

Aug. 7, 1945.

H. HARDINGE

2,381,351

METHOD AND MEANS OF FEEDING MATERIAL TO GRINDING MILLS

Filed April 23, 1942

4 Sheets-Sheet 1

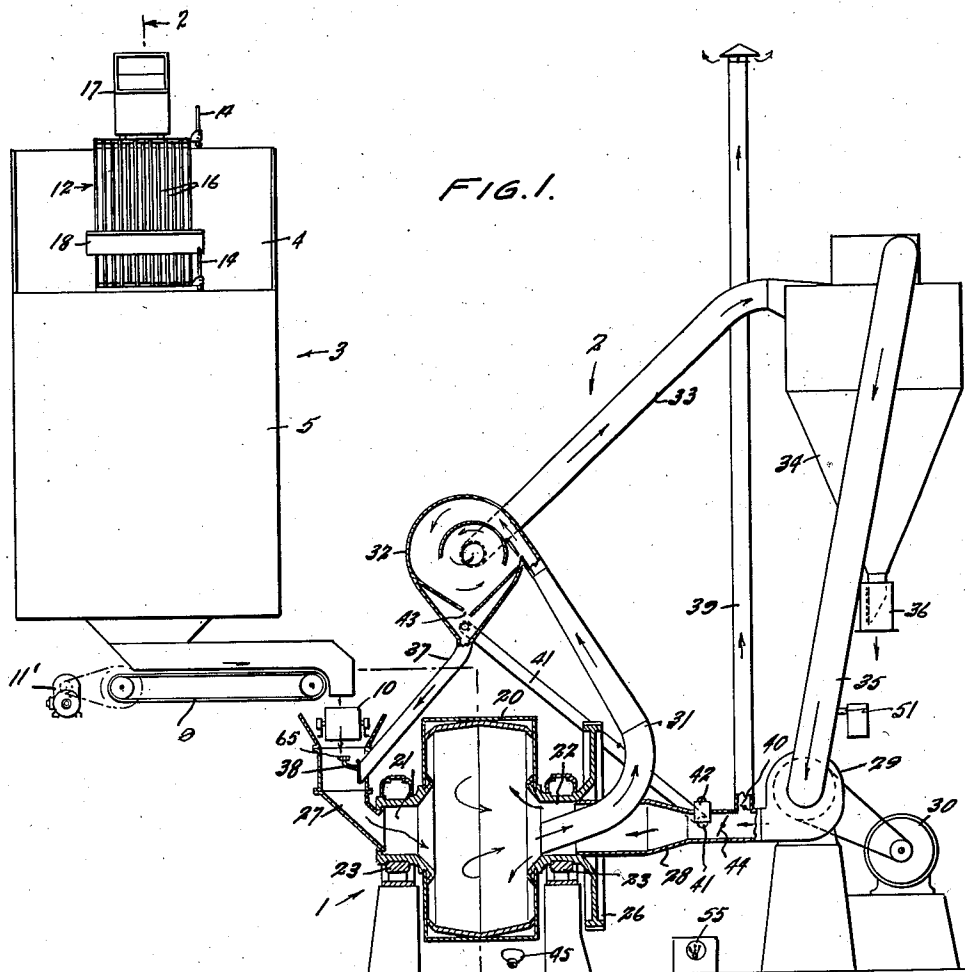


FIG 13

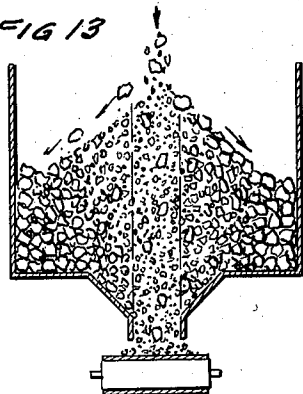
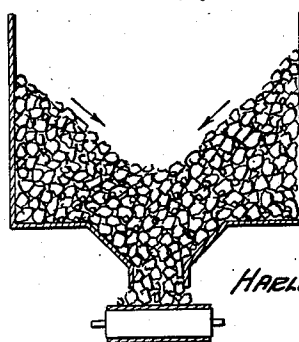


FIG 14



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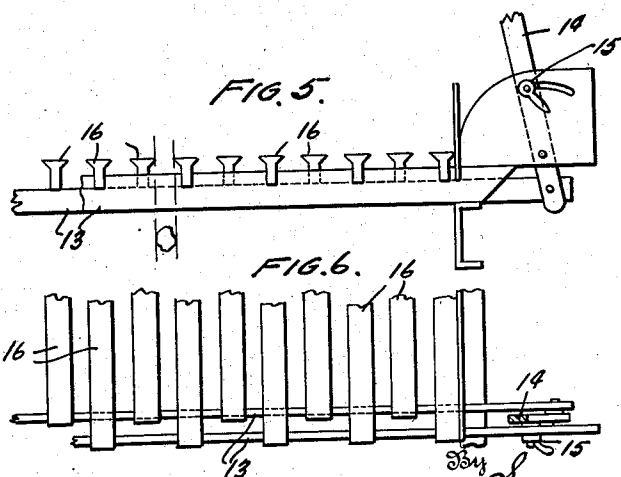
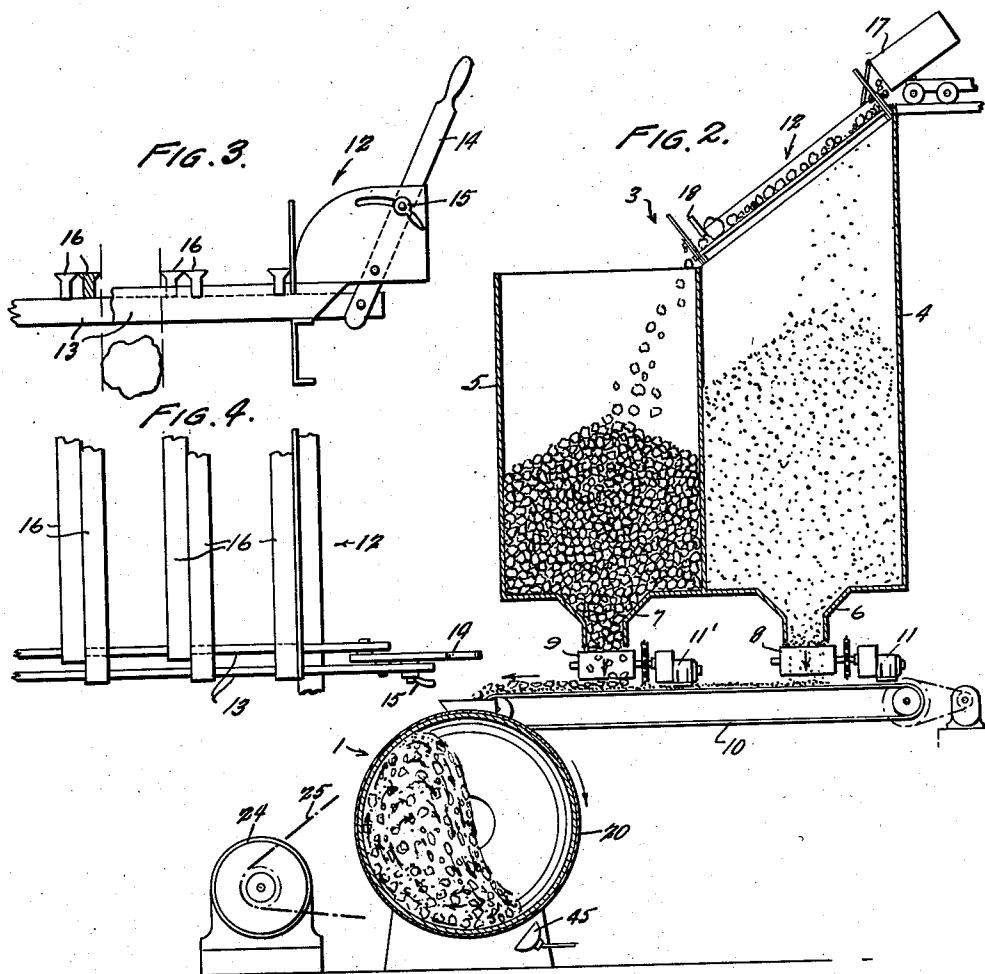
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4 Sheets-Sheet 2



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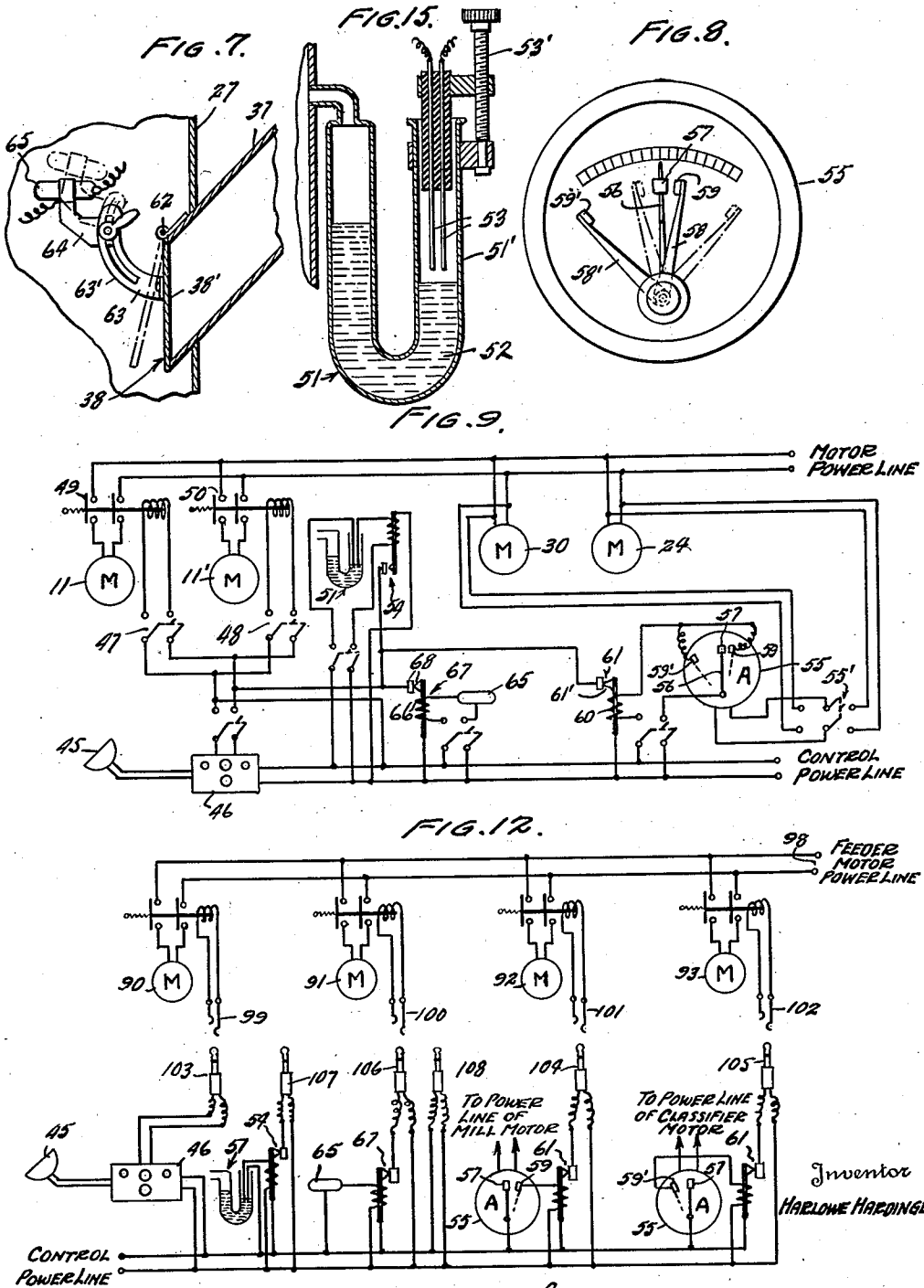
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METHOD AND MEANS OF FEEDING MATERIAL TO GRINDING MILLS

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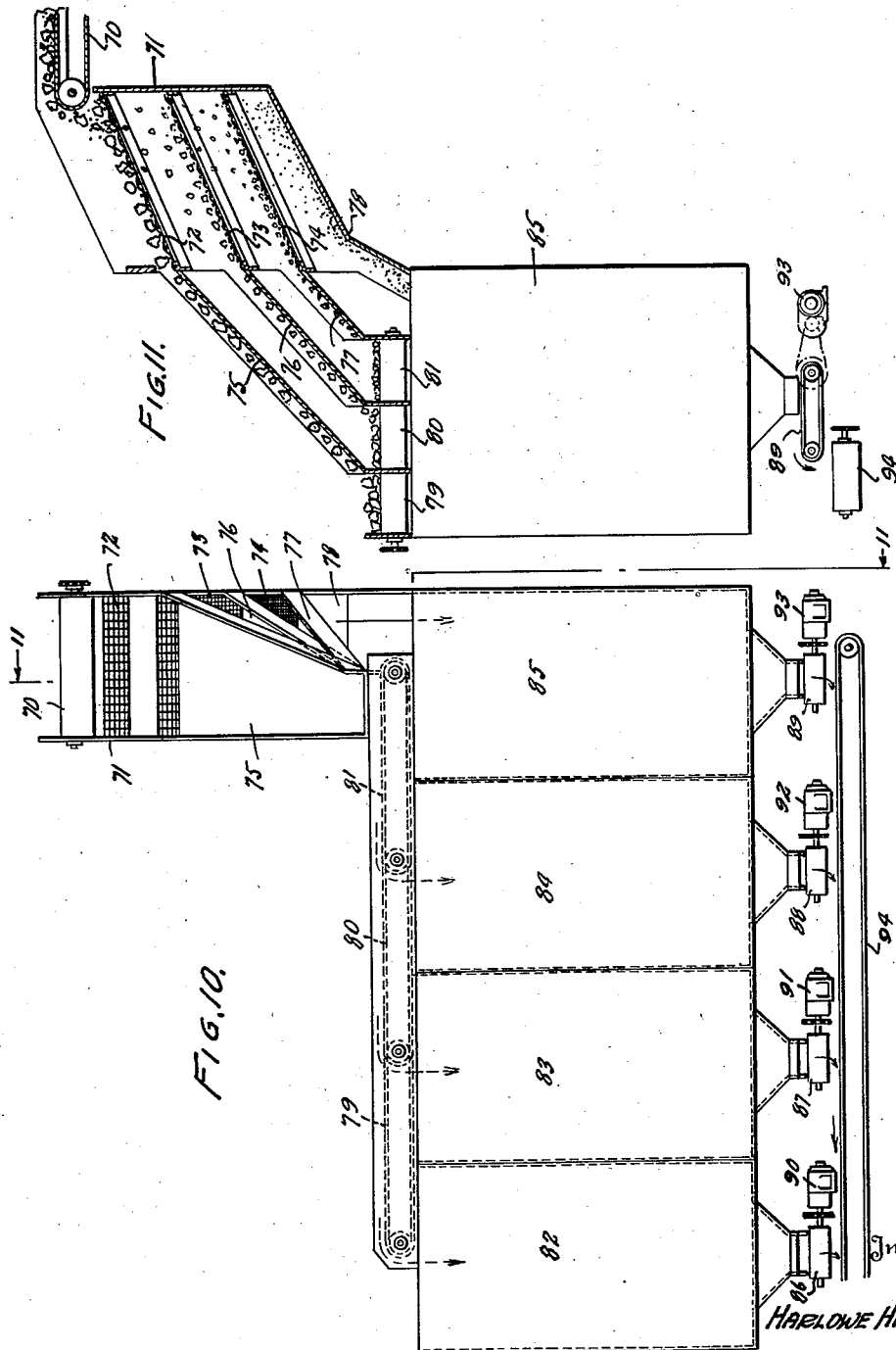
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METHOD AND MEANS OF FEEDING MATERIAL TO GRINDING MILLS

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4 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE

2,381,351

METHOD AND MEANS OF FEEDING MATERIAL TO GRINDING MILLS

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22 Claims. (Cl. 241-24)

The present invention relates to ore reduction and more particularly to a method and apparatus for controlling the feed of material to a grinding mill which is adapted to use "run of the mine" ores and which utilizes such material as its own grinding medium.

By "run of the mine" ores is meant a mixture of both coarse and fine material, the larger particles being of sufficient size to crush themselves and the finer particles by dropping or cascading in a mill. It is well known to those familiar with handling such material that when it is piled, as in the mine, quarry or onto rock piles, or when dumped into bins, it tends to segregate according to size; the finer particles remaining at the top and the coarser particles rolling down toward the bottom. The coarsest pieces usually are found at the bottom of the slope defining the angle of repose of the material.

As an example of this segregating action, reference is made to the diagrammatic figure, 13, of the drawings which represents a storage bin with a conical bottom. As ore is dumped into the bin, as from a mine car, the fines will build up in the central portion of the bin while the coarser particles, moving down the slope of the pile, build up around the bin's sides forming a distinctly segregated mass.

This bin is primarily a storage reservoir for material to be withdrawn from the bottom thereof to the grinding mill to be pulverized; and, under normal conditions, when the mill is operating, the feed to the bin has either been stopped or greatly exceeds the discharge rate to the mill. Under these conditions the material flowing from the bottom of the bin is active in a zone vertically above the bin opening directly to the top of the mass. Thus the finer material in the center of the mass will be withdrawn first.

If material is still being fed to the bin at a rate in excess of the discharge, the ore will continue to segregate according to size as above and the fines will predominate in the discharge. After the feed has been stopped and the fines discharged, the top of the mass will cone down, the base of this inverted cone gradually widening toward the coarser material at the outer boundary of the mass. At this time the coarser particles will roll down the slope of the cone toward the discharge and the withdrawn material will coarsen in character until the base of the cone reaches the periphery of the bin. From then on until the bin has emptied the discharge will be predominately the coarse material with a relatively few fines filling the spaces between

the coarse particles. This condition is diagrammatically illustrated in Figure 14.

The type of mill best adapted to handle run of the mine ores is that which utilizes the material itself as a grinding agent. Such a mill employs a rotating drum into which the ore is fed and tumbled by rotation of the drum. The grinding action due to such tumbling is well known; the coarser particles of ore acting in a manner similar to the steel balls or special pebbles used as the grinding media in ball or pebble mills.

To obtain the most efficient operating condition in the mill and to obtain its maximum output, there must be maintained a certain ratio between the coarse, fine and intermediate sizes of ore particles within the mill. For instance, if the charge of material were almost exclusively composed of fine particles, these particles in tumbling in the mill would simply abrade each other, and their grinding and crushing action would be extremely low.

On the other hand, if the mill contains nothing but coarse pieces and its speed is such as to cause them to drop a sufficient distance upon other coarse pieces without the cushioning effect of finer particles, they will rapidly break up into smaller pieces when the abrading condition above mentioned will again result.

Both of these conditions will result from bin segregation as described above. For instance, during the first part of the run the feed to the mill would be predominately fines and during the latter part predominately coarse. In either case, the mill gradually overloads until grinding substantially ceases. Even with the introduction of some coarse material at this time, the cushioning effect of the accumulated material in the mill is so great that before actual grinding is resumed the mill will become sufficiently overloaded to spill over, thereby making its operation entirely impractical.

However, if the proper ratio of coarse to fine material is maintained in the mill, the larger pieces in dropping and tumbling about will crush and grind the smaller pieces with sufficient force to rapidly reduce them to the desired fineness, yet being sufficiently cushioned with finer sizes so as not to be rapidly broken down themselves.

These conditions have been recognized by those engaged in ore reduction, and various attempts have been made in the past to increase the efficiency of the grinding operation. As a typical example, larger pieces of ore have been selected from the mined material and retained to be fed to the mill when required as grinding media.

The balance of the material has then been crushed to a predetermined maximum size by other suitable crushing equipment and fed to the mill with the larger pieces.

However, due to variables prior to the grinding operation, such as methods of mining or quarrying; methods and intervals of removing mined ore to the feed bins; condition of the ore itself varying as it does in hardness, moisture content, weight per cubic foot and size; and particularly its inherent size segregating properties on the storage pile or in the feed bin; none of these attempts have resulted in the utilization of the maximum operating capacity of the grinding mill.

Therefore the principal object of my invention is to provide a method of continuously operating an ore reducing system wherein the size ranges of run of the mine material fed to the grinding mill is controlled to maintain an optimum operating condition within the mill whereby the whole of such run of the mine material may be reduced to required fineness without additional pre-treatment of the material prior to grinding.

Another object is to provide a method and apparatus for continuous operation of an ore reducing system which utilizes the operating conditions of the system for controlling the size range of run of the mine material fed thereto.

A further object is to provide a controlled method of feeding run of the mine material to an ore reducing system whereby a minimum of size ranges of material necessary for optimum grinding operation are always maintained.

Yet another object is to provide a method and apparatus for continuous reduction of run of the mine ore by provision of means whereby the ore, as mined, is segregated by controlled methods whereby it is accumulated in masses defining definite size ranges and then recombined also by controlled methods in such a ratio of coarse to fine that optimum operation of the system is maintained.

Briefly my invention comprises first segregating run of the mine ore into a plurality of storage bins. Each of these bins is adapted to contain a predetermined size range of the material. The ore is then withdrawn from the bins by controlled means to effect a definite ratio of coarse to fine material and continuously fed to a grinding mill either of the so-called wet or dry types.

While the present invention is adaptable for controlling the feed to grinding mills of either the so-called wet or dry types I have chosen to show and describe herein a dry grinding type of mill which utilizes the material itself as its own grinding agent. This type of mill is, in effect, a drum rotating on hollow trunnions, the material to be ground entering the drum through one trunnion and the ground product being withdrawn through the other trunnion.

Air is continuously circulated through the mill by a fan to remove the smaller particles of crushed and ground ore to a classifier where the oversize material is separated and returned through an air lock back to the mill. The fines or finished product is carried by the air stream to a collector where it is separated from the air and discharged to storage while the air is returned to the suction side of the fan to be recirculated.

The definite control of the ratio between the coarse and finer particles of ore has important bearing on the grinding efficiency of this particular type of mill and its capacity for handling all of the ore as it comes from the mine without

precrushing and without its accumulating a quantity of critical or hard-to-grind sizes.

There are a number of variables in the operation of the mill and classifier that serve as indicators of the system's functioning, and one or more of which I propose to utilize to effect this ratio control.

First and possibly the most sensitive of these indicators is the sound emanating from the mill itself. For example, if the mill contained a predominance of coarse material with very little fine to act as a cushion, the sound level would be high and, as stated above, the mill would be operating at a very low efficiency. Likewise, if all fine material were being supplied to the mill, its grinding efficiency would still be reduced but the sound level would be low. This variation in sound level may be utilized to effect a change in feed rate of either the coarse or finer material to obtain an optimum balance of sizes of ore for highest operating efficiency of the mill. By employing a sound sensitive device such as shown in my Patent No. 2,235,928, operation of one or more of the feed motors of the storage bins may be automatically controlled.

Another variable which may be utilized is the load imposed on the operating motor for the mill, or rather the power consumed by this motor, for varying conditions within the mill. Considering material is being fed to the mill at a continuous rate and at an optimum ratio of size ranges, grinding conditions are normal, and a certain power is consumed to operate the mill. However, as grinding conditions change, the consumption of power changes. For instance, should the grinding rate decrease, and as the mill loads up, prior to actual overload, the power consumption increases due to the increased load on the electric motor. Also should the mill empty abnormally due to abnormal feed conditions and its load decrease, the power consumption will also decrease. This mill power variable, effected by improper relationship of ore sizes, may also be utilized to automatically return the feed ratio to its optimum by employment of a suitable power responsive meter and relay in the supply line to the mill motor which will, in turn, affect the operation of the feed motors for the bins.

A similar power responsive circuit may also be used in the motor circuit for the classifier fan, as loading of this fan motor by material being moved through the classifier is an indication of the operating conditions within the system.

Yet another variable which can be used to govern the amount and kind of feed to the mill is the amount of oversize returned from the classifier to the mill for regrinding, an amount substantially different than a so-called "normal" for a given operating condition indicating inefficient grinding conditions in the mill. It is contemplated, under certain conditions, to utilize this movement of returned oversize to vary the feed rate of at least one of the ore size ranges to the mill.

A still further variable, which tests have proved to be very effective in maintaining proper feed conditions, is the differential in classifier air pressures caused by differences in material loading of the classifier air, in turn caused by varying operating conditions within the mill.

Obviously, the feed rate from any or all of the storage bins may be controlled manually, and it is contemplated to utilize any or all of the above mentioned automatic control means or manual means either singly or in any combination to

control the rate of feed and the ratio of coarse to fine material being supplied to the mill to effect grinding conditions in the mill which will result in enabling the mill to grind the entire ore as it comes from the mine in an efficient economical manner.

In addition to the above, yet another control means for size ratio of the coarse to fine material is contemplated. This is the provision of an adjustable grizzly or grizzlies or screens associated with the storage bins over which the run of the mine ore may pass to regulate the amount and size of material loaded into each bin. This feature is particularly desirable in maintaining a constant supply of the different size ranges of material over long periods of time. In other words, the grizzlies may be so adjusted that independently of the type of material being brought from the mine, or the size ratio of material being supplied the mill, there always may be maintained an adequate supply of the coarser sizes of material for proper grinding conditions. This manually adjustable bin classifying method may also serve as a supplemental balance for the automatic feed control mentioned above.

In the drawings which form a part of this specification and in which like characters of reference are employed to designate like parts—

Figure 1 is a diagrammatic side elevational view, partly in section, showing a grinding mill in closed circuit with an air classifier system.

Figure 2 is a sectional view taken substantially along the line 2—2 of Figure 1 looking in the direction of the arrows.

Figure 3 is a fragmental end elevation of the sizing grizzly showing the grizzly bars adjusted to pass the maximum size ore.

Figure 4 is a plan view of the arrangement shown in Figure 3.

Figure 5 is a view similar to Figure 3 showing the grizzly bars adjusted to pass ore of a smaller size.

Figure 6 is a plan view of the arrangement shown in Figure 5.

Figure 7 is a sectional view of the discharge end of the oversize return duct, air lock and the control apparatus associated therewith.

Figure 8 is a face view of the power meter used to control ratio of feed sizes of ore.

Figure 9 is a wiring diagram showing one method of feed control.

Figure 10 is a side elevational view showing a modified arrangement of feed bins and means to control the segregation of ore.

Figure 11 is a sectional view taken along the line 11—11 of Figure 10 looking in the direction of the arrows.

Figure 12 is a wiring diagram of one method of controlling feed from the arrangement of bins shown in Figure 10.

Figure 13 is a view of a bin filling and discharging simultaneously.

Figure 14 is a view similar to Figure 13 illustrating the discharge from a partially emptied bin; and

Figure 15 is a diagrammatic view illustrating a circuit closing device actuated by pressure differentials in the classifier system for controlling flow of material from the feed bins.

Referring to the drawings, I have shown somewhat diagrammatically a grinding mill 1 in closed circuit with an air classifying system indicated generally as 2 and a mill feeding system indicated generally as 3. While, for the sake of simplicity, two feed bins 4 and 5 are shown to

segregate the incoming ore into two size ranges, under certain conditions of operation, it may be necessary to segregate the ore into additional intermediate size ranges. To provide for such conditions, I have shown in Figures 10 to 12 an arrangement of four bins with interlocking discharge control means.

The bins 4 and 5 are positioned adjacent each other and are provided with hopper bottoms 6 and 7, respectively. Discharging conveyors or feeders 8 and 9 are respectively positioned under the opening of each bottom 6 and 7 for feeding material from the bins onto a common conveyor 10 adapted to convey the material to the grinding mill 1. These conveyors 8 and 9 are adapted to be driven by electric motors 11 and 11'.

Disposed above one of the bins, the bin 4, is an adjustable grizzly 12 comprising pairs of lateral beams 13 movable longitudinally relative to each other by means of levers 14. Suitable locking means 15 are provided to maintain the beams in desired position. A plurality of spaced parallel bars 16 extend between each pair of beams to provide a grating through which ore of a given size may pass. Reference to Figures 3 and 5 will clearly show that as the lever 14 is moved the bars 16 will move toward or away from each other to vary the size of the opening between the bars 16. Thus ore, as it is dumped, as from a mine car 17, onto the grizzly, will move down over the grizzly bars 16, the smaller pieces dropping into the bin 4 while the pieces larger than the spaces between the bars 16 pass downward over the end of the grizzly and into the bin 5. A baffle plate 18 is disposed laterally across the end of the grizzly and spaced above it a distance equal to the size of the largest piece of ore desired to be deposited in the bin 5. Any oversize material is caught by this plate where it may be removed or broken by the operator.

As stated, the mill 1 is of the dry grinding type adapted to use the material to be ground as its own grinding medium and comprises a cylindrical drum 20 provided at each end with a hollow trunnion 21 and 22 journaled in bearings 23 in which the mill is adapted to revolve. Rotary motion is transmitted to the mill by means of an electric motor 24 through a chain 25 and sprocket gear 26 carried by the trunnion 22. Material from the bins 4 and 5 is conveyed by the conveyor 10 to a tubular chute 27 which projects into the trunnion 21.

Rotation of the drum 20 causes the material therein to be carried upward by friction and centrifugal action until gravity overcomes these forces when it drops or cascades down to provide a continuous tumbling action of the material in the mill. In this tumbling, the larger particles of material crush, grind and finally pulverize the smaller particles; they themselves gradually becoming broken by this action and, in turn, ground by incoming larger pieces.

The other trunnion 22 has connected therewith one end of a tubular conduit 28, the opposite end of which connects with the pressure side of a blower or fan 29 driven by a motor 30. Air is forced by the fan 29 into the drum 20 where it picks up the fines from the ground material, reverses its flow and is withdrawn through a conduit 31 to a classifier 32. Here the dust or finished product is separated from oversize and carried through a conduit 33 to a product collector 34 where the entrained air is separated by cyclonic action and returned to the suction side of the fan 29 through a pipe 35. The finished

product is discharged through an air lock 36 at the base of the collector 34 where it may be transferred to storage or further treatment.

The oversize from the classifier 32 is returned to the grinding mill for further reduction through a return conduit 37 which terminates in the feed chute 27. The discharge end of the conduit 37 is provided with a hinged gate or air lock 38.

The conduit 28 is provided with a vent stack 39 controlled by a damper 40 through which leakage air entering the system and moisture which may have entered with the feed may pass out. A portion of the air stream from the fan 29 is by-passed through a line 41, controlled by a damper 42, into the bottom of the classifier 32 and up through a baffled opening 43 to clean the oversize. The main stream of air from the fan 29 to the mill is controlled by means of a damper 44.

In order to utilize the sound of the mill 1, which indicates grinding conditions therein, to control the type of feed, I place a microphone 45 adjacent the drum 20 as indicated in Figure 2. This microphone forms a part of a sound sensitive apparatus such as is disclosed in my Patent No. 2,235,928. The apparatus and its circuit therefore will not be described in detail. The microphone 45, however, is connected through a suitable regulating and relay apparatus 46 to a pair of single throw switches 47 and 48. These switches are connected with the control circuits 49 and 50, respectively, of the feeder motors 11 and 11'.

Thus by closing either or both of the switches 47-48 the rate of feed from either or both of the bins 4-5 may be controlled by the grinding conditions within the mill. As an example, the smaller particles of ore from the bin 4 may be continuously fed to the mill by opening the switch 47. Then by closing the switch 48 the sound of the operating mill may be used to regulate the feed of coarse material from the bin 5 by means of the microphone 45, relay circuit 46, to the control apparatus 49 of the feeder motor 11 to either start and stop this motor or regulate its speed through a suitable rheostat or other speed change device not shown.

Alternately the coarse material from bin 5 may be fed at a constant rate and the rate of feed from the bin 4 may be automatically controlled by the sound level in the mill 1. Or, as yet another method of feed, the rate of flow from both bins 4 and 5 may be automatically regulated by the sound responsive system. Then the desired balance between coarse and fine material may be regulated by manipulation of the adjustable grizzly 12 to regulate the segregation of material being admitted to the two bins.

Considering the finer material being supplied to the mill at a constant rate from the bin 4 and the microphone 45 being employed to regulate the flow of coarse material; as long as the mill is operating normally, that is, grinding at its optimum efficiency, the flow will continue at a given ratio of coarse to fine. However, should the grinding efficiency fall off due to a change in the type of material being loaded into the bins, or from other causes, the sound level will either raise or lower according to a predominance of coarse or fine material or the amount of the total load in the mill. As this sound level changes, the sound sensitive apparatus will function to supply either less or more coarse to the mill to again obtain the desired balance.

As the second means of controlling the feed

to the mill, which may be used either in combination with or independently of the mill noise level, the power demand of the mill and classifier may be utilized. To accomplish this, a current responsive relay device is connected into the power circuit of either the mill motor 24 or the classifier motor 30 by means of a double throw switch 55'. Such a device is illustrated diagrammatically in Figure 8 where the numeral 55 represents a power meter whose pointer 56 may be supplied with a double contact point 57. Arms 58 and 58' having contact points 59 and 59', respectively, are positioned on either side of the pointer 56 and are adjustable concentrically with respect to the pointer shaft so that the points 59 and 59' may be moved toward or away from the contact point 57.

The contact points 57 and 59 or 59' are adapted to close electric circuit to the heating element 60 of a thermal time delay relay 61 whose contact points 61' are adapted to be connected in series with the operating circuit of either one or both of the feeder motors 11-11'. The time delay relay 61 may be considered normally closed and its purpose is to prevent "chatter" due to brief fluctuations in power or operating conditions of the system.

If the meter 55 is connected in the mill motor circuit, the contact arm 58 will be in the path of movement of the pointer 56 as operating current for the motor increases. As long as grinding conditions of the mill 1 are normal, a substantially constant amount of current is consumed and the pointer 56 remains virtually stationary. However, as the mill tends to overload as heretofore explained, thus increasing the load on its driving motor and increasing the operating current, the pointer 56 and its contact 57 moves toward the pre-adjusted contact point 59 until the predetermined overload condition of the mill has been reached. At this time the contacts 57 and 59 close, supplying current to heat the thermal relay which will open to break circuit to either or both of the feeder motors 11-11' until the mill has again returned to its normal load. It is to be understood that the above action takes place prior to the time that an actual overload occurs in the mill at which time the operating current for its motor may decrease.

Overloading the system, particularly to the point where fines spill over into the classifier circulating system, will affect the operating characteristics of the fan motor 30, decreasing its power consumption as the material overload increases.

Under certain conditions it is advantageous to control the feed by this variation in current consumption, in which case the meter 55 is connected in the power circuit of the fan motor by means of switch 55'. As the material load increases and the amount of fines in the classifier increases, the current consumption of the fan motor will decrease. In this present instance the contact arm 58' adjustably located on the low current side of the pointer 56 is adjusted so that the point 57 will contact the point 59' when the current consumption of the fan motor has decreased to a predetermined amperage to control the operation of either or both of the feeder motors 11-11'.

The third variable in operating conditions of the system, the return of oversize to the mill, may be employed to control the feed as follows: The air lock 38 adapted to close the discharge end of the oversize return conduit 36 comprises a gate or flap 38' hinged at its upper edge as indicated

at 62 to the conduit 37. Attached to the flap 38' is a bracket 63 having an arcuate slot 63' in which is adapted to be adjustably secured one end of an arm 64 which supports a mercury switch 65. The switch 65 is adapted, upon movement of the flap 38' through a predetermined arc, to supply current to the heating element 66 of a thermal, retarded relay or time delay switch 67. The contact points 68 of the relay 67 in turn supply current of the control circuits of either or both of the feeder motors 11—11'.

Thus it is obvious that the oversize material in excess of normal amounts returning from the classifier 32 to the mill 1 through the conduit 36 will raise the flap 38' a sufficient amount to tilt the mercury switch 65 to close its contacts to supply current to the thermal relay 67. If the points 68 of this relay are considered normally closed, they will then open to cause the control circuit of either the fine or coarse feeder motor 11 or 11', or both, to stop the feeders until the oversize flow has returned to normal.

Under certain conditions, it may be found that a reduction in the amount of oversize returned to the mill will be the factor indicating an overload or improper mill conditions. In such case the action of the mercury switch 65 may be reversed by adjustment of its bracket to function when the amount of returned oversize has fallen below a predetermined amount.

To utilize the differential in air pressure for controlling the feed to the mill I may employ a device such as is diagrammatically shown in Figure 15. As stated above, when the mill 1 tends to overload, the amount of material removed therefrom by the fan 39 to the classifier 32, through the duct 31, will tend to load the pipe 31 and the air pressure in the system will change. For example, an increase in the load of material in the duct 31 will result in an increase in the partial vacuum in the air return duct 35.

To utilize this differential in pressure, I propose to connect one end of an open U-tube 51 to communicate with the air return duct 35. This U-tube 51 contains an electrically conductive liquid 52 and has adjustably inserted in its opposite leg 51' a pair of electrodes or contact points 53. The position of the electrodes 53 relative to the surface of the liquid 52 may be controlled by a suitable adjusting means such as a thumb screw 53' supporting the electrode bracket. A thermal delay switch 54 is provided to cooperate with the electrode in a manner similar to the switches 61 and 67.

As the pressure in the duct 35 decreases due to an increase in material load in the classifier system, the column of liquid in the leg 51' of the U-tube will obviously lower. The position of the electrodes 53 is adjusted so that they will be immersed in the liquid 52 during normal operation of the system. When, however, the pressure in the duct 35 lowers, due to an increase in loading of the classifier air with material, the liquid in the leg 51' of the U-tube will lower to break contact between the electrodes 53. This causes the normally closed delay switch 54 to open, thereby opening the operating circuit of either one or both of the feeder motors 24 or 30.

Obviously, the U-tube 51 could be connected with the pressure side of the fan 29 utilizing an increasing air pressure in the system to accomplish the same result.

In operating the system, if from observation of the ore or by test runs, it is found desirable to feed the coarser material from the bin 5 at a

constant rate and automatically regulate the feed of finer material from the bin 4, the switch 47 will be closed and the switch 48 opened. Thus, by means of the sound responsive apparatus 45—46 the flow of fine material may be speeded up or slowed down depending on grinding conditions within the mill, as indicated by its sound level, to maintain the optimum balance of size ratio for the most efficient operation.

On the other hand, conditions may warrant feeding the fines at a constant rate and automatically balancing the coarse to the fine feed. In this case the switch 47 will be opened and the switch 48 closed. Then again, the balance in material loading into the feed bins may be such as to permit a constant feed from both bins 4 and 5, in which case the grizzly 12 may be manually adjusted to maintain this balance which may vary due to fluctuations in sizes brought from the mine.

If the feed is such as to tend to overload either the mill or the circulating system of the classifier, and since such overloading directly affects the power consumption of the mill or classifier motors, in proportion to the amount of overloading, it may be desirable to maintain the balance in ratio of coarse to fine material by means of the power responsive device, described heretofore, connected with either the mill or fan motor, or the device responsive to air pressure differential, to control either or both of the feeders 8 and 9.

Overloading of the system or a predominance of small, hard-to-grind material, or fluctuations in hardness of ore being supplied the feed bins may be the deciding factor in regulating the feed. In this case the amount of returned oversize is utilized, as has been described, to regulate the feed in a manner to most efficiently reduce this ore.

In addition to the above automatic control means, and adapted to be used either in combination with or independently thereof, is the adjustable grizzly 12 whereby the material being segregated may be so regulated that independent of the rate of feed from either bin 4 or 5 or intermittent loading of the bins, a substantial balance of feed size ranges may be made available for continuous, efficient operation of the reduction system.

Since under certain operating conditions, or to adapt the ore reducing system to certain types of material, it may be necessary to segregate the ore into further size ranges than those described above, I provide a segregating and feeding arrangement such as illustrated in Figures 10, 11 and 12 to accomplish this.

Here the run of the mine material is passed as by a conveyor 70 into a hopper 71 provided with a series of superposed inclined screens 72, 73 and 74. These screens are of different size mesh, the coarsest being on the top while the finest is at the bottom. For the purpose of illustrating a typical example of operation to be later described, the top screen 72 may be considered a six-inch mesh, the next a two-inch mesh and the bottom screen one-half inch mesh. They are removably mounted in the hopper 71 for the purpose of replacement with screens of a different size depending upon the size ranges of the segregated material desired. Obviously adjustable grizzlies such as the grizzlies 12 described above may be employed in lieu of the screens.

Each screen has in operative association therewith an inclined chute designated 75, 76 and 77, respectively, while the bottom of the hopper 71

forms a fourth inclined chute 78. The chutes 75, 76 and 77 are adapted, respectively, to discharge onto conveyor belts 79, 80 and 81 which, in turn, respectively discharge into bins 82, 83 and 84 while a fourth bin 85 is provided for the discharge from the hopper chute 78.

The bins are similar to the bins 4 and 5 and are provided with discharging feeders 86, 87, 88 and 89 driven by motors 90, 91, 92 and 93, respectively. The feeders 86-89 discharge onto a conveyor 94 which is adapted to discharge its collected material into the feed chute of the grinding mill 1.

Material from the mine, rock pile, etc., is passed by the conveyor 70 into the segregating hopper 71 from which, if the screens are as above described, will be classified so that material of minus 12"-plus 6" will pass into the bin 82; material of sizes ranging from minus 6" to plus 2" passes to the bin 83; material of minus 2" to plus 1/2" passes to bin 84 and the finest material, that is, minus 1/2" to dust, passes to the fourth bin 85.

As diagrammatically illustrated in Figure 12, each of the feeder motors 90-93 has its control circuit electrically connected with a suitable circuit completing device, such as jacks and which are designated 99 to 102.

The jacks 99 to 102 are adapted to be put into selective operative connection with the several automatic feed control means heretofore described. To accomplish this, the output circuit of the sound responsive device 45, the retarded relays 61 of both the mill and classifier power consumption devices, and the retarded relay 54 of the pressure responsive device 51 and the retarded relay 67 of the device responsive to the returned oversize are respectively provided with plugs 103, 104, 105, 106 and 107. These plugs may be singly connected with any one of the jacks 99 to 102 or may be connected therewith in any combination desired to effect a ratio of the several size ranges of material to be fed to the mill which will accomplish the desired result. In other words, the feed rate from any or all of the bins 82 to 85 may be automatically controlled by operating conditions within the reducing system as indicated by either sound emanating from the mill, loading conditions within the mill or the classifier circulating system, the amount of returned oversize or a combination of all of these. Additionally, any of the feeders 86 to 89 may be operated at a constant rate by connecting in a plug 108 connected directly to the control power line.

As a typical example of operating this system with the above method of bin segregation and feed control, consider that the run of mine material has been segregated in the bins 82 to 85 in the manner described above. In this example also consider the feed containing a relatively small amount of coarse material and comparatively large amounts of very fine material. This coarse material, that is, the minus 12" plus 6" size, will be the most critical size so far as the rate of feed to the mill is concerned. The intermediate size, minus 2" plus 1/2", may be considered the most critical size so far as rate of grinding is concerned. In other words, this size is the most difficult to grind.

In order to operate the system so as to obtain the best over-all mill capacity to result in the required fineness of the final product and since there is a deficiency in both the coarse and intermediate sizes, it is desirable that the feed of coarse sizes be kept under control whereby they

may be prevented from breaking down too quickly and losing their effect as grinding media.

Since the hard-to-grind material, that is, minus 2" plus 1/2", in the bin 84 is too large to be crushed readily by itself and too small to act as a crushing medium, it is advisable to feed this size to the mill at a constant rate by driving its feeder motor directly from the line 98 and balance the other sizes to it at a ratio which will result in most efficient grinding by automatically controlling their feed rates by the operating conditions in the system.

As previously brought out, the sound produced in the mill during the grinding operation is an efficient indicator of the effect of conditions within the mill for, if the mill were filled with nothing but coarse material without any fines acting as a cushion load, the sound level would be high. Likewise, if all material in the mill were fine, the sound level would be very low. The sound level would also be reasonably low if only a few lumps of coarse material were in the mill and the mill were practically empty. Therefore I propose to use the sound of the mill in this particular example of operation to control the feed of the coarsest material from the bin 82 by connecting the sound sensitive device 45-46 to the feeder motor 90 to control the rate of feed from the bin 82.

The other intermediate size, that is, minus 6" plus 2", in the bin 83 might be considered such size as to tend to overload the mill, and since an increase in mass within the mill directly affects the power consumption of its operating motor, I employ the power sensitive device 55 to control the rate of feed of this size material from its bin 83. The remaining size, that is, the size from minus 1/2" to dust, which is contained within the bin 85, is that size which, if not present in too great a quantity, is a material which will grind most readily but since, as stated above, this size was in predominance it will have the effect, if not controlled, of overloading the circulating system of the classifier. Therefore, either the power responsive device 55 connected with the classifier fan motor or the device responsive to air pressure differential in the classifier circulating system may be connected with the feeder motor for this size material. Or, if condition of material warrants, the mercury switch connected with the oversize return air lock 38 may be used to control the rate of feed from this bin 85.

Obviously other combinations of control may be employed where conditions and type of material; conditions of mining and loading of the feed bins; and operating conditions within the system itself are such that the most efficient and economical operation of the system may be effected by other combinations.

Thus it will be seen that I have provided a system of controlling the feed of run of mine material to an ore reducing system which is sufficiently flexible in its adaptability to the system to utilize one or more of severable variables in operating conditions to control the relation between coarse, semi-ground and fine particles of ore to permit the system to grind the entire material just as it is delivered from its original source. This system of feed control is also sufficiently flexible in adaptability to provide efficient mill operation when handling ores which may vary widely in their size ratios, weight per cubic foot, moisture content, hardness, etc. Additionally, it will provide for continuous operation of the system which would otherwise be difficult to main-

tain due to intermittent delivery conditions of the ore, by maintaining a sufficiently constant supply of the different size ranges of material.

Past experience and observation of grinding operations under various conditions have shown me the difficulties encountered in efficiently and economically reducing run of the mine ores in both wet and dry grinding systems and the greatly increased operating efficiency resulting from the application of my method of feed control. For example, I have noted that when operating conditions were bad, a so-called 100 ton per twenty-four hour mill would produce hardly 50 tons per day. On the other hand, when conditions were good, the same mill would produce 150 tons during this interval. While an average of these grinding rates might be acceptable, their extreme variations make it practically impossible to properly regulate mining operations or properly control the treatment of the product.

However, by applying my method of feed control, not only is the capacity range of the grinding system caused to approach an almost constant figure, but the average output of the mill is increased beyond that formerly obtainable.

I wish to emphasize that while I have shown and described herein my method of controlling feed of run of the mine ore to a dry grinding system which utilizes the ore itself as its grinding medium, and is in closed circuit with an air classifier, it is also adaptable in its broadest aspect for use with wet grinding and classifying. For instance, it is easily adaptable for use with such grinding systems as are disclosed in my Patents Nos. 2,115,223 and 2,171,268, dated April 26, 1939, and August 29, 1939, respectively, and both entitled "Ore reducing machine." Both of these machines are designed to reduce run of the mine ore, using the ore as its own grinding agent, and both may be operated in closed circuit with wet classifiers. Thus the mill sound, power consumption of mill or classifier, the amount of oversize returned from the classifier and differential in head or pressure due to varying densities in the hydraulic classifier may be effectively utilized individually or in combination to maintain an optimum ratio of feed sizes, in the manner described above to obtain a maximum mill efficiency.

While the method and apparatus shown and described herein are simple in their fundamental principles, the results derived therefrom are of great importance in advancing the art of ore reduction by both wet and dry processes. I therefore wish my invention to be limited only by the prior art and the scope of the appended claims.

I claim:

1. A method of operating a continuous grinding system adapted to pulverize material, where such material varies in size between substantial limits, comprising segregating the material into predetermined size ranges, recombining the segregated material in amounts regulated by the sound emanating from the system and delivering the recombined material to the grinding system.

2. A method of operating a continuous grinding system adapted to pulverize material where such material varies in size between substantial limits, comprising segregating the material into predetermined size ranges, recombining the segregated material in amounts controlled by the power requirements of the system and delivering the recombined material to the grinding system.

3. A method of continuously operating an ore

reducing system including a grinding mill adapted to pulverize material which varies in size between substantial limits, comprising segregating material into predetermined size ranges, recombining the segregated material in amounts controlled by the power requirements of the grinding mill and delivering the recombined material to the grinding mill.

4. A method of continuously operating an ore reducing system including a grinding mill and a classifier in closed circuit therewith said mill adapted to pulverize material which varies in size between substantial limits, comprising segregating the material into predetermined size ranges, recombining the segregated material in amounts controlled by the power requirements of the classifier, and delivering the recombined material to the grinding mill.

5. A method of continuously operating an ore reducing system including a grinding mill and a classifier in closed circuit therewith and adapted to return oversize material to the mill, said mill adapted to pulverize material which varies in size between substantial limits, comprising segregating the material into predetermined size ranges, recombining the segregated material in amounts controlled by the amount of returned oversize from the classifier and delivering the recombined material to the grinding mill.

6. A method of continuously operating an ore reducing system including a grinding mill adapted to pulverize material which varies in size between substantial limits, comprising assorting the material into a plurality of size ranges, delivering at least one of the size ranges to the grinding mill at a substantially constant rate and delivering at least one of the other size ranges to the grinding mill in amounts controlled by the sound level of the grinding mill.

7. A method of continuously operating an ore reducing system including a grinding mill adapted to pulverize material which varies in size between substantial limits, comprising assorting the material into a plurality of size ranges, delivering at least one of the size ranges to the grinding mill at a substantially constant rate and delivering at least one of the other size ranges to the grinding mill in amounts controlled by the power requirements of the grinding mill.

8. A method of continuously operating an ore reducing system including a grinding mill and a classifier in closed circuit therewith, said mill adapted to pulverize material which varies in size between substantial limits, comprising assorting the material into a plurality of size ranges, delivering at least one of the size ranges to the grinding mill at a substantially constant rate and delivering at least one of the other size ranges to the grinding mill in amounts controlled by the power requirements of the classifier.

9. A method of continuously operating an ore reducing system including a grinding mill and a classifier in closed circuit therewith and adapted to return oversize material to the mill, said mill adapted to pulverize material which varies in size between substantial limits, comprising assorting the material into a plurality of size ranges, delivering at least one of the size ranges to the grinding mill at a substantially constant rate and delivering at least one of the other size ranges to the grinding mill in amounts controlled by the returned oversize from the classifier.

10. An apparatus for continuously reducing ores and the like which range in size between substantial limits, comprising a grinding mill

adapted to utilize the ore as its own grinding medium, a plurality of feeding bins adapted to receive the ore, a sorting device associated with the bins whereby the ore being admitted into the bins is divided according to predetermined size limits, a sound responsive device associated with the mill, proportioning delivery means associated with the bins for delivering ore to the mill, and means for operatively connecting said delivery means and sound device, whereby the amount of ore delivered from at least one of the bins is controlled by the sound vibrations emanating from the mill.

11. An apparatus for continuously reducing ores and the like which range in size between substantial limits, comprising a grinding mill adapted to utilize the ore as its own grinding medium and an electric motor adapted to impart movement to the mill, a plurality of feeding bins adapted to receive the ore, a sorting device associated with the bins whereby the ore being admitted into the bins is divided according to predetermined size limits, a power responsive device associated with the motor proportioning delivery means associated with the bins for delivering ore to the mill, and means for operatively connecting said delivery means and power responsive device whereby the amount of ore delivered from at least one of the bins is controlled by the power requirements imposed on the motor.

12. An apparatus for continuously reducing ores and the like which range in size between substantial limits, comprising a grinding mill adapted to utilize the ore as its own grinding medium, a power operated classifying system in closed circuit with the mill, a plurality of feeding bins adapted to receive the ore, a sorting device associated with the bins whereby the ore being admitted into the bins is divided according to predetermined size limits, a power responsive device associated with the classifying system, proportioning delivery means associated with the bins for delivering ore to the mill, and means for operatively connecting said delivery means and power responsive device whereby ore from at least one of the bins may be delivered to the grinding mill in amounts regulated by the power requirements of the classifier.

13. An apparatus for continuously reducing ores and the like which range in size between substantial limits comprising a grinding mill adapted to utilize the ore as its own grinding medium, a classifier in closed circuit with the mill, a duct for returning oversize material from the classifier to the mill, a plurality of feeding bins adapted to receive the ore, a sorting device associated with the bins whereby the ore being admitted into the bins is divided according to predetermined size limits, means associated with the duct and responsive to the amount of returned oversize, proportioning delivery means associated with the bins for delivering ore to the mill, and means for operatively connecting said delivery means and oversize responsive means whereby material from at least one of the bins may be delivered to the grinding mill in amounts regulated by the amount of oversize returned from the classifier to the mill.

14. An apparatus for continuously reducing ores and the like which range in size between substantial limits, comprising a grinding mill adapted to utilize the ore as its own grinding medium, a classifying system in closed circuit with the mill, a plurality of feeding bins adapted to receive the ore, a sorting device associated with the bins whereby the ore being admitted into the bins is divided according to predetermined size limits, a

pressure responsive device associated with the classifying system, proportioning delivery means associated with the bins for delivering ore to the mill, and means for operatively connecting said delivery means and pressure responsive device whereby the amount of ore from at least one of the bins may be delivered to the grinding mill in amounts regulated by the changes in pressure in the classifier.

15. A method of continuously operating an ore reducing system including a grinding mill and classifier in closed circuit therewith and adapted to pulverize material which varies in size between substantial limits, comprising segregating the material into a plurality of size ranges, recombining the segregated material in amounts controlled by changes in pressure in the system, and delivering the recombined material to the grinding mill.

16. A method of continuously operating an ore reducing system including a grinding mill and a classifier in closed circuit therewith and adapted to pulverize material which varies in size between substantial limits, comprising segregating the material into a plurality of size ranges, recombining the segregated material in amounts controlled by a reduction in pressure in the system below a predetermined amount and delivering the recombined material to the grinding mill.

17. A method of continuously operating an ore reducing system including a grinding mill and a classifier in closed circuit therewith and adapted to pulverize material which varies in size between substantial limits, comprising segregating the material into a plurality of size ranges, recombining the segregated material in amounts controlled by an increase in pressure in the system above a predetermined amount and delivering the recombined material to the grinding mill.

18. A method of continuously operating an ore reducing system including a grinding mill and a classifier in closed circuit therewith and adapted to pulverize material which varies in size between substantial limits, comprising segregating the material into a plurality of size ranges, delivering at least one of the size ranges to the grinding mill at a substantially constant rate and delivering at least one of the other size ranges to the grinding mill in amounts controlled by changes in pressure in the system.

19. A method of continuously operating an ore reducing system including a grinding mill and an air classifier in closed circuit therewith and adapted to pulverize material which varies in size between substantial limits, comprising segregating the material into a plurality of size ranges, delivering at least one of the size ranges to the grinding mill at a substantially constant rate and delivering at least one of the other size ranges directly to the grinding mill in amounts controlled by a reduction in air pressure in the system below a predetermined amount.

20. A method of continuously operating an ore reducing system including a grinding mill and an air classifier in closed circuit therewith and adapted to pulverize material which varies in size between substantial limits, comprising segregating the material into a plurality of size ranges, delivering at least one of the size ranges to the grinding mill at a substantially constant rate and delivering at least one of the other size ranges to the grinding mill in amounts controlled by an increase in air pressure in the system above a predetermined amount.

21. In a grinding system including a mill for

grinding run of mine material of different size particles wherein large pieces of the feed act as grinding media to reduce themselves as well as the smaller pieces present, and where there are variations in the amount of feed within various size ranges from time to time over a relatively extended period of normal operation, a sorting device for dividing the run of mine material into a plurality of size ranges, means for separately storing the material of each of said size ranges, said storage means being of sufficient capacity to store the material of its respective size range regardless of normal variations in the amount of said material in the feed during the said period of operation, means for delivering the material from each of said storage means and recombining it with material from the other storage means, and means responsive to an operating condition produced by the milling operation for controlling the said delivery means to maintain discharges from the several storage means at rates having a ratio which substantially corresponds to the average ratio between the amounts of material of the said several size ranges in the run of mine material for the said period of normal operation.

22. In a grinding system including a mill for grinding run of mine material of different size particles wherein large pieces of the feed act

as grinding media to reduce themselves as well as the smaller pieces present, and where there are variations in the amount of feed within various size ranges from time to time over a relatively extended period of normal operation, a sorting device for dividing the run of mine material into a plurality of size ranges, means for adjusting said sorting device to vary the limits of said size ranges, means for separately storing the material of each of said size ranges, said storage means being of sufficient capacity to store the material of its respective size range regardless of normal variations in the amount of said material in the feed during the said period of operation, means for delivering the material from each of said storage means and recombining it with material from the other storage means, and means responsive to an operating condition produced by the milling operation for controlling the said delivery means to maintain discharges from the several storage means at rates having a ratio which substantially corresponds to the average ratio between the amounts of material of the said several size ranges in the run of mine material for the said period of normal operation.

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