

Feb. 19, 1963

H. HARDINGE
AUTOGENOUS GRINDING PROCESS AND MILL
SYSTEMS TO PERFORM THE SAME

3,078,050

Filed Jan. 8, 1960

5 Sheets-Sheet 1

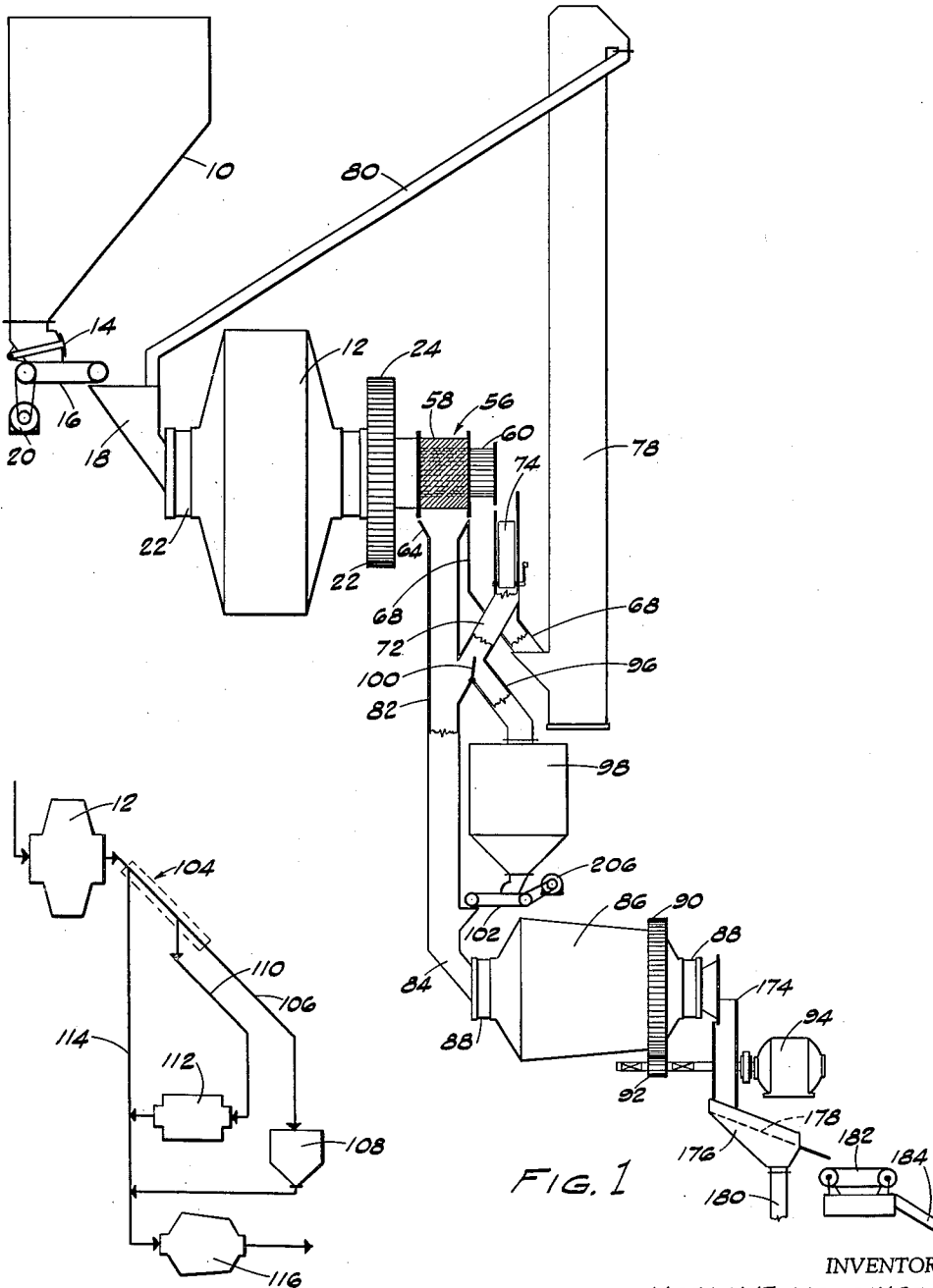


FIG. 2

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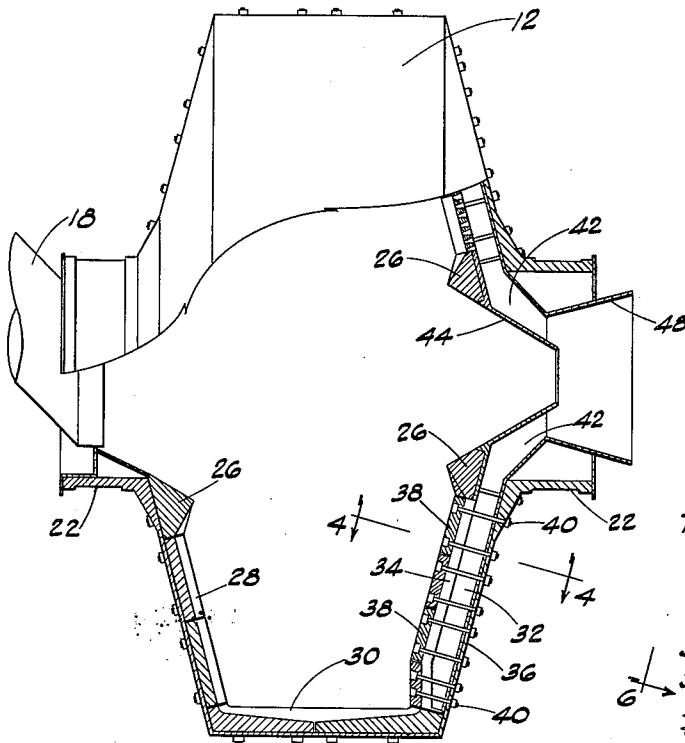


FIG. 3

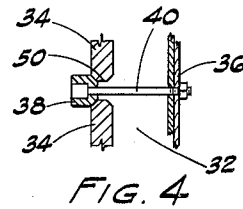


FIG. 4

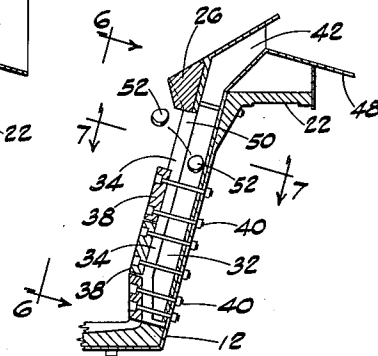


FIG. 5

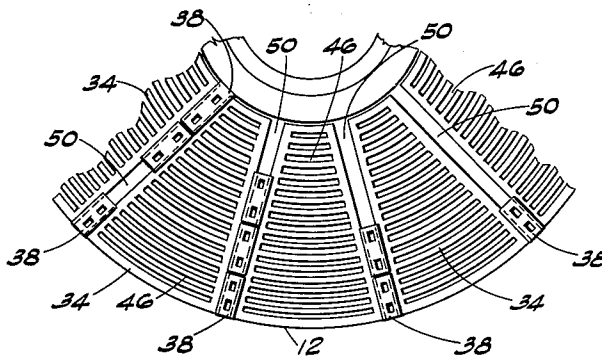


FIG. 6

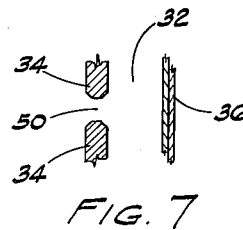


FIG. 7

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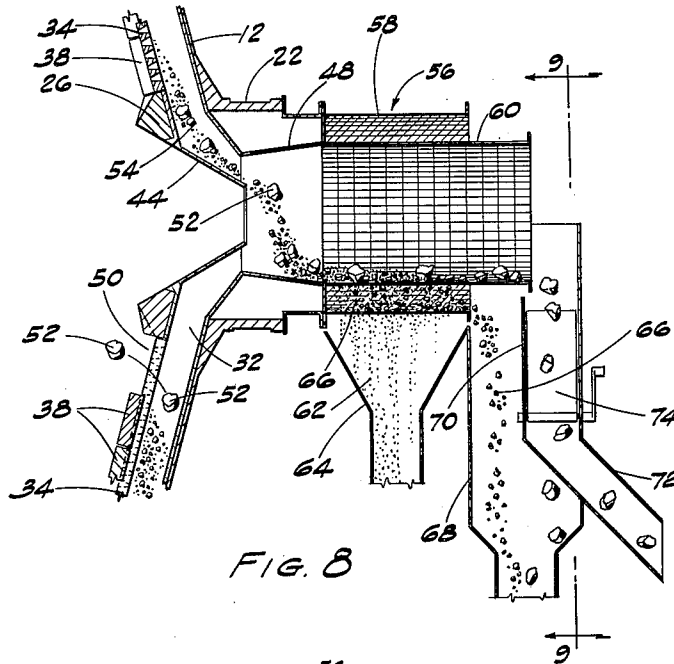


FIG. 8

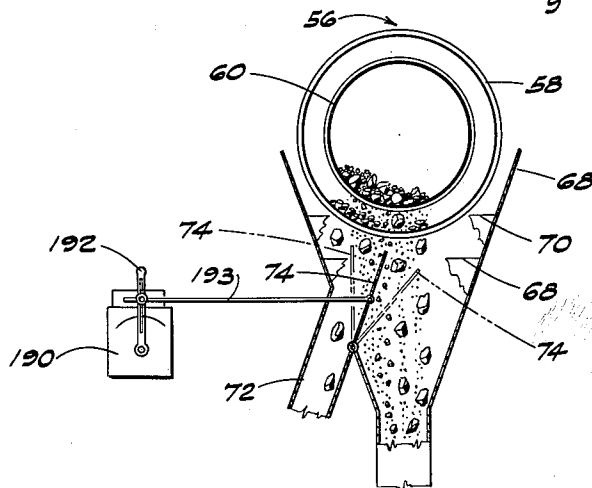


FIG. 9

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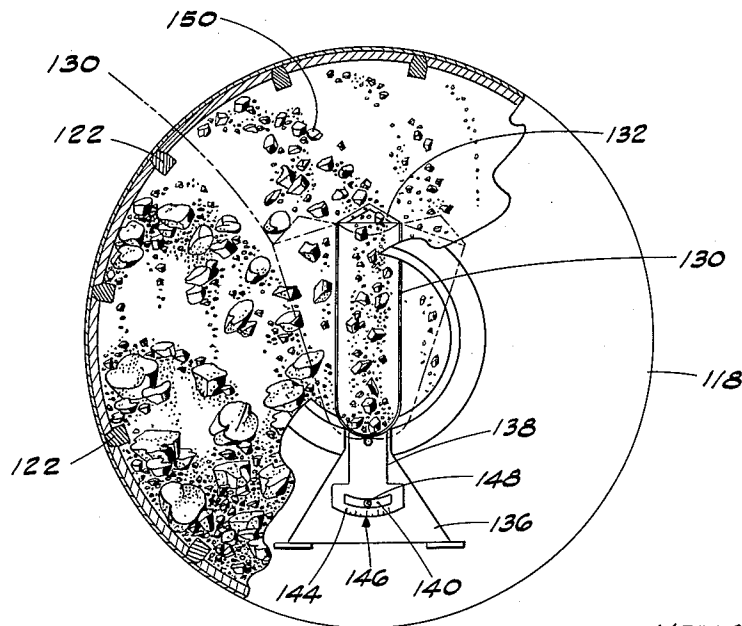
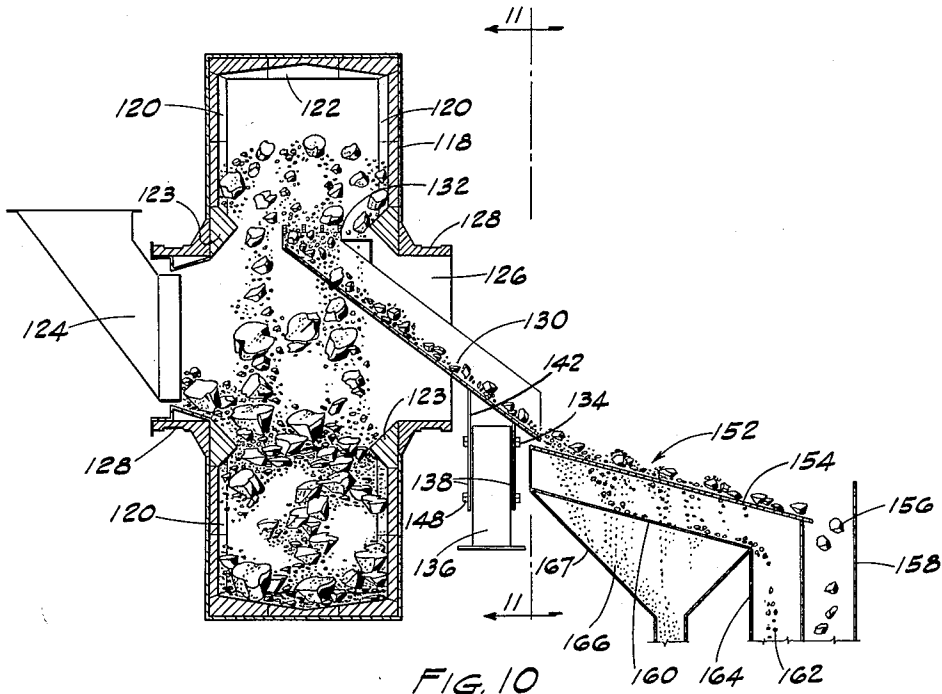
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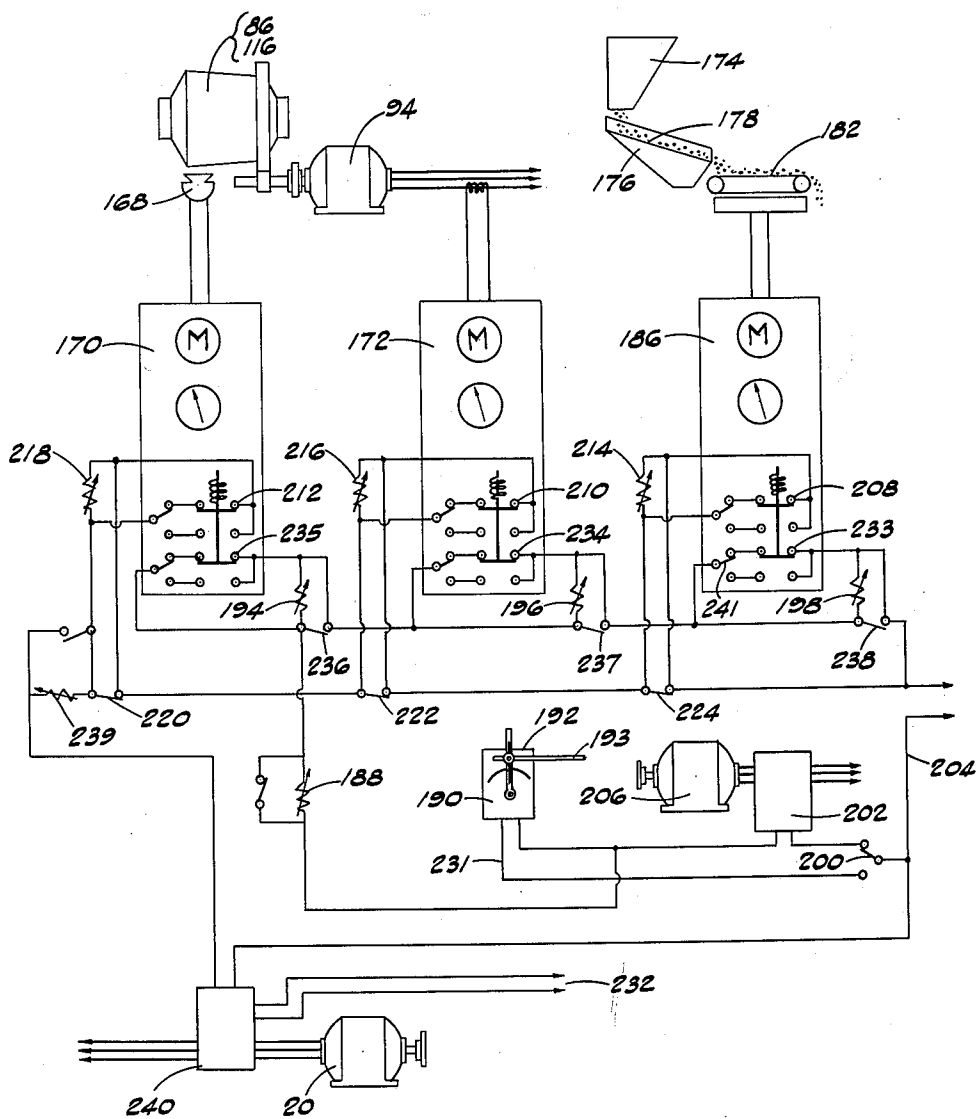


FIG. 12

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3,078,050

AUTOGENOUS GRINDING PROCESS AND MILL SYSTEMS TO PERFORM THE SAME

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Filed Jan. 8, 1960, Ser. No. 1,291

50 Claims. (Cl. 241-26)

This invention relates to improvements in a grinding process and a number of embodiments of mill systems capable of performing the same and, more particularly, to the utilization of tumbling type mills, of which auto-

genous grinding mills are one preferred type, to perform novel procedural steps and employ novel structure to achieve such procedural steps.

Heretofore in the employment of tumbling type mills and particularly autogenous grinding mills, wherein run-of-the-mine friable material is fed to the mill and actually grinds itself, it has been found in many situations, which depend largely upon the type of material being treated by the mill, that an undesired excess of relatively large lumps, pebbles, or cobs were produced and, as a result of this, reduced the grinding efficiency of the mill system. Further, in many situations, the grinding efficiency, particularly of an autogenous grinding mill, can be improved if the relative proportions of various ranges of sizes of friable material can be maintained substantially in a predetermined proportion which has been found to produce maximum efficiency in producing fine products within desired ranges, for example, from a certain material fed to the mill in run-of-the-mine condition. In using known types of tumbling mills and particularly autogenous type grinding mills heretofore, it has not been possible to produce such predetermined and desired proportions of various ranges of sizes of friable material within the mill to effect maximum efficiency in producing a desired range of fine materials which ultimately are discharged from the mill.

To overcome the difficulties and deficiencies of existing and previously used systems and processes for grinding solid friable material to reduce the same to desired ranges of fine material, as well as to effect other efficiencies and improvements in the reduction of solid friable materials to desired ranges of fine sizes, preferably by the use of grinding mills and even more particularly by the use of autogenous grinding mills, it is the principal object of the present invention to provide a novel and efficient process of grinding solid friable material preferably by the use of a primary and one or more secondary grinding mills comprising a grinding system which operates substantially as a unit and has inter-related feeding, segregating and classifying mechanism which may be operated either manually or automatically, to effect desired adjustment and control of the operation of said mill system to produce a maximum amount of a desired range of sizes and particularly fine sizes of product material at minimum operational costs. The term "solid friable material," as used herein, is considered to be material of varying degrees of hardness which can be broken by tumbling action and the word "friable" is considered to be generic to cover a wide range and classes of mineral materials which are capable of being processed in accordance with the principles of the present invention.

Another object of the invention which is a corollary of the foregoing object is to employ the friable material being ground either in part or in whole as the grinding media and so arrange the distribution of said media in the primary and secondary mills, either manually or automatically, so as to obtain optimum results in the circuit comprising all of the mills employed therein.

A still further object of the invention which is at least somewhat corollary to the foregoing objects is to employ a primary mill in the overall mill system which is utilized

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to reduce the coarser fraction of the friable material fed thereto and some or all of the products of said primary mill then are fed in predetermined desired proportions of ranges of different sizes to other grinding means which may be considered secondary or re-grinding mills, and also provide means to regulate the feed of material between the various mills in such a manner that, as the friable grinding media obtained from the primary mill is consumed by the re-grinding processes effected in the secondary mills, the required grinding media therefor is replenished from the main feed supply source or from the primary mill, such supply being controlled either manually or automatically as dictated by the operating conditions in either the primary or secondary mills, or both.

Still another object of the invention is to utilize in the above-described secondary or re-grinding mills of the foregoing objects the excess of pebbles produced in the primary mill, which pebbles usually are quite well rounded so as to render them ideal as pebble type grinding media, in predetermined, controlled quantities in the secondary or re-grinding mills of the grinding system.

A still further object of the invention is to provide a process and various embodiments of mechanical arrangements to achieve the same for purposes of removing, preferably continuously and at adjustable rates, from either the primary or secondary mills the product material produced thereby, classify the same into a plurality of desired ranges of sizes, and then utilize said ranges of sizes either in the primary or secondary mills by controlled feed which may if desired re-introduce some of the sizes back into the mill from which it is removed for purposes of either serving as grinding media or to be reduced further in size by larger pieces of grinding media, all of such operations being controlled either manually or automatically to effect maximum efficiency in the overall mill system.

One other object of the invention is to provide in a mill system of the type described above means for indicating and controlling the operating conditions in a tumbling mill system, and preferably an autogenous grinding mill system, composed of a plurality of inter-related grinding components or mills, whereby the operating conditions of one component or mill bears a relation to the operating characteristics of another component or mill and also including the utilization of this relationship to effect maximum overall efficiency in the operation of the mill system.

Details of the foregoing objects and of the invention, as well as other objects thereof, are set forth in the following specification and illustrated in the accompanying drawings comprising a part thereof.

In the drawings:

FIG. 1 is an exemplary side elevation, shown partly in vertical section to illustrate certain details, of a mill system embodying the principles of the present invention and capable of performing a grinding process in accordance with the principles of the invention.

FIG. 2 is a substantially diagrammatic mill system shown in vertical elevation on a smaller scale than that employed in FIG. 1 and comprising a different embodiment of mill system from that shown in FIG. 1.

FIG. 3 is an enlarged vertical elevation, partly in section to illustrate certain details, of an exemplary primary mill unit of the type generally illustrated in FIGS. 1 and 2.

FIG. 4 is a fragmentary sectional view of a detail of the mill unit shown in FIG. 3 as shown on the line 4-4 of said figure.

FIG. 5 is a fragmentary vertical sectional elevation of a portion of the primary mill unit shown in FIG. 3 but in which a section of the lifter and clamping bar arrange-

ment has been removed to provide exit means for a larger size of pebble or cob material than would be permitted by the arrangement illustrated in FIG. 3.

FIG. 6 is a fragmentary side elevation of the interior face of the mill as seen on the line 6—6 of FIG. 5 and illustrating four different exemplary arrangements of exit space means respectively provided in the four lifting and clamping bar arrangements shown therein.

FIG. 7 is a fragmentary transverse sectional view taken on the line 7—7 of FIG. 5.

FIG. 8 is a fragmentary vertical sectional view of the exit end of the exemplary primary mill illustrated in FIGS. 1 through 3 and utilizing a larger scale than in any of said figures to illustrate details of one embodiment of segregating means for the material discharged from the exit of said primary mill.

FIG. 9 is a vertical sectional elevation taken on the line 9—9 of FIG. 8.

FIG. 10 is a vertical sectional elevation of another embodiment of primary mill structure and discharge means with still another embodiment of material segregating means which receives product material from the primary mill, said mill and segregating means also embodying the principles of the present invention.

FIG. 11 is a vertical elevation at 90° to the view shown in FIG. 10 as seen on the line 11—11 of said figure, part of one end wall of the primary mill being broken away in FIG. 11 to illustrate details of the tumbling of the material within said primary mill.

FIG. 12 is a diagrammatic view of an exemplary automatic control system, electrically actuated, for various adjustable operations of certain components of the mill systems illustrated in the preceding figures.

Referring to the drawings, and particularly FIG. 1, an exemplary mill system employing the present invention is illustrated therein, this illustration being intended to be that of a typical mill circuit, principally to illustrate the basic principles of the invention. Such a system, as illustrated, and also in accordance with the principles of the present invention, may be operated either as a wet or dry grinding mill system. Further, the system may embody the principles of either a closed or open circuit with screens or classifier system.

The mill system shown in FIG. 1 essentially comprises a feed bin 10 for the primary mill 12. Material of a friable nature to be treated is fed from the bin 10 by the feeder belt 16, in a so called run-of-mine or heterogeneous condition, through an adjustable outlet means 14. The feed belt 16, for example, operates at a regulatable, desired speed to introduce the raw material to entrance chute 18 of the primary mill 12 in controlled amounts. Said feed belt 16 is powered by suitable means such as an electric motor 20 whereby, when the speed of the belt 16 and possibly the adjustment of the outlet means 14 are regulated relative to each other, a desired feed rate of raw material to the entrance chute 18 is produced.

The primary mill 12 is preferably of the tumbling type and rotates about trunnions 22 positioned in suitable bearings, not shown, the mill being powered by drive gear 24 which is driven by suitable drive means to effect a desired rotational speed of the primary mill 12 in accordance with conventional operating practice for mills of this type.

Referring to FIG. 3, it will be seen that the mill 12 is illustrated on a larger scale than FIG. 1 and certain details of the interior of the mill 12 are shown. Details and operational characteristics of this type of mill are illustrated in applicant's co-pending application Serial No. 822,612, filed June 24, 1959. Specifically, but without intention to restrict the invention thereto, the mill 12 employs autogenous grinding principles. Aside from conventional lining plates, the interior of the mill 12 is provided with deflecting rings 26 to insure substantial transverse dispersion of the various ranges of sizes of the ma-

terial as the mill 12 is rotated about its axis for treatment of the raw friable material which is introduced through entrance chute 18.

Substantially radial clamping and lifting bars 28 are arranged at one end of the mill, and these cooperate with transverse clamping and lifting bars 30 around the interior perimeter of the mill. The opposite end of the mill is provided with an annular space 32 between the segmental grate sections 34 and the outer end wall 36 of the mill. The segmental grate sections 34 are clamped in operative position by a series of separable clamping and lifting bar sections 38 which are secured by bolts 40 to the mill. The substantially radial lifter bars 38 extend from the deflector rings 26 of the mill approximately to the outer perimeter thereof as is clearly shown in the lower portion of FIGS. 3, 5 and 6. The lifter bars are spaced from each other circumferentially.

As raw solid friable material which is to be treated is introduced to the mill 12, it will be tumbled as a result of being elevated by the rotation of the mill shell and various lifter bars. It will also be deflected transversely and otherwise especially by the deflecting rings 26 which extend inwardly from opposite ends of the mill. The larger lumps or cobs of said friable material will serve as grinding media to reduce the size of smaller particles of the material and, in turn, will gradually be reduced in size themselves in an autogenous mill. As the friable material is gradually reduced in size to the width of the slots 46 in the grate sections 34, said material will pass through said grate slots and thus be screened and sized as it moves into the annular space 32 and then will be raised by the lifter plates 42 therein so that, when elevated, the material will fall by gravity from the spaces between the lifter plates 42 and will be deflected by the exit cone 44 for discharge through the discharge cone 48.

In normal operation of a mill of this type, the width of the grate slots 46 will serve as restricting means to control the size of the product material discharged from the mill. However, in accordance with the principles of the present invention, assume by way of example only that the grate openings or slots 46 are $\frac{3}{8}$ inch wide. Similarly, assume that the radial spaces 50 between the edges of adjacent grate sections 34 is of the order of 3 inches. Normally, these radial spaces 50 are closed by the clamping and lifting bar sections 38. However, according to the principles of the invention, a predetermined number of the sections 38, at predetermined locations in the various slots 50 are removed in accordance with one or more exemplary illustrations in FIG. 6 so as to provide additional restricting discharge or exit spaces of predetermined width and length to produce a desired variable discharge location and area of such spaces through which a desired quantity of larger and preferably rounded pieces of friable material having a maximum dimension of 3 inches can pass, together with some intermediate and fine sizes of such material, as illustrated in exemplary manner in FIG. 5. In this figure, the larger pieces 52 of material are shown respectively on opposite sides of the grate 34, one of these being in the space 32. Such pieces 52 as well as those of intermediate and fine sizes which fall into the space 32 will be discharged from the discharge cone 48 as the mill 12 continues to rotate. Under normal circumstances however, in accordance with the principles of the invention, the minus $\frac{3}{8}$ inch material which passes through the grate openings or slots 46 will preferably compose the major portion of the material discharged. In the event some auxiliary grinding media such as balls are employed in the primary mill, such media to be retained in the primary mill should be of a size exceeding the minimum dimension of the open spaces 50.

By referring to FIG. 6, it is to be understood that the four different arrangements of spaces 50 and clamping and lifting bar sections 38 shown therein principally are intended to be illustrative of different exemplary arrangements of extent and position of open spaces 50 rather than

being of the preferred manner of arranging such open spaces. However, if found advantageous, some such heterogeneous arrangement of spaces may be utilized, as desired.

By virtue of the possibility of arranging the extent and positions of the open spaced sections 50 as shown in FIG. 6, the operator of the mill can determine by trial and error the desired selection of the most efficient extent and location of such discharge spaces in order to provide a desired discharge rate of minus 3 inch pebbles, for example, and such intermediate and fine sizes of materials as happen to pass through the spaces 50. By way of further illustration of the spaces 50, FIG. 4 is a sectional view showing the space 50 closed by the clamping and lifting bar 38, while FIG. 7 shows an open space 50 resulting from removal of the bar section 38.

Reverting to FIG. 1 and also additionally referring to FIG. 8, the mixture of material 54 exiting from the mill and consisting of ranges of sizes from minus 3 inches, for example, of which the larger pieces 52 represent the largest sizes, and on down to the minus $\frac{3}{4}$ inch sizes which have passed through the grate slots 46, are discharged into the classifying or segregating mechanism or trommel 56.

Specifically, and particularly as illustrated in FIG. 8, the trommel mechanism 56 comprises an outer cylindrical screen 58 which preferably is connected to the exit end of mill 12 and rotates therewith, as does also the inner cylindrical grate bar member 60 of the trommel. By way of example only, assume that the screen 58 is 4 mesh, that is, somewhat less than $\frac{1}{4}$ inch material may pass therethrough, and the parallel bars comprising the grate bar member 60 are 1 inch apart. It will be seen from FIG. 8 that the minus 4 mesh material 62 will be sifted through the bars 60 and screen 58 and fall into hopper 64, while the minus 1 inch-plus 4 mesh material 66 will not pass through the screen 58 but, rather, will be discharged from the outer end thereof into another hopper 68.

Arranged internally of hopper 68 is still another hopper or sub-hopper 70 which has a discharge chute 72. Flexibly connected at one end to one side of the upper end of discharge chute 72 is an adjustable deflector plate or splitter 74 which may be moved to any desired position in the chute, of which the various dotted line positions thereof shown in FIG. 9 are exemplary, for purposes of intersecting the fall of a desired amount of the minus 3 inch-plus 1 inch material 52 as it is discharged from the outer end of grate bar member 60, thereby controlling the amount of such material which will be discharged from hopper 68 into the lower end of material elevator 78, see FIG. 1, for return by gravity through conduit 80 from the upper end of elevator 78 to the entrance chute 13 of the mill for further reduction of size of such particles. If however the deflector plate or splitter 74 is extended to the right, as considered relative to FIG. 9, to its maximum intended position, substantially all of the minus 3 inch-plus 1 inch material will be deflected into discharge chute 72 for one of several purposes, as follows.

By referring to FIG. 1, it will be seen that the hopper 64 communicates with a downwardly extending conduit 82 which communicates at its lower end with entrance chute 84 of a secondary or regrind mill 86 which is of a tumbling nature and is mounted on suitable trunnions 88 for rotation about its axis, it being understood that the conventional bearings employed to support both the mills 12 and 86 are omitted in the various figures to simplify the illustration. Mill 86 is driven by conventional drive gear 90 and a pinion gear 92 which is driven by suitable means such as an electric motor 94.

It will therefore be seen that the system, if desired, can be operated as a complete unit to the extent that no outside source of material or pebbles for the auxiliary or re-grind mill 86 are required. The overall operation is simple and economical and subject to appreciable flexibility. It is possible and very simple to change the size of pebbles desired by changing, for example, the sizes of

the openings 50 between the grate sections of the mill, as well as the size dimensions of the trommel screen 58 or grate bar member 60, either with or without adjustment of the deflector plate 74. It will be understood of course that all of these members need not be changed or adjusted in order to effect a desired resulting product but it is desired to emphasize that all of these possible adjustments are available, either singly or in combination with each other to effect the production of a desired range of fine products economically and with minimum power consumption.

Where the size ratio of friable material undergoing reduction varies considerably over an extended period of time and might require a considerable amount of adjustment of deflector splitter plate 74 the use of a surge bin 98 may be desirable. Pebbles from the discharge chute 72 are deflected into the surge bin 98 by opening deflector plate or gate 100. The friable pebbles are then fed to the mill 86 by a separate controlled rate feeder 102 in the quantity desired. While some adjustment of the quantity of pebbles cobbled from the system by regulating deflector plate 74 from time to time may be necessary, this need be done only over relatively extended periods of time, thus making the system more stable and easier to control.

Whereas the mill system arrangement shown in FIG. 1 can be considered a closed circuit system by employing the elevator 78 and return conduit 80, a so-called open circuit arrangement is shown, diagrammatically, in the system illustrated in FIG. 2. In this embodiment, it will be assumed that suitable feeding means are provided for supplying raw friable material to the entrance of the tumbling mill 12. The exit of the mill 12 substantially continuously discharges a mixture of product material comprising mostly relatively fine material which is sufficiently fine to pass through the slots of the grate sections of the mill, this material for example, being of the order of minus $\frac{3}{4}$ inch. This material together with relatively large sizes of minus 3 inch, for example, and intermediate sizes as controlled by adjusting and regulating the spaces 50 between the grate sections of the mill, is all discharged either onto or into suitable classifier or segregating means 104 which results in the exemplary coarse particles and lumps ranging from minus 3 inch to plus 1 inch size being discharged along the line 106 comprising conduit means, for example, discharging into surge bin 108. The minus 1 inch to plus 4 mesh material is discharged into suitable conduit means represented by line 110 for introduction into the entrance end of another or third tumbling mill 112 which, for example, may be a rod mill or a pebble mill. If a rod mill is used, then metal rods will readily reduce the minus 1" portion to a size suitable for the secondary mill. If a pebble mill is used, for example, then the use of larger pebbles such as minus 5" plus 3", cobbled directly from the mill feed, will serve adequately to reduce the minus 1" portion that is delivered to the third mill, which mill will accomplish similar results to a rod or ball mill for this size reduction range, as is well known in the art. Thus, by employing this alternate method of reducing the minus 1" plus 4-mesh fraction 66 that is discharged through the spaces 50 and not of a suitable size for reduction in the secondary mill 116, it is possible to avoid the use of material elevator 78. In effect, this is an open circuit operation to accomplish the same general end result as the closed circuit arrangement of FIG. 1 which uses elevator 78 to return the minus 1" plus $\frac{1}{4}$ " fraction to the primary mill. The minus 4 mesh material is discharged from segregating means 104 and travels along other conduit means 114 to the entrance of secondary or re-grind mill 116 of the tumbling type and similar, for example, to mill 86 shown in FIG. 1 both as to structure, operation, and function. It will be seen that considerable flexibility is offered by the mill system shown in FIG. 2, due particularly to the inclusion of the intermediate grinding mill 112. The

product of this mill is so adjusted to approximate that desired as feed material for the secondary mill such as, for example, minus 4 mesh size. When the material has been reduced to this size in intermediate mill 112, it is discharged into the line 114 for feed to the secondary or re-grind mill 116.

To insure that the secondary mill 116 will have adequate grinding media, the accumulated larger size friable pebbles and cobs in surge bin 108 are fed at a desired rate therefrom into the line 114 for introduction into the secondary or re-grinding mill 116 and in which an overall product of a desired range of fineness is produced.

In referring to the various sizes of mesh and other sizes of products produced either finally or intermediately in the processes and mills illustrated in FIGS. 1 and 2, it is distinctly to be understood that the sizes which have been specifically recited solely are by way of example and are in no wise to be considered as restrictive of the present invention to these sizes. A relatively wide range of sizes is capable of being used in and produced by the mill systems described above and illustrated in FIGS. 1 and 2, all within the spirit of the present invention.

Referring now to the embodiment shown in FIGS. 10 and 11, a tumbling mill 118 is provided which is somewhat different from mill 12 shown in FIGS. 1 and 2 for example. Mill 118 is a primary mill and, is intended as in the previously described mill to be illustrative of an autogenous grinding type as well as one which may also employ some auxiliary grinding bodies such as steel balls, whereby the same is provided with radial lifting bars 120 on the opposite ends of the mill and transverse lifting bars 122 on the internal periphery of the primary mill 118. Conical, annular deflecting rings 123 also may be employed to insure thorough intermixing of all ranges of sizes of the material while being ground within the mill after being fed thereto through entrance chute 124. Additional details of mills of this general type are described in greater detail in applicant's co-pending application referred to above.

Rather than being provided with grate means through which the bulk of a product of a predetermined range of fine sizes is discharged as in the embodiment of mill shown in FIGS. 1 and 2, the mill 118 is of the type having an exit 126 of relatively large size extending coaxially of supporting trunnion 128, it being understood that the mill is rotatably supported by a pair of such trunnions which are mounted in suitable bearings not shown in order to simplify the illustration.

Extending preferably at an upwardly and inwardly inclined angle into the circular exit opening 126 is a material discharge means comprising a chute 130 provided at its upper entrance end with inlet sizing means such as a series of spaced grate bars or grizzly 132. This grizzly will serve to prevent pieces in excess in size of the spaces between the grate bars 132 from entering the chute 130.

This discharge chute 130 preferably is mounted for at least limited pivotal movement about the axis of aligned trunnions 134, which are rotatable in bearings supported by base 136 which is stationarily supported on a suitable foundation. Appropriate positioning means such as for example, radial arm 138 having an arcuately slotted head 140 on the outer end thereof is keyed or otherwise fixed at its upper end to one of the brackets 142 which is directly fixed to the chute 130. If desired, a suitable scale 144 may be arranged on the head 140 for association with a fixed reference point 146 on base 136. Releasable locking means such as a headed bolt 148 is disposed within the slot of head 140 and, when tightened, will hold said head as well as its arm 138 and chute 130 in a desired fixed position to dispose the grizzly 132 in any one of a number of possible adjusted positions as shown in exemplary manner by broken lines in FIG. 11.

When in a preferred position, the mixtures of friable material 150, while falling in various curved paths as illus-

trated in FIG. 11, will engage the grizzly 132, whereby the pieces of a size larger than the spaces between the bars of the grizzly will be deflected back into the mill, while the material which will pass through said spaces will be discharged by gravity along chute 130 onto the classifier or screen 152. Eventually, the larger pieces of friable material which initially are rejected by grizzly 132 will be decreased in size by impact and abrasion until they finally pass through the grizzly. It also should be understood that while the grizzly 132 is desired in the preferred embodiment of the invention, the same may be dispensed with particularly under conditions where the maximum size of material supplied to the mill either in run-of-the-mine condition or otherwise is not greatly in excess of the material which will pass through the grizzly, or the chute 130 is moved sufficiently to avoid all falling pieces considered too large for use as pebbles.

The classifier or screen 152 in FIG. 10 is so illustrated here as to show another of several well known arrangements of devices to classify or divide material into different size components but, if desired, a trommel such as shown in FIG. 2 or other arrangement may be employed.

The separator or screen 152 has a plurality of spaced, parallel and sloping bars comprising a grate or grizzly 154. The spaces between the bars of the grizzly 154 will pass lumps or pieces of friable material of which most are usually rounded by the time they are discharged from the mill and which are minus 1 inch in minimum size. Pieces 156 which are minus 3 inch to plus 1 inch in size will be discharged in chute 158 for return to the mill by suitable means, not shown, but of the type employed in FIG. 1 for example, or for feed of such material either to a surge bin for delayed and controlled feed to an auxiliary or re-grind mill or for direct feed to an auxiliary mill in the manner described above relative to FIG. 1.

Another screen or grizzly 160 of 4 mesh size, for example, is mounted below the grizzly 154. Accordingly, the minus 1 inch to plus 4 mesh size material 162 will pass along the top of screen or grizzly 160 and be discharged into chute 164, while the minus 4 mesh to 0 size material 166 will be discharged in the chute 167 and will constitute either finished material if of sufficiently fine size desired for certain uses or, if otherwise desired, the chute 167 may communicate with the entrance of a secondary or re-grind mill such as the mill 86 of FIG. 1 or 116 of FIG. 2 for example, for further reduction of the size of such material.

In autogenous mills of the type shown in FIGS. 10 and 11, it has been found that the larger pieces of friable material being processed in the mill usually orbit within a path relatively close to the inner periphery of the mill and, depending upon the speed of the mill, most usually will travel somewhere approximately between the 6 o'clock and 9 o'clock positions. Much of the material of intermediate and even fine sizes will orbit along with these larger pieces and gradually be reduced in size by the larger pieces while said larger pieces themselves also are being reduced in size. These smaller pieces of more intermediate size usually will rise to higher levels within the mill and, again depending upon the speed of the mill and the size of these pieces, they may rise to the 10 o'clock or even the 12 o'clock position of the mill as viewed relative to FIG. 11. With this material, a substantial part of the smaller sizes also will be elevated for fall along curved paths such as illustrated in exemplary manner in FIG. 11. The material at the 11 o'clock or, in some circumstances, possibly even toward the 1 o'clock position, depending upon the speed of the mill, specific gravity of the material and size of the particles, will mainly be the smaller pieces and finer sizes.

In view of such orbiting of certain ranges of sizes at different zones within a tumbling mill of this type, for example, it will be seen that the chute 130 can be tiltably positioned to different positions and will receive mate-

rial of widely different size ranges, depending upon its location relative to the falling streams or paths of material. The grizzly 132 may be of a replaceable nature so as to enable the grizzlies of different openings, as desired, to be used.

It will be further seen that, by reference to FIG. 11 particularly, suitably choosing the position of the grizzly 132 within the mill will avoid the same being struck by the very heavy pieces of material except occasionally. Still further, if the grizzly and upper end of the chute 130 are moved to the extreme permissible right-hand dotted line position as illustrated in FIG. 11, only the finer segments of material will be encountered. Even more important is the fact that the position of the chute 130 and its grizzly 132 relative to the interior of the mill may be adjusted while the mill is operating as, for example, when a change occurs in the nature, such as size consistency, of the material being fed to the mill and, by adjusting the position of the chute 130 suitably to meet the new conditions, maximum efficiency of the mill can be continued without stopping the mill.

In comparing the embodiment of primary mill and adjustable discharge means of FIGS. 10 or 11 with the mill 12 of the embodiments shown in FIGS. 1 and 2, it will be seen that the use of the grizzly 132 in the former has a very similar effect to the adjustment of the radial spaces 50 in the latter and the movement of the chute 130 in the former will produce similar effects as the removal of some of the lifting bar sections 38 regarding amounts and relative location in the various zones in the mill. However, these two embodiments principally are exemplary of desirable structures for the purpose of removing a desired amount of coarse, pebble material from a primary mill, together with finer material to be reduced further in size by said coarse material in a second mill. Other structures to accomplish this purpose are conceivable within the spirit of the invention.

Generally in regard to the overall mill systems described above, as the secondary or re-grind mill operates while employing friable grinding media produced by the primary mill and consisting of the same type of material as that being processed in both the primary and secondary mills, there will be a reduction in size not only of the intermediate and finer sizes of material within these mills but likewise a reduction in the friable grinding media pebbles or cobs themselves, whereby their supply must be replenished. Pebbles or cobs made up of the same material as that being ground usually are not as hard as commercial flint pebbles or metal balls supplied from outside sources and will wear down and be consumed at a much greater rate. They must therefore be available in considerably greater quantities, which is the case in this instance unless the material being ground is of a very unusual nature. It is obvious that if suitable grinding pebbles and cobs can be obtained directly from the mill system itself without resorting to outside sources, or the use of metal balls, the overall operation of the mill system will be much more economical and of great advantage to the user of such a system as compared to those systems which require the use of outside sources of grinding media.

The various adjustments of certain elements of the mill system described hereinabove have been referred to principally as being manual in nature. For example, this has been so in regard to regulation of the primary mill feed gate means 14, FIG. 1, the speed of the feed belt 16, the adjustment of the deflector plate or splitter 74, the positioning of deflector member or gate 100, as well as the speed of the pebble feed belt 102 in the embodiment illustrated in FIG. 1. This invention also contemplates however the use of automatic means for maintaining operating conditions at the optimum or at any other desired rate for the purpose of reducing to a minimum the necessity for making manual adjustments after the system once has been set for a desired opera-

tion such as to produce a range of products wanted at a desired rate of production. In considering the automatic adjustable means and methods of employing the same, several variables must be considered as well as the members or parts of the mill system subject to adjustment to obtain the objectives desired. In this regard, in practicing this invention, the following exemplary components may be employed in one form or another in the several systems described hereinabove and be adjusted to produce desired controlled operating characteristics for the entire mill system:

- (1) The primary mill feed rate control means.
- (2) The secondary or re-grind mill motor power differential under different load conditions.
- (3) The secondary or re-grind mill sound level by which different load conditions are observed.
- (4) Pebble cobber quantity selector device, as well as pebble bin surge feeder, if used, for controlling the rate of cobbing of pebbles and feeding thereof to the secondary or re-grind mill.
- (5) The rate of oversize or coarse component of secondary or re-grind mill discharge for controlling the overall output of the primary mill circuit and pebble cobbing or pebble feed rate to the secondary or re-grind mill, or combinations thereof.

(6) Other phenomena in the system, well known in the art, that also act in a manner that can be used to act on components so as to change the mill operation.

It is known in the art of grinding in tumbling mills either of the complete or fully autogenous grinding type wherein all sizes are comminuted simultaneously, or the partially autogenous grinding type which uses pebbles to grind relatively fine feed sizes, that among other factors the following conditions have influence upon the operations of various mills, assuming the mills are first adjusted and operated at or reasonably close to their optimum capacity to deliver the desired character of product. With respect to the operation of the secondary or re-grind mill of the types of mill circuits or systems described hereinabove, it has been found that:

(1) A decrease in sound indicates too much fine fraction of the material in comparison to the coarse fraction thereof in the mill and that the proportion of fine fraction to coarse fraction is too high, as well as possible coating of the lining.

(2) An increase in sound indicates an over supply of pebbles or a decrease in rate of feed or both.

(3) A decrease in normal power consumption can indicate either a decreased rate of pebble supply or possible overload of pebble charge. In this regard, this can result if the so-called normal mill load is such as to be very close to that which will draw the maximum power that can be consumed by the mill.

(4) An increase in power over the so-called normal setting indicates a greater than normal pebble loading for a given power setting if said setting is sufficiently below the maximum power obtainable to allow some leeway.

(5) An increase in power and a simultaneous decrease in sound normally indicates too great a pebble charge, together with too many fines in the mill and/or possible coating of the lining.

(6) An increase in power and increase in sound normally indicates too many pebbles and a deficiency of fine material.

(7) A decrease in power and decrease in sound can indicate either insufficient or possibly too many pebbles, if operated too close to the maximum power obtainable, and also possibly too high a percentage of fine material.

(8) A decrease in power and increase in sound normally indicates a decrease in pebble charge if the normal power line is set sufficiently below the maximum but, if this latter condition does not exist, said decrease in power and increase in sound could also indicate too great a peb-

ble charge. In either situation, a deficiency of fine material also is indicated in the mill.

(9) An increase in the rate of oversize from the secondary or re-grind mill indicates either too much feed to the primary mill as well as to the secondary re-grind mill, or insufficient pebbles in the secondary re-grind mill and, under such circumstances, any increase of pebble feed rate to the secondary or re-grind mill will remove some of the intermediate size range from the primary mill and tend to balance the load in the primary mill without changing primary mill feed rate, other conditions being normal.

The aforementioned indices of the principal variables in the operation of the various components of the mill system and the causes of such condition which have generally been determined from long experience, can be employed in an additive or subtractive manner, automatically, to correct all but unusual conditions. These indices can be utilized to vary the component elements mentioned above, either simultaneously or separately, as conditions dictate and do so automatically.

The particular characteristics of the overall operation, such as feed conditions and other variables, are first observed, by making a series of preliminary tests, and by using manual controls for observation and corrective purposes. The normal limitations are also established during this period of manual control of the various adjustable components and approximate optimum operating conditions under various circumstances are noted and established. An exemplary control circuit for achieving automatic adjustment, regulation, and operation of the mill systems described hereinabove is illustrated in FIG. 12.

For example, in placing the mill system initially in operation, the feeder for the primary mill is first adjusted so as to cause the mill to operate normally under the conditions at hand. The pebble selector or segregating mechanism adjacent the exit of the primary mill in the circuits described above are so adjusted that the pebbles cobbled from the primary mill are fed to the secondary or re-grind mill at approximately the desired rate, preferably to match the consumption of the pebbles during operation of the secondary mill. The contemplated principal controlling elements utilized to maintain conditions constant in the circuit and particularly in the secondary or re-grind mill have been selected to utilize sound, power consumption, and quantity of oversize produced by the secondary or re-grind mill, as measured by suitable means. These three controlling elements or phenomena are examples of operating conditions which can be utilized to indicate certain conditions of the mill system and effect actuation of a circuit relay system when adjusted to function at the points desired. Other known conditions and appropriate controlling means may be used within the spirit of the invention.

With respect to sound in the secondary mill, the functioning of the circuit relay system would occur when the sound reaches the noise level desired to be maintained. With respect to the power consumption by the motor which drives the secondary mill, the circuit relay system would function when a predetermined power input to the motor is reached. Concerning the oversize produced by the secondary mill, the circuit relay system would be actuated when a predetermined rate of production of oversize considered optimum for a given condition is discharged from the secondary or re-grind mill.

The controlling circuitry employed in the diagrammatic illustration of FIG. 12 principally comprises standard components and includes suitable relay systems, adjustable means to match any given condition desired, indicators, and time delay elements to eliminate fluttering or too rapid action, particularly where there is a tendency for momentary variations when average conditions are desired. Inasmuch as standard elements are employed in this circuit, detailed description of each element is considered unnecessary, and general reference to the various

elements and the functions thereof is furnished to understand the operation of the circuit as it is intended to be employed to control the principal variables automatically, after initial manual adjustment and setting. The operation of the various feed mechanisms, sizing and segregating mechanisms, as well as other elements of the overall mill systems, as described in detail hereinabove, are referred to hereinafter in conjunction with the following detailed description of the circuit shown in FIG. 12.

Referring to FIGS. 1 and 12 specifically, there is arranged in suitable position relative to the secondary or re-grind mills 86 or 116 a microphone 168 which is connected by a suitable circuit to sound control unit 170. The power feed control circuit of the secondary mill driving motor 94 is connected to a power level control unit 172. The discharge from the secondary mill 86 passes to a suitable chute 174, see FIG. 1, for discharge onto separation means 176 comprising an angularly disposed screen 178, for example, of a desired mesh through which maximum sizes of fine product material will pass for discharge into product conduit 180, for example.

The oversize portion of the product which will not pass through the screen 178 is discharged onto suitable weighing means as indicated by a traveling belt 182 mounted on an indicating and weight recording scale device of any suitable type well known in the art. Said belt discharges into a chute 184 which delivers the oversize material either to other means outside of the system or to suitable elevating means for return to the primary or secondary mill for further reduction in size. The variation in weight of the oversize material as recorded by the weighing belt 182 is utilized, as seen by referring to FIG. 12, to actuate an oversize quantity control unit 186.

Assuming that the pebble or cob deflector plate or splitter 74 has been manually adjusted to the desired position initially, then by adjustment of the manually controlled resistance 188 in the main control power line to the modulator 190 and set to be just at the point of actuating plate 74 through lever 192 connected thereto by a link 193, and assuming further that all of the control elements are also adjusted so as to be just on the functioning or actuating point, then the degree of change desired between the various controlling elements such as element 170 responsive to sound, element 172 responsive to secondary mill power, and element 186 responsive to the rate of oversize discharged from the secondary mill is controlled by resistances 194, 196 and 198 respectively. All of these control elements are correlated and each is variable. Each can be adjusted or eliminated from effect upon the circuit at will. The variability of these resistances makes it possible for the operator to select the degree of change desired in the circuit of each controlling element since one sensing element will usually have greater effect on the circuitry than another, depending upon conditions.

If the pebble cobbing supply is to be done solely by movement of deflector splitter 74 of segregating mechanism 56 of FIG. 1 and the pebbles are passed directly to secondary mill 86, switch 200 is then set so that line 204 is connected with line 231. However, if it is desired to utilize surge bin 98, switch 200 then is altered to connect lines 202 and 204, whereby the sensing elements then control pebble feeder motor 206 which drives feed belt 102. When pebble feed from the surge bin is employed, the pebble cobbing selector or deflector plate 74 is manually controlled to maintain an adequate supply of pebbles in the surge bin and is manually adjusted from time to time as conditions dictate. Gate deflector member 100 also is opened manually. The variable resistor 188 may or may not be shunted out of the circuit when the system is adjusted for automatic control at the will of the operator, depending on the use of one or more of the other resistors 194, 196, 198 which vary the degree of control by sound element 170, secondary mill power element 172, or rate of oversize discharge element 186, or in any combination thereof.

In the event that conditions within the overall grinding system are such that full normal operation can not be maintained due to excessive variations in the primary mill feed characteristics that will have a major effect on the pebble supply, a supplementary control is illustrated that will also control the primary mill feeder motor 20 of the embodiment shown in FIG. 1. This will help maintain the supply of pebbles necessary to meet the requirements in the secondary mill circuit and will act in a supplementary manner to any other controlling elements which may normally control the primary mill as indicated generally by circuit 232. These elements are not shown, but are well known in the art for controlling the operation of the primary mill by the sound of the grinding conditions therein, or the power consumed by the driving motor for the primary mill, or other means. These latter control arrangements are not part of the present invention, but the present invention does illustrate means of further complementing the controls of the primary mill itself if they are desired.

The aforementioned auxiliary control of the primary mill feed rate is exemplified by contacts 208, 210 and 212, which operate in conjunction with the other contacts 233, 234 and 235 connected into the pebble cobbing control system, as described above, and in turn have their own means of supplying the degree of change desired by resistances 214, 216 and 218 which are also included in the circuitry for the motor 20 which drives the primary mill feeder. Any one or all of the contactors may be connected into or disconnected from the circuit at will by actuating switches 220, 222, or 224 for the primary mill feed circuit, or switches 236, 237 or 238 for the pebble feed cobbing circuit. The primary mill feeder motor speed, and hence, the feed rate, is regulated by control unit 240 of conventional design and variable resistance 239 complementary to or independent of the other motors 214, 216 and 218.

Under ordinary operating conditions, the sound of the secondary or re-grind mill, through its control unit 170 and resistor circuit 194, normally controls the rate of feed of pebbles to said secondary mill when the sound deviates from the preset sound level desired. Simultaneously, it can also control the feed rate to the primary mill if switch 220 is opened.

Power consumption by the secondary mill motor, by means of its control unit 172, may be used to control the pebble feed to the secondary or re-grind mill if the power control resistor 196 is set primarily to operate below the maximum power level. This unit can also be used to control the primary mill feed rate if the switch 222 is opened.

The secondary mill oversize discharge rate, by means of its control unit 186 and resistor 198, may be used to change the pebble feed rate to the re-grinding mill under circumstances where the oversize rate differs from the desired amount and said oversize discharge rate control can also be set to alter the primary mill feed rate if switch 224 is opened.

It should be understood that under certain unusual conditions the material hardness or feed size range for the primary mill, with relation to the effect on the secondary or re-grind mill, might cause one or more of the combinations of the controls to function differently than the manner outlined above. Provision is contemplated to reverse the control functioning of any one or all of the elements used, if desired. Each element has a bearing upon the operation as a whole, and is so placed in the circuit that it can be used or not used, as desired, and to any degree desired, with relation to the other control elements, as illustrated, that may also be functioning at the same time. For example, sound control may be used and adjusted to affect the feed rate in an amount of 15%, for example, while another controlling element such as the power consumption control unit, might only be adjusted

to affect the feed rate in the amount of 5%, and still another element not be utilized for one reason or another which in many cases can only be determined by trial. At the same time, for example, the oversize control circuit may be arranged to alter the primary mill feed rate only, or it can at the same time be so connected into the secondary mill circuit as to neutralize the effect of the other control units by altering switch 241 in the control unit 186 from a normally closed to a normally open setting or vice versa.

To illustrate the manner of operation of the system, one of the influencing conditions affecting the milling circuit will be described as an example. It is to be understood, however, that such illustration should be interpreted broadly and in accordance with the various other conditions already outlined. For example, the mill system is first adjusted to operate in a normal manner and the control devices also adjusted including the pebble cob deflector plate 74, which is properly set to deliver the required amount of pebbles to the secondary mill. After a period of time, the mill power in mill 86 or 116 we will assume, for some reason, decreases. The signal to the power control circuit 172 will also decrease, which, in turn, will cause relay 234 to close if it were previously set to be in a normally open position. We will assume in this case that only the mill motor power is being used in the automatic controlling circuit, in which case switch 237 will be open and switches 236 and 238 closed. Switch 200 in the pebble supply circuit, when moved to the lower contact, will cause cobber control modulator 190 to be subjected to the signal caused by control unit 172 and specifically relay 234.

Closing of a circuit around resistance 196 will remove resistance 196 from the circuit. This increases the control signal which will, in turn, actuate modulator 190 to increase the pebble feed to the secondary mill. This can be accomplished if relay 234 is arranged to be normally open, as previously stated. We will also assume, for example, resistance 196 was set to change the signal strength by 10%. This will cause an equivalent alteration in the movement of cobber modulator 190, and when set so as to move the cobber plate 74 to increase the supply of pebbles 76 to the secondary mill 86—116, this will increase the pebble load in the mill and the mill motor power will gradually increase. So also will the signal entering power control unit 172. When the relay 234 again opens, the current in the circuit energizing cobber modulator 190 returns to that originally set and so also the cobber plate 74. This cycle will be repeated whenever the mill power again decreases, thus a so-called high-low adjustment is made in the pebble supply. As stated previously, the operator by adjusting resistance 196 may control the degree of change that will take place each time the relay closes.

Control by sound and also oversize may be made to operate the pebble cobbing modulating unit 190 in a like manner or a reverse manner, individually or cooperatively, as the case may be, in which case, switches 236 or 238 or both are opened. If all switches are opened, then mill power, mill sound, and oversize are all in a position to control the modulator 190. If it is desired to control, for example, the modulator 190 so as to decrease the pebble cobbing feed rate when the oversize increases, merely by changing relay 233 to the normally closed position by moving switch 241 to the upper contact, as shown, this objective can be attained since now resistance 198 is removed from the circuit, then added in when relay 233 opens, just the reverse of the other example, as described for the mill motor power control. The same equivalent reversal effect is possible with the other two relays 235 and 234, controlled by sound and power. It will be seen, as illustrated in these particular examples, that a normally open relay switch, when closed, increases the actuating control current signal, while a normally closed switch, when opened, will decrease the actuating control signal.

If for example the power control signal strength change was set at 10% as stated in the previous example, and the oversize at 6%, then if both circuits were placed in operation and when both were being actuated the net change in pebble cobbing rate would be 10% minus 6% or 4% increase in pebble cobbing rate.

It is obvious that an additive or subtractive effect can be obtained by use of the various units set at various percentage changes in either acting separately or in combination, thus adding to or subtracting from or partially nullifying the over-all degree of control by proper actuation of the various switches 236, 237, 238, which, in turn, cut in or out, as the case may be, resistors 194, 196, 198. Instead of controlling the pebble feed by the modulator 190, the same general effect can be achieved by turning switch 200 to the lower contact, in which case the pebble feeder motor 206 is actuated in like manner.

As to the control of feed to the primary mill through an operating condition of the secondary mill, a decrease, for example, of oversize in the secondary mill can be made to increase the feed to the primary mill. If switch 224 is opened and after appropriate adjustment of resistors 214 and 239, is made, and also relay 208 is arranged to be normally open so that, when closed on a decrease in oversize, for example, resistor 214 is shunted. When resistor 214 is shunted, this will increase the energy going to the feed motor control unit 240, which in turn, increases the speed of the primary mill feeder motor, and hence, the primary mill feed rate will be increased.

It is obvious also that simultaneous actuation of pebble feed to the secondary mill and feed to the primary mill may be obtained by appropriate actuation of the various switches in the different control circuits.

The action that occurs in tumbling mills under various conditions differs materially and what will affect power very considerably in one situation will not have any appreciable effect on the sound or oversize produced by the secondary mill, and vice versa. Those skilled in the art are familiar however with the fact that under certain conditions when handling materials differing substantially in characteristics, all three or any one of the three aforementioned controlling elements, namely, sound, power consumption and oversize production, will vary considerably within the system and at times tend to be self compensating and at others cumulatively coacting.

Furthermore, while the invention contemplates mainly the use of an autogenous grinding mill as the preferred type of tumbling mill, such mills may be a combination type of mill wherein other grinding media is employed, at least in part, than the ore or material itself, such as by the addition of balls, either into the primary or secondary mill circuit, as required or desired, and as sometimes is employed in mills of these types. While the size ranges mentioned may be considered normal, a widely different selection of mesh sizes and pebble sizes is also contemplated under various operating conditions. Still further, other means of removing portions of the coarser fractions or pebbles from the primary mill may be employed than those specifically illustrated.

The action also contemplates the employment of wet grinding, as well as dry grinding, mill circuits. If the entire system is operated in a closed circuit, normal circuitry will comprise the primary mill operating in its own closed circuit and the secondary mill operating in its own closed circuit; or the oversize from the secondary mill may be delivered back to the primary mill, if desired, or only a portion of the intermediate products or sizes of either the primary or secondary mills may be removed from the circuit entirely for separate treatment, as desired.

It further is to be understood that other means of indicating the operating conditions of the secondary or re-grind mill than those specifically illustrated and described may be employed, whereby the specifically illustrated indicating and recording control and actuating devices shown in the system as a whole are to be regarded as exemplary rather than restricting.

Although only a single secondary mill has been employed in the mill system and processes described hereinabove, with the possible exception of the use of auxiliary mill 112 in the embodiment shown in FIG. 2, it is to be understood that the present invention contemplates the use of additional secondary mills respectively receiving material either from the primary mill and/or surge bin associated with the discharge thereof, or to receive material from the secondary mill presently illustrated in the systems described hereinabove and illustrated in the drawings if the employment of such additional secondary mills is found desirable and necessary to the achievement of a desired product of some type of solid material which may require the use of additional auxiliary mills even though such additional auxiliary mills are not specifically illustrated in the drawings.

It is to be understood also that other means of operating a grinding circuit are contemplated which utilize a plurality of control elements as described in detail hereinabove, such for example, as in a situation wherein bin 98 is employed as the principal feed source for mill 86 and does not necessarily comprise a means solely for feeding pebbles. Under such circumstances, the control of the feed rate by feeder 102 then may be affected by one or more of the elements of the overall control system of FIG. 12, in combination or separately, as operating conditions of the mill 86 dictate, to produce an integrated control for optimum results.

Hereinabove and in the appended claims, the term "autogenous" is meant to pertain to using the friable material undergoing reduction, either in whole or in part, as its own grinding media. The term "run-of-mine material," as used hereinabove and in the appended claims, pertains to a mixture of friable material which normally includes coarse, intermediate and fine sizes, the larger sizes being sufficient to reduce themselves in size along with the other sizes present even though certain size ranges may be eliminated or partially treated separately.

Although various embodiments of mill unit and systems are described and illustrated, it is to be understood that while they have certain basic principles in common, they are not to be regarded as equivalents since they have different characteristics which lend them to functioning differently under various operating conditions and when treating different types of materials.

While the invention has been described and illustrated in its several preferred embodiments, it should be understood that the invention is not to be limited to the precise details herein illustrated and described since the same may be carried out in other ways falling within the scope of the invention as claimed.

I claim:

1. A grinding mill system for subjecting a range of sizes of friable material to self-reduction of all sizes and comprising a first tumbling mill, means to feed solid friable material thereto for reduction into a range of sizes, segregating means arranged to receive at least some of said friable material from said first mill and separate the same into a plurality of ranges of sizes including some coarse friable material suitable for use as grinding media, a second tumbling mill, and means independently of said second mill and operable to feed a desired amount of said segregated coarse friable material at a controlled rate to said second mill to produce a desired grinding condition within said second mill for friable material to be reduced in size therein.

2. A grinding mill system for subjecting a range of sizes of friable material to self-reduction of all sizes and comprising a first tumbling mill, means to feed solid friable material thereto for reduction into a range of sizes, segregating means arranged to receive at least some of said friable material from said first mill and separate the same into a plurality of ranges of sizes including some coarse friable material suitable for use as grinding media, a second tumbling mill, and adjustable means in-

dependent of said second mill and operable to control the rate of feed of a desired range of sizes of said segregated friable material including a controlled amount of said coarse material to said second mill and utilizing said coarse material as grinding media to produce a desired grinding condition within said second mill for material to be reduced in size therein.

3. A grinding mill system for subjecting a range of sizes of friable material to self-reduction of all sizes and comprising a first tumbling mill, means to feed solid friable material thereto for reduction into a range of sizes, means operable to segregate said material from said first mill into a plurality of ranges of sizes including some coarse friable material suitable for use as grinding media, a second tumbling mill, means operable to feed one portion of said segregated coarse friable material to said second mill to produce a desired grinding condition within said second mill for reduction of material fed thereto, and means to return the other portion of said coarse friable material from said segregating means back to the first tumbling mill for further reduction in size.

4. A grinding mill system for subjecting a range of sizes of friable material to self-reduction of all sizes and comprising a first tumbling mill, means to feed solid friable material thereto for reduction in size including a range of fine sizes, classifying means arranged to receive the said material produced by said first mill and segregate the same into a plurality of ranges of sizes including some coarse friable material suitable for use as grinding media, a second tumbling mill, storage means operable to receive material partially reduced in size, means to feed at least some of said segregated coarse friable material to said storage means, and adjustable means operable to feed a desired amount of said segregated coarse friable material from said storage means to said second mill to produce a desired grinding condition therein for material fed thereto.

5. A tumbling type grinding mill system for subjecting a range of sizes of friable material to self-reduction of all sizes and comprising a first tumbling mill, means to feed solid friable material thereto for size reduction therein, adjustable material handling means operable to receive said material from said first mill and segregate the same into a plurality of size ranges including a coarse range of friable material suitable for use as grinding media, a second tumbling mill, and means operable to feed to said second mill desired proportions of said segregated ranges of friable coarse sizes at a desired rate controlled by the adjustment of said material handling means to produce a desired grinding condition within said second mill for reduction in size of material fed thereto.

6. A tumbling type grinding mill system for subjecting a range of sizes of friable material to self-reduction of all sizes and comprising a first tumbling mill, means to feed solid friable material thereto for reduction to a range of mixed sizes, adjustable material handling means operable to receive material from said first mill and segregate the same into a plurality of size ranges including a coarse range of friable material suitable for use as grinding media, a second tumbling mill, and means responsive to an operating condition of said second mill and operable to adjust said material handling means to cause the delivery of desired proportions of said segregated size ranges of material to said second mill, said segregated size ranges including a proportion of said coarse range to produce a desired grinding condition within said second mill for material fed thereto.

7. A tumbling type grinding mill system for subjecting a range of sizes of friable material to self-reduction of all sizes and comprising a first tumbling mill, means to feed solid friable material thereto for reduction to a range of mixed sizes, adjustable material handling means operable to receive said material from said first mill and segregate the same into a plurality of size ranges including a coarse range of friable material suitable for use as

grinding media, a second tumbling mill, and means responsive to the sound of said second mill during grinding operation thereof and operable to adjust said material handling means to cause the delivery of desired proportions of said segregated size ranges of material to said second mill and including a controlled proportion of said coarse range to produce a desired grinding condition within said second mill for material fed thereto.

8. A tumbling type grinding mill system for subjecting a range of sizes of friable material to self-reduction of all sizes and comprising a first tumbling mill, means to feed solid friable material thereto for reduction to a range of mixed sizes, adjustable material handling means operable to receive said material from said first mill and segregate the same into a plurality of size ranges including a coarse range of friable material suitable for use as grinding media, a second tumbling mill, power means to drive said latter mill, and means responsive to the power consumption of said second mill and operable to adjust said material handling means to cause delivery of desired proportions of said segregated size ranges to said second mill and including controlled proportions of said coarse range to produce a desired grinding condition within said second mill for material fed thereto for reduction in size therein.

9. A tumbling type grinding mill system for subjecting a range of sizes of friable material to self-reduction of all sizes and comprising a first tumbling mill, means to feed solid friable material thereto for reduction to a range of mixed sizes, adjustable material handling means operable to receive said material from said first mill and segregate the same into a plurality of ranges of sizes including a coarse range of friable material suitable for use as grinding media, a second tumbling mill, means responsive to the quantity of oversize material discharged from said second tumbling mill and operable to adjust said material handling means to cause the delivery of desired proportions of said segregated size ranges of products from said first tumbling mill to said second mill and including a controlled amount of said coarse range to produce a desired grinding condition within said second mill for material fed thereto.

10. A tumbling type grinding mill system for subjecting a range of sizes of friable material to self-reduction of all sizes and comprising a first tumbling mill, means to feed solid friable material thereto for reduction to a range of mixed sizes, material handling means operable to receive material from said first mill and segregate the same into a plurality of size ranges including a coarse range of friable material suitable for use as grinding media, a second tumbling mill, adjustable means operable to cause the delivery of desired proportions of said segregated size ranges to said second mill and including a desired controlled proportion of said coarse range to produce a desired grinding condition within said second mill for material fed thereto to produce a range of fine products of predetermined size range and oversize coarser products and discharge the same therefrom, means operable to separate said coarser oversize product material from said range of fine products, and means responsive to the quantity of coarser product produced by said second mill to control the adjustment of said adjustable delivery means for said second mill.

11. A grinding mill system comprising a first tumbling mill operable to receive and subject a range of sizes of friable material to self-reduction by tumbling the same autogenously within said mill, said mill having entrance and exit means, size-limiting screening means adjacent said exit means and operable to control the sizes of material discharged from the grinding zone of the mill, the majority of the openings of said screening means being of a size to permit passage therethrough of a predetermined maximum size of fine and intermediate sizes of material and capable of discharging therethrough the majority of the output of said mill, said screening means also includ-

ing a minor number of discharge openings substantially larger in size than said majority of openings and comprising a minor percentage of the total screen opening area and operable to discharge from said grinding zone an amount of coarse pieces of material capable of serving as grinding media that is less than the percentage of fine and intermediate sizes of material discharged through said screening means, means to receive from said screening means said mixture of fine and intermediate sizes of material and minor percentage of coarse pieces of friable grinding media and operable to segregate said coarse pieces from said fine and intermediate sizes of material and also separate said fine sizes from said intermediate sizes, a second tumbling mill, means operable to feed a desired amount of said segregated coarse pieces to said second mill, and means operable to return said intermediate sizes of material and any excess segregated coarse pieces of material to said first mill for further reduction in size.

12. A grinding mill system for subjecting a range of sizes of friable material to self-reduction of all sizes and comprising a first tumbling mill, means to feed solid friable material thereto for reduction to a range of sizes, said first tumbling mill having means to discharge a range of smaller size material and adjustable outlet means operable to regulate the rate of discharge from said mill of a restricted amount of a range of relatively coarse friable material of predetermined maximum size capable of serving as grinding media, a second tumbling mill, and means to feed said range of coarse sizes of friable material to said second mill to produce a desired grinding condition within said second mill for said smaller material fed thereto for reduction in size therein.

13. A grinding mill system for subjecting a range of sizes of friable material to self-reduction of all sizes and comprising a first tumbling mill, means to feed solid friable material thereto for reduction to a range of sizes, said first tumbling mill having outlet means operable to prevent discharge of material from said mill in excess of a predetermined maximum size, material handling means operable to receive and segregate all the product material discharged therefrom into size ranges of predetermined limits and discharge from said material handling means an adjusted restricted amount of such ranges of material including a range of relatively coarse sizes of predetermined maximum size capable of serving as grinding media, a second tumbling mill, and adjustable means operable to feed from said discharged material regulated desired proportions of said segregated size ranges of material to said second mill to produce a desired grinding condition within said second mill for said material fed thereto.

14. A grinding mill system comprising a first tumbling mill, means to feed solid friable material thereto for reduction to a range of sizes, segregating means arranged to receive such material from said first mill and separate the same into a plurality of ranges of sizes including some coarse sizes suitable to serve as grinding media, a second tumbling mill, a storage bin, means operable selectively to feed desired proportions of said coarse sizes directly to said second mill and to said storage bin for controlled feed to said second mill as required by the grinding operations of said second mill to produce a desired grinding condition therein utilizing said coarse sizes as grinding media and producing a desired range of fine products, and conducting means extending between said segregating means and the entrance of said first mill and operable to conduct excess coarse sizes of material back to said first mill for further reduction in size.

15. A grinding mill system for subjecting a range of sizes of friable material to self-reduction of all sizes and comprising a first tumbling mill, means to feed run-of-mine raw solid friable material to said mill at variable rates for reduction into a range of sizes, means to control

said feed of raw material to said mill, segregating and classifying means operable to receive material from said first mill and separate therefrom a range of relatively coarse friable material suitable for use as grinding media, a second tumbling mill, feed means for said second mill operable to feed said separated range of coarse friable material thereto at a predetermined controlled rate to produce a desired grinding condition within said second mill for material fed thereto, and feed control means for said second mill interconnected to said feed control means for said first mill and operable to control the rate of feed of said raw material thereto.

16. A grinding mill system for subjecting a range of sizes of friable material to self-reduction of all sizes and comprising a first tumbling mill, means to feed run-of-mine raw solid friable material to said mill at variable rates for reduction into a range of sizes, segregating and classifying means operable to receive material from said first mill and separate therefrom a range of relatively coarse friable material suitable for use as grinding media, a second tumbling mill, feed means for said second mill operable to feed said separated range of coarse friable material thereto at a predetermined controlled rate to produce a desired grinding condition within said second mill for material fed thereto from said first mill for further processing, and control means for said feed means for said first mill responsive to an operating condition of said second mill and operable thereby to vary the rate of feed of raw material to said first mill in accordance with said operating condition of said second mill.

17. A grinding mill system for subjecting a range of sizes of friable material to self-reduction of all sizes and comprising a first tumbling mill, means to feed run-of-mine raw solid friable material to said mill at variable rates for reduction into a range of sizes, segregating and classifying means operable to receive material from said first mill and separate therefrom a range of relatively coarse friable material suitable for use as grinding media, a second tumbling mill, feed means for said second mill operable to feed said separated range of coarse material thereto at a predetermined controlled rate to produce a desired grinding condition within said second mill for material fed thereto from said first mill for further processing, and control means for said feed means for said first mill responsive to the operating sound of said second mill and operable thereby to vary the rate of feed of raw material to said first mill in accordance with the sound of said operating condition of said second mill.

18. A grinding mill system for subjecting a range of sizes of friable material to self-reduction of all sizes and comprising a first tumbling mill, means to feed run-of-mine raw solid friable material to said mill at variable rates for reduction into a range of sizes, segregating and classifying means operable to receive material from said first mill and separate therefrom a range of relatively coarse friable material suitable for use as grinding media, a second tumbling mill, feed means for said second mill operable to feed said separated range of coarse friable material thereto at a predetermined controlled rate to produce a desired grinding condition within said second mill for material fed thereto, and control means for said feed means for said first mill responsive to the consumption of operating power by said second mill and operable thereby to vary the rate of feed of raw material to said first mill in accordance with said consumption of operating power by said second mill.

19. A grinding mill system for subjecting a range of sizes of friable material to self-reduction of all sizes and comprising a first tumbling mill, means to feed run-of-mine raw solid friable material to said mill at variable rates for reduction into a range of sizes, segregating and classifying means operable to receive material from said first mill and separate therefrom a range of relatively coarse friable material suitable for use as grinding media, a second tumbling mill, feed means for said second mill

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operable to feed said separated range of coarse friable material thereto at a predetermined controlled rate to produce a desired grinding condition within said second mill for material fed thereto, and control means for said feed means for said first mill responsive to the quantity of material in excess of a predetermined size produced by said second mill and operable thereby to vary the rate of feed of raw material to said first mill in accordance with said excess material condition of said second mill.

20. A grinding mill system for subjecting a range of sizes of friable material to self-reduction of all sizes and comprising a first comminuting mill, means to feed solid friable material thereto for reduction to a mixed range of sizes, means positioned and operable to receive material from said first mill and segregate the same into a plurality of ranges of sizes including a substantially coarse range of friable product suitable to serve as grinding media, a second comminuting mill of the tumbling type, means to feed at least some of said segregated coarse range of friable product to said second mill of a controlled rate adequate to produce a desired grinding condition therein for material fed thereto to produce a desired range of products, and a third comminuting mill operable to receive from said first mill an undesired proportion of said segregation ranges of sizes for further comminution within said third mill.

21. A grinding mill system for subjecting a range of sizes of friable material to self-reduction of all sizes and comprising a first comminuting mill, means to feed solid friable material thereto for reduction to mixed ranges of size from fine to coarse, means positioned and operable to receive said mixed friable material from said first mill and operable to segregate the same into separated ranges of sizes including fine, intermediate and coarse, said coarse range of friable material being suitable to serve as grinding media, a second comminuting mill of the tumbling type, means to feed to said second mill said segregated fine range and at least some of said coarse range of product at a controlled rate to produce a desired grinding condition therein for further reducing said fine material in size, a third comminuting mill, and means to deliver from said first mill to said third mill the segregated intermediate range of material for further comminution therein to finer sizes.

22. A grinding mill system for subjecting a range of sizes of friable material to self-reduction of all sizes and comprising a first comminuting mill, means to feed solid friable material thereto for reduction to mixed ranges of size from fine to coarse, means positioned and operable to receive said mixed friable material from said first mill and operable to segregate the same into separated ranges of sizes including fine, intermediate and coarse, said coarse range of friable material being suitable to serve as grinding media, a second comminuting mill of the tumbling type, means to feed to said second mill said segregated fine range and at least some of said coarse range of product at a controlled rate to produce a desired grinding condition therein for further reducing said fine material in size, a third comminuting mill, means to deliver from said first mill to said third mill the segregated intermediate range of material for further comminution therein to finer sizes, and means to deliver said further comminuted material from said third mill to said second mill for still further comminution therein by the coarser material in said second mill.

23. A grinding mill system for subjecting a range of sizes of friable material to self-reduction of all sizes and comprising a first tumbling mill, means to feed solid friable material thereto for reduction in size thereof, and discharge means positioned relative to the grinding zone of said mill to effect discharge of ground and semi-ground friable material and said discharge means also including means forming passage openings of a size adequate to permit discharge from the mill of coarse friable pebble material larger than said ground and semi-

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ground material and suitable for use as grinding media, said means forming passage openings also being variable in position relative to said mill to afford discharge of a regulated desired quantity of said coarse friable material for use as grinding media in a second mill.

24. A grinding mill system for subjecting a range of sizes of friable material to self-reduction of all sizes and comprising a first tumbling mill, means to feed solid friable material thereto for reduction into a range of sizes, discharge means operable relative to the interior of said mill to effect discharge from the mill of ground and semi-ground friable material of a predetermined maximum size, and additional means forming discharge passage openings of a size adequate to permit discharge from the mill of coarse friable material larger than said ground and semi-ground material and suitable for use as grinding media, said additional means forming discharge passage openings being variable in extent, whereby the total area of said passage openings being variable to effect discharge of a desired quantity of said coarse friable material from said mill for use in a second mill.

25. A grinding mill system for subjecting a range of sizes of friable material to self-reduction of all sizes and comprising a first tumbling mill, means to feed solid friable material thereto for reduction into a range of sizes, discharge means operable relative to said mill to effect discharge from the mill of ground and semi-ground friable material of a predetermined maximum size, and additional discharge means forming discharge openings and being variable in position within said mill to position said openings where desired and said openings being of a size adequate to permit discharge from the mill of coarse friable material larger than said ground and semi-ground material and suitable for use as grinding media, the total area of said discharge openings also being variable and in conjunction with the variable positioning of said discharge openings effecting discharge of a quantity of said coarse material to be fed to a second mill, and means operable to deliver a sufficient amount of said coarse material to a second mill to produce a desired grinding condition therein for reduction of material fed thereto.

26. A grinding mill system comprising a first tumbling mill, means to feed solid friable material thereto for reduction into a range of sizes, discharge grate sections operable to permit passage of ground and semi-ground friable material of a predetermined maximum size from said mill, said grate sections having passage openings therebetween which are larger than the openings within said grate sections to permit exiting from the mill of an amount of coarse friable material larger than that which passes through said grate openings and suitable for use as grinding media, means selectably positionable within said passage openings between said grate sections to cover portions of said openings at selected locations relative to said grate sections, thereby to effect discharge of a desired quantity of said coarse material to be fed to a second mill, and means operable to deliver said desired quantity of coarse friable material to a second mill to produce a desired grinding condition within said second mill for reduction of material fed thereto.

27. A grinding mill system comprising a first tumbling mill having entrance and exit means, means to feed solid material thereto for reduction to a range of mixed sizes, material discharge means extending into and adjustably positionable within said mill with the inner end thereof arranged to receive a selected portion of a mixture of said ground and partially ground material while the same tumbles in said mill, the average size and amount received being variable and in accordance with the adjusted position of said discharge means within said mill and the larger sizes of said material being capable of serving as grinding media for the smaller sizes, a second tumbling mill, and means to feed said mixture of material received by said discharge means to said second mill

to produce a desired grinding condition therein for said material fed thereto.

28. An autogenous grinding mill system comprising a first tumbling mill having entrance and exit means, means to feed solid material thereto for reduction to a range of mixed sizes, material discharge means extending into said mill and operable to receive material while falling within said mill during tumbling thereof and operable to conduct the material falling thereon through said exit, segregating means arranged to receive the material discharged from the first mill by said material discharge means and classify the same into a plurality of ranges of sizes including a substantially coarse range of predetermined maximum size and capable of serving as a grinding media, a second tumbling mill, and means to feed desired selected proportions of said classified ranges of sizes of material including at least a portion of said coarse range to said second mill to produce a desired grinding condition within said second mill for said material fed thereto.

29. An autogenous grinding mill system comprising a first tumbling mill having entrance and exit means, means to feed solid material thereto for reduction to a range of mixed sizes, material discharge means extending into said mill and the inner end thereof being adjustably positionable within said mill to receive material from a selected location while falling within said mill during tumbling and conduct the same through the exit of said mill, segregating means arranged to receive material from said material discharge means and classify the same into a plurality of ranges of sizes including a substantially coarse range capable of serving as a grinding media, a second tumbling mill, and means to feed desired selected proportions of said classified ranges of size of material including said coarse range to said second mill to produce a desired grinding condition within said second mill for said material fed thereto.

30. A grinding mill system comprising a tumbling mill, means to feed solid material thereto for reduction, a discharge chute extending at one end into said mill and operable to receive ground and also semi-ground material of larger size while tumbling therein, and means movably supporting said discharge chute relative to said mill to effect selective positioning of the inner end thereof relative to said mill to effect selected restrictive discharge of amounts and sizes of material from a selected position within said mill.

31. A grinding mill system comprising a tumbling mill, means to feed solid material thereto for reduction, and material discharge means in said mill having adjustable means forming exit openings which are variable in total area and thereby operable to permit a selective restricted discharge of material of larger size.

32. An autogenous grinding mill system comprising a first tumbling mill, means to feed solid material thereto for reduction to a range of mixed sizes, material discharge means including a first restricting means operable to permit relatively small sizes of material of predetermined maximum size to pass from said mill and a second restricting means operable to permit larger sizes of material of predetermined maximum size capable of serving as a grinding media to be discharged from said mill and said second restricting means being variable to cause selectively different amounts of said larger sizes of material to be discharged, a second tumbling mill, and means to feed desired selective proportions of said relatively large sizes of material to said second mill together with said relatively small sizes to produce a desired grinding condition within said second mill for said material fed thereto.

33. An autogenous grinding mill system comprising a first tumbling mill, means to feed solid material thereto for reduction to a range of mixed sizes, material discharge means including sizing means having openings operable to permit removal of ranges of relatively fine material from the mill and discharge openings substantially larger

than the openings of said sizing means operable to permit discharge of a substantially coarse range of material substantially larger than said relatively fine material and capable of serving as a grinding media and determine the maximum size thereof, a second tumbling mill, means operable to feed desired proportions of said ranges of relatively fine and coarse material to said second mill to produce a desired grinding condition within said mill for said material fed thereto, and means operable to vary the extent of said larger discharge openings to effect discharge of a predetermined proportion of said coarse range of material from said first mill for use in said second mill.

34. An autogenous grinding mill system comprising a first tumbling mill, means to feed solid material thereto for reduction to a range of mixed sizes, material discharge means including sizing means having openings operable to permit removal of ranges of relatively small sizes of material from the mill and discharge openings substantially larger than the openings of said sizing means operable to permit discharge of a substantially coarse range of material substantially larger than said small sizes of material and capable of serving as a grinding media and determine the maximum size thereof, a second tumbling mill, means operable to feed desired portions of said ranges of small sizes and coarse material to said second mill to produce a desired grinding condition within said second mill for said material fed, and closure means positionable over selected extents of said larger discharge openings and at selected positions thereof within the grinding zone of said first mill to effect discharge of a predetermined proportion of said coarse range of material from selected grinding zones of said first mill for use in said second mill.

35. An autogenous grinding mill system comprising a first tumbling mill, means to feed solid material thereto for reduction to a range of mixed sizes, material discharge means including apertured sizing means within said mill operable to remove from the grinding zone of said mill ranges of relatively small material the maximum size of which is controlled by said sizing means, exit means for said mill, segregating means exterior of said mill arranged to receive from said exit material of larger size than said relatively small material and operable to separate from said larger size material a substantially coarse range of predetermined maximum size capable of serving as a grinding media, a second tumbling mill, and means to feed desired proportions of said classified ranges of coarse sizes of products to said second mill together with said relatively fine sizes to produce a desired grinding condition within said second mill for said material fed thereto.

36. A grinding mill system for subjecting a range of sizes of friable material to self-reduction of all sizes and comprising a tumbling mill, adjustable feed means operable to deliver solid friable material to said mill at a desired rate for reduction in size thereby and producing various operating conditions in said mill, a plurality of adjustable control means for said feed means respectively responsive to said different operating conditions of said mill, a control circuit for said mill system, and means in said circuit operable to integrate the functional results of said plurality of adjustable control means to produce a composite resultant operation of said feed means which will produce a desired optimum grinding condition in said mill.

37. A grinding mill system for subjecting a range of sizes of friable material to self-reduction of all sizes and comprising a first tumbling mill, adjustable feed means operable to feed solid friable material to said mill at a desired rate for reduction in size thereof, means to discharge from said mill ranges of relatively fine sizes of material of predetermined maximum size and a range of relatively coarse size material capable of serving as grind-

ing pebble media, a second tumbling mill, and adjustable means to feed said grinding pebble media to said second tumbling mill at a regulated rate operable to grind material within said second mill at an optimum reduction rate while producing various operating conditions in said second mill, a control circuit for said mill system, a plurality of control means for said feed means for said mills connected in said circuit and responsive to said various operating conditions in said second mill, and means in said control circuit operable to integrate the functional results of said plurality of adjustable control means to produce a composite resultant control of said feed means for said mills which will maintain said optimum reduction rate of material in said second mill.

38. A process of grinding solid friable run-of-mine raw material to effect simultaneous self-reduction of all sizes thereof and comprising the steps of subjecting the raw material to autogenous grinding action in a primary mill to reduce the size of the pieces and particles thereof, removing from said mill a desired range of the larger sizes of said pieces not exceeding a predetermined maximum size and capable of serving as friable grinding media, and introducing into a second tumbling mill a selected proportion of said removed pieces at a controlled rate suitable to produce optimum grinding results therein and utilizing said friable pieces fed to said second mill as grinding media for material in said mill to produce autogenously therefrom a desired range of finer sizes of ground product material.

39. A process of grinding solid friable run-of-mine raw material to effect simultaneous self-reduction of all sizes thereof and comprising the steps of subjecting the raw material to autogenous grinding action in a primary mill to reduce the size of the pieces and particles thereof, removing from said mill a desired range of the larger sizes of said pieces not exceeding a predetermined maximum size and capable of serving as friable grinding media, introducing into a second tumbling mill a selected proportion of said removed pieces at a controlled rate suitable to produce optimum grinding results therein and utilizing said friable pieces fed to said second mill as grinding media for material in said mill to produce autogenously therefrom a desired range of finer sizes of ground product material, and returning the non-selected range of larger sizes of material to the primary mill for further reduction in size.

40. A process of grinding solid friable run-of-mine raw material to effect simultaneous self reduction of all sizes thereof comprising the steps of subjecting the raw material to autogenous grinding action in a primary mill to reduce the size of the pieces and particles thereof, removing from said mill a desired range of relatively coarse sizes of said pieces capable of serving as friable grinding media, introducing a desired amount of said removed relatively coarse friable pieces into a second tumbling mill at a controlled rate and utilizing said pieces in said second mill as friable grinding media for material in said mill to produce a desired range of ground product material, grinding the undesired relatively coarse friable material in a third mill to reduce the size thereof to a desired range of smaller sizes, and feeding the latter range of smaller size material to said second tumbling mill for further reduction to produce a range of relatively fine product size.

41. A process of grinding solid friable run-of-mine raw material of various sizes autogenously to reduce the size thereof simultaneously to ranges of finer sizes and comprising the steps of subjecting the raw material to primary tumbling in a mill to reduce the size of the pieces and particles of said raw material, discharging the products of said mill and segregating from said discharged products the finer size ranges of predetermined maximum size and a desired range of relatively coarse sizes of said pieces of predetermined maximum size capable of serving

as friable grinding media, feeding said finer ranges of said discharged products to a second tumbling mill, and also introducing into said second tumbling mill a controlled amount of said relatively coarse range of friable material sufficient to produce a desired optimum grinding effect in said second mill further to reduce the size of the finer size ranges of products fed thereto from said primary mill and thereby produce a controlled range of desired fine products.

42. A process of grinding friable run-of-mine material of various sizes to reduce all sizes thereof simultaneously to a range of fine sizes and comprising the steps of subjecting the raw material to tumbling in a primary mill to reduce the size of the material autogenously, removing from said mill a desired range of relatively coarse sizes of said pieces capable of serving as friable grinding media, removing smaller sizes of the products from said primary mill and subjecting said smaller sizes to tumbling and grinding in a second mill by a controlled amount of said relatively coarse pieces of friable material to produce at optimum efficiency a desired range of fine particle products, and controlling the amount of relatively coarse friable material fed to said second mill in accordance with an operating condition within said second mill.

43. A process of grinding friable run-of-mine raw material of various sizes to reduce all sizes thereof simultaneously to a desired range of fine products and comprising the steps of subjecting the raw material to grinding within a primary tumbling mill to reduce the size of said material to various sizes including a coarse range of sizes suitable for use as a friable grinding media and finer sizes, removing the ground products from said mill, feeding the finer sizes of said ground products and a controlled proportion of the said coarse size pieces to a second tumbling mill for use as grinding media for the smaller sizes of material fed to said second tumbling mill, and controlling the proportion of coarse size pieces fed to said second mill in accordance with the sound of grinding conditions within said second mill.

44. A process of grinding friable run-of-mine raw material of various sizes to a desired range of fine products comprising the steps of subjecting said raw material to tumbling in a primary mill to reduce said material autogenously to various sizes including a range of coarse friable pieces capable of serving as grinding media and finer sizes, removing the ground products from said primary mill, feeding the finer sizes and a controlled proportion of said coarse range of pieces of material to a second tumbling mill and utilizing said coarse friable pieces therein to produce a controlled desired range of fine particle products, and controlling the proportion of said coarse pieces of material fed to said second mill in accordance with the power consumed to drive said second mill.

45. A process of grinding friable run-of-mine raw material of various sizes to a desired range of fine products comprising the steps of subjecting said raw material to tumbling in a primary mill to reduce said material autogenously to various sizes including a range of coarse friable pieces capable of serving as grinding media and finer sizes, removing said ground material from said primary mill, feeding the finer sizes and a controlled proportion of said coarse range of pieces to a second tumbling mill and utilizing said coarse friable pieces therein to produce a controlled desired range of fine particle products, and controlling the proportion of coarse pieces of material fed to said second mill in accordance with the amount of oversize product material produced by said second mill.

46. A process of grinding friable raw solid material of various sizes to reduce the size thereof to a range of fine sizes comprising the steps of subjecting the material to autogenous grinding in a primary mill to reduce the size of said raw material, retaining within the mill all material in excess of a predetermined maximum size, removing

from said mill a predetermined maximum size of relatively fine ground product and a relatively coarse size of friable product of predetermined maximum size selected from a desired grinding zone of said primary mill and suitable for use as grinding media, feeding said removed sizes of material to a second tumbling mill for further reduction of said relatively fine ground product by said coarse size of product while using a controlled proportion of the relatively coarse product which is smaller than the proportion of relatively fine ground product, and tumbling the said controlled proportions of relatively fine and coarse material in said mill to grind the fine material fed to said secondary mill to a desired range of finer sized product.

47. A process of grinding friable run-of-mine material to reduce the size thereof to a desired range of fine sizes, said process comprising the steps of subjecting the raw material to autogenous grinding by tumbling in a primary autogenous grinding mill to reduce the size thereof, selecting a grinding zone thereof for removal of a range of comminuted products from said mill comprising a desired relatively large proportion of ground and partially ground relatively fine products and a smaller proportion of relatively coarse size friable pieces suitable for use as grinding media for said relatively fine products, segregating said relatively coarse and fine size ranges, and feeding said removed relatively fine products to a second tumbling mill and also feeding said coarse size pieces to said second tumbling mill at a controlled rate to operate therein as grinding media for the relatively fine products, thereby producing desired controlled grinding conditions within said second mill to produce a desired range of fine products.

48. A process of grinding raw solid friable material of various sizes to produce a range of fine products comprising the steps of subjecting such raw material to tumbling in a primary mill to reduce the size of said material to a mixture including a desired range of fine sizes, subjecting the products of said mill to sizing and removing from said mill a range of fine products of maximum size controlled by said sizing, selecting a desired range of relatively coarse pieces of material from said primary mill capable of serving as friable grinding media for said fine products and removing the same from said mill through discharge openings therein, feeding to a second tumbling mill said fine products and a desired smaller proportion of said coarse friable pieces at a controlled rate and utilizing said coarse pieces therein as grinding media to reduce said fine sizes of material to a controlled desired range of finer

particle products, and controlling the proportion of said coarse pieces to be fed to said second mill by selecting the size and total area of discharging openings in said primary mill through which said coarse pieces of material exit therefrom.

49. A process for reducing the size of solid friable material by autogenous tumbling action within a mill capable of developing a number of different operating conditions and comprising the steps of feeding material to said mill at a rate to produce optimum autogenous grinding conditions within said mill for the material fed thereto, said rate being determined by integrating the results of said different operating conditions of said mill as said material is ground autogenously thereby to produce a collective resultant to effect any adjustment of the feed rate which may be necessary to achieve said optimum rate of feed for said mill.

50. A grinding mill mounted for rotation to effect reduction in size of friable material autogenously by tumbling, said mill having a diameter appreciably greater than the length thereof and being provided with means operable to elevate and mix laterally the mass of material undergoing treatment, means to feed solid material to said mill, and material discharge means extending laterally into the grinding zone of the mill and having receiving means positioned within said grinding zone of the mill to intercept and receive a portion of the mixture of ground material of various sizes while the same is tumbling within the mill, said means being operable to restrict the discharge to a predetermined maximum size, whereby the oversize material remains in the mill for further reduction in size.

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