains connected to feed device 24 to continue the reduced rate of feed of ore grinding media to mill 10. Override feed control 52 may be of a type which if it continues to remain connected to feed device 24 causes a progressive decrease in the rate of ore media fed by feed device 24. Alternatively, as previously mentioned, override feed control 52 when in control may entirely stop the feed of ore grinding media to mill 10.

The decreased rate of feed by feed device 24 which may include a complete stoppage of feed of ore grinding media, under the control of the override feed control 52, as just described, will continue until the total charge of ore grinding media in the mill decreases to a point less than loading point D of FIG. 2 (loading point D corresponds to the critical maximum power draft B), and the mill begins to again operate on the portion A-B of the power draft curve below the critical maximum power draft. When this point in the mill loading is reached, the power increase or decrease sensing device 57 will then begin to sense a decrease in power input

to grinding mill 10 with further decrease in total charge of ore grinding media in the mill. The power increase or decrease sensing device 57 will then transmit a "power decrease" signal over conductor means 64 to relay 66, as previously described, causing relay 66 to move contact 44 of switch 42 out of engagement with terminal 46 and into engagement with terminal 48, thereby reconnecting normal feed control 36 to feed device 24. The movable contact 44 will then remain in engagement with terminal 48 as just described, until the next operation of timer 50 moves contact 44 back into engagement with terminal 46, as previously described. The "power decrease" signal will also cause relay 66 to open contact 60, as previously explained.

Modified Control Arrangement of FIG. 4

Referring now to FIG. 4, there is shown a modified control arrangement for controlling the feed of ore grinding media to the secondary autogenous type grinding mill generally indicated at 100. Mill 100 receives five feed ore 112 from a hopper generally indicated at 114 in the same manner as described in connection with the embodiment of FIG. 1. The rate of feed of the fine ore 112 to mill 100 is separately controlled by means which form no part of this invention.

The "ore grinding media" 118 which serves as the grinding media in mill 100 is similar to that described in connection with the embodiment of FIG. 1 and is dispensed from a hopper 120 onto a moving conveyor belt 122. In the embodiment illustrated in FIG. 4, the rate of feed of the ore grinding media to the grinding mill 100 is controlled by controlling the speed of motor 127 which drives the movable conveyor belt 122. However, the rate of feed of the ore grinding media 118 to mill 100 may also be controlled by controlling a feed device 24 which controls the position of a variable adjustment gate 26 in the same manner as described in connection with the embodiment of FIG. 1.

An electric drive motor 128 rotatably drives the grinding mill 100 through a pinion 130 which engages a ring gear 132 on the outer periphery of grinding mill 100, as is conventional in the art.

A kilowatt meter or kilowatt-hour meter 134 measures the power input to mill drive motor 128.

As seen in the diagrammatic view of FIG. 4, a normal feed control 136 for the ore grinding media 118 is provided and is similar to the normal feed control 36 of the embodiment of FIG. 1. Normal feed control 136 is connected by conductor means 138 to kilowatt meter 134 and by conductor means 140 to terminal 148 of a single pole switch generally indicated at 142. The normal feed control 136 controls the rate of feed of ore grinding media to grinding mill 100 as a function of the power demand by grinding mill 100. Switch 142 includes a movable switch contact 144 which normally engages switch terminal 148. Movable switch contact 144 is connected by conductor means 156 to motor 127 which drives conveyor belt 122 which delivers ore grinding media 118 to input spout 116 of grinding mill 100. A timer 150 is mechanically connected to movable switch contact 144 in such manner that at suitable predetermined time intervals, such as, for example, once every 60 minutes, timer 150 moves switch contact 144 out of contact with terminal 148 and thus disconnects normal feed control 136 from its electrical connection to belt drive motor 127, thereby causing motor 127 and hence conveyor belt 122 to stop operating dur-

ing the period when normal feed control 136 is disconnected. When conveyor belt 122 is not operating, as just described, no ore grinding media 118 is delivered to mill 100. The disconnection of normal feed control 136 from its electrical connection to belt drive motor 127, as just described, in effect "overrides" the normal feed control 136 in the sense used in the claims.

A power increase or decrease sensing device 157 which is capable of sensing either an increase or a decrease in power input to grinding mill 100, and which may be similar to power increase or decrease sensing device 57 of FIG. 1, is connected by electrical conductor means 158 to kilowatt meter 134 in series with a normally open contact 160 which is closed by timer 150 when movable contact 144 is moved out of engagement with terminal 148. Conductor means 164 transmits a "power decrease" output signal from the power increase or decrease sensing device 157 to a relay 166 when device 157 senses a decrease in the power consumption by grinding mill 100 in the same manner as described in connection with the embodiment of FIG. 1. Relay 166 is energized or triggered by the "power decrease" signal from the power increase or decrease sensing device 157. Energization of relay 166 by a "power decrease signal" causes relay 166 to return movable contact 144 into engagement with terminal 148, thereby reconnecting the normal feed control 136 to the belt drive motor 127 and thereby causing the conveyor belt 122 to resume movement to again deliver ore grinding media to mill 100.

Summary of Operation of Embodiment of FIG. 4

In operating in accordance with the apparatus and method of the invention as shown in the modified arrangement of FIG. 4, the belt drive motor 127 which drives conveyor belt 122 and thus controls the rate of dispensing of the ore grinding media 118 to grinding mill 100, is normally automatically controlled as a function of the power draft by mill drive motor 128, as indicated on kilowatt meter 134. Thus, in normal operation the speed of the belt drive motor 127 is controlled by the normal feed control 136, which is responsive to the reading of kilowatt meter 134, through the connection of the movable contact 144 of switch 142 to the fixed terminal 148, whereby the normal feed control device 136 is connected through switch 142 to belt drive motor 127. When kilowatt meter 134 indicates that the power drawn by the mill is below the set point S (FIG. 2), the normal feed control 136 acts to cause the belt drive motor 127 to increase the feed rate of the ore grinding media 118 to mill 100; and conversely, when kilowatt meter 134 indicates that the mill is drawing power above the set point S, the normal feed control 136 acts to cause the belt drive motor 127 to diminish the rate of feed of ore grinding media 118 to grinding mill 100, thus tending to reduce the power draft by the grinding mill back to the set point S.

At suitable time intervals, say once in every 60 minutes, for example, timer 150 moves movable contact 144 out of engagement with fixed terminal 148, thereby disconnecting normal feed control 136 from belt drive motor 127 thereby causing belt drive motor 127 to stop operating, stopping conveyor belt 122, and thereby discontinuing the feed of ore grinding media 118 to grinding mill 100. At the same time, timer 150 acts to close contact 160 to thereby connect power increase or decrease sensing device 157 to kilowatt meter

134. A "power decrease" signal is transmitted by device 157 over conductor means 164 to relay 166 when device 157 senses a decrease in the power draft of mill 100.

Since the complete stoppage in the feed of ore grinding media 118 to the grinding mill 100 due to the opening of switch 142 as just described, causes a measurable effect on the power consumption by mill 100 within a few minutes, power increase or decrease sensing device 157 will detect a change in power consumption by mill 100 within a short time after switch 142 is opened.

If, during the period when switch 142 is open and the normal feed control 136 is electrically disconnected from belt drive motor 127, with resultant stoppage of feed of ore grinding media to grinding mill 100, the mill 100 is operating on portion A-B of the power input curve of Fig. 2, it can be seen from an inspection of FIG. 2 that a decrease in the total charge of ore grinding media in the mill will cause a decrease in the power consumption by the grinding mill. Hence, if during the override period when the belt drive motor 127 has stopped due to opening of switch 142, the mill is operating on portion A-B of the curve, the power increase or decrease sensing device 157 will sense a decrease in power consumption. In this case, an electrical signal indicative of the power decrease will be transmitted by device 157 over conductor means 164 to relay 166, causing relay 166 to return movable contact 144 into engagement with terminal 148, thereby reconnecting the normal feed control 136 to belt drive motor 127. When energized or triggered by the "power decrease" signal, relay 166 will also open contact 160, thereby disconnecting sensing device 157 from kilowatt meter 134. The normal feed control 136 when reconnected will reenergize belt drive motor 127, causing conveyor belt 122 to again resume the feeding of ore grinding media to mill 10, to again reach set point S on the curve of FIG. 2. The normal feed control 136 will remain connected to belt drive motor 127 until the next override period occurs, as determined by timer 150.

However, if, during the period when switch 142 is opened and conveyor belt 122 is not moving, with resultant complete stoppage of feed of grinding media 118 to mill 100, the power increase or decrease sensing device 157 detects an increase in power consumption despite the decrease in mill charge caused by the disconnection of the normal feed control 136, this will indicate that the grinding mill is operating on portion B-C of the power curve of FIG. 2, and thus is operating beyond the critical peak power draft to the grinding mill. In this case, relay 166 will not be triggered into operation, and switch 142 will remain open, with belt drive motor 127 remaining disconnected from feed control 136.

As the belt drive motor 127 continues to remain disconnected from the normal feed control 136 and thus the complete stoppage of the feed of ore grinding media 118 to grinding mill 100 continues, the total charge of ore grinding media 118 in the mill will eventually decrease to a point less than the loading point D corresponding to the critical maximum power draft B and the mill will begin to again operate on the portion A-B of the power draft curve below the critical maximum power draft. When this point in the mill loading is reached, the power increase or decrease sensing device 157 will then begin to sense a decrease in power input to grinding mill 100 and will transmit a "power

decrease" signal over conductor means 164 to relay 166 causing relay 166 to move contact 144 of switch 142 into engagement with terminal 148, thereby reconnecting normal feed control 136 to belt drive motor 127. Belt drive motor 127 will resume operation, thereby causing the feed of ore grinding media 118 to mill 100 to resume. The "power decrease" signal will also cause relay 166 to open contact 160 to thereby disconnect the power increase or decrease sensing device 157 from kilowatt meter 134, as previously explained. Switch 142 will remain closed with movable contact 144 in engagement with terminal 148, as just described, until the next operation of timer 150 reopens switch 142, as previously described.

It can be seen from the foregoing that there is provided in accordance with the embodiments of the invention an apparatus and method which provide a check of the grinding mill operation at suitable intervals to determine whether the grinding mill is operating on the portion A-B of the power draft curve or on the portion B-C of the power draft curve, and for making appropriate adjustments to the rate of ore grinding media fed to the mill if the control determines that the mill is operating at a point on the power draft curve beyond the point of critical maximum power draft. Because of the checking and appropriate grinding media feed adjustment made, if necessary, in accordance with the apparatus and method of the invention, the mill may be operated at a set point which is closer to the point of critical maximum power draft than is the case in connection with the prior art apparatus and method. As previously mentioned, it is common practice in accordance with the prior art to establish the set point of the mill power draft at a point which is substantially lower than the point of critical peak power, such as, for example, 85 percent or 90 percent of the critical peak power, in order to safely avoid increasing the amount of the total ore grinding media charge in the mill beyond that requiring the critical peak power draft. In accordance with the apparatus and method of the invention, the operating set point of the power draft may be set at, for example, 95 percent of the critical peak power, thereby increasing the grinding capacity of the given grinding mill.

In describing the embodiment of the apparatus and method of the invention shown in FIG. 1, a switching device has been shown which selectively connects either the normal feed control 36 or the override feed control 52 in controlling relation to feed device 24. However, it will be understood that other means may be employed to render either the control 36 or the control 52 selectively either effective or ineffective to control the feed device 24. For example, instead of mechanically switching either control 36 or control 52 into controlling relation to device 24, the same result may be accomplished by maintaining a continuous connection of both controls 36 and 52 to device 24, and selectively energizing or deenergizing the controls 36 and 52. For this reason, the terms "activate" and "deactivate" are respectively used in the claims to cover any manner of respectively rendering effective (to activate) or ineffective (to deactivate) the ability of control 36 or of control 52 to control feed device 24. Thus, for example, when control 36 is disconnected from feed device 24, it has been "deactivated" and when it is connected to feed device 24 it is "activated." In a similar manner, if control 36 were to be deenergized,

although connected to device 24, it would be "deactivated" and if it were energized while connected to device 24, it would be "activated."

The terms "activated" and "deactivated" are used in the same sense as just described in the embodiment of FIG. 4, as well as in the embodiment of FIG. 1.

All references herein to mesh sizes are to Tyler mesh sizes, a well known standard.

From the foregoing detailed description of the present invention, it has been shown how the objects of the invention have been obtained in a preferred manner. However, modifications and equivalents of the disclosed concepts such as readily occur to those skilled in the art are intended to be included within the scope of this invention.

I claim:

1. In combination, a grinding mill of the type which is capable of operating in the vicinity of its critical peak power draft, means for feeding a grinding media to said mill, first control means for normally controlling the rate of feed of grinding media to said mill as a function of the electrical power draft of the mill, second means actuatable into overriding relation to said first control means at predetermined intervals and effective when in said overriding relation to reduce the rate of feed of grinding media to said mill sufficiently to cause a measurable effect on the power draft of the mill, means for sensing the direction of change in power draft of said mill caused by the reduction in feed rate effected by said second means whereby to indicate where said mill is operating relative to the critical peak power draft of the mill on the curve of power draft v. mill charge of grinding media for said mill, and means responsive (1) to a sensed decrease in the power draft of said mill caused by the reduction in feed rate effected by said second means for restoring said first control means in controlling relation to the feed of grinding media to said mill, and (2) to a sensed increase in the power draft of said mill caused by the reduction in feed rate effected by said second means for maintaining said second means in controlling relation to the feed of grinding media to said mill.

2. The combination defined in claim 1 in which said

second means is operative to substantially completely stop the feed of grinding media to said grinding mill.

3. The combination defined in claim 1 in which said grinding mill is a secondary autogenous grinding mill and the grinding media whose rate of feed is being controlled is the ore grinding media for said secondary autogenous grinding mill.

4. The method of controlling a grinding mill of the type which is capable of operating in the vicinity of its critical peak power draft which comprises the steps of: (1) Normally controlling the rate of feed of grinding media to said mill by a normal feed control as a function of the electrical power draft of said grinding mill; (2) overriding the normal feed control at suitable intervals whereby to cause the rate of feed of the grinding media to decrease sufficiently to produce a measurable effect on the power draft of the mill; and (3) sensing the direction of change of the power draft of the mill caused by the decrease in feed rate of grinding media when said normal feed control is overridden as an indication of where the mill is operating relative to the critical peak power draft of the mill on the curve of power draft v. mill charge of grinding media for said mill.

5. The method defined in claim 4 in which said grinding mill is a secondary autogenous grinding mill and the grinding media whose rate of feed is being controlled is the ore grinding media for said secondary autogenous grinding mill.

6. The method defined in claim 4 in which the override action causes the feed of grinding media to the mill to substantially stop whereby to produce a measurable effect on the power draft of the mill.

7. The method defined in claim 4 which includes the step when a decrease in power draft by the mill is sensed in step (3) of reactivating the normal feed control.

8. The method defined in claim 4 which includes the step when an increase in power draft by the mill is sensed in step (3) of continuing to provide a reduced rate of grinding media feed to said mill until a decrease in power draft by said mill is sensed.

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