This invention pertains to a process and mill for grinding, autogenously and under wet or dry conditions, solid friable materials of varying degrees of hardness, such as ores, non-metallic minerals, coal and the like, to reduce the size thereof from the run-of-the-mine condition of the raw material to a desired range of fine, intermediate or coarse particle sizes. The term “autogenous” as used herein is considered to be a generic term and covers the entire range and class of materials referred to as autogenous. Such material, in the raw or so-called run-of-the-mine state or condition, includes coarse lumps, intermediate and relatively fine sizes and may also have undergone some pre-crushing treatment. By grinding this material autogenously, said material is used as its own grinding medium although, particularly in regard to certain types of materials, it sometimes is found advisable to add a limited amount of auxiliary grinding means, such as a few balls, rods, or other aids to the grinding zone of the mill. The general term “autogenous,” as used here, includes the use of such aids when employed.

Details of autogenous grinding are set forth to a substantial extent in Patent No. 2,381,351, dated August 7, 1945; and in U.S. Patent Nos. 3,078,049 and 3,078,050, issued February 19, 1963, all in the name of Harlowe Harding. Thus, the present description of the invention relative to autogenous grinding will include primarily only such details that conveniently will afford an understanding of such autogenous grinding process and mill characteristics to afford a basis of comparison and contrast for a complete understanding of the present invention and particularly the improvements afforded by said invention as described and claimed in said aforementioned patents.

Autogenous grinding and certain details and advantages thereof have been known and appreciated for a substantial period of time. A number of attempts have been made to utilize the procedure advantageously and, at least prior to the development of the inventions covered by the above-mentioned references, many of such attempts met with failure or at least such an inefficient result was evident that the same could not be considered successful from the standpoint of being economically desirable and advantageous. The method and various designs of apparatus comprising the subject matter of said aforementioned last two patents afford certain improvements over said prior attempts and mark a distinct step forward in this type of comminution of solid friable material. As the procedures have been continuously utilized, however, it now has been discovered that there are other procedural steps and additional mill structures which comprise substantial improvements over those afforded by the inventions covered by said aforementioned last two patents.

Concerning such improvements, it has been found that one of the principal reasons for lack of success of a number of prior attempts to grind friable material autogenously heretofore has been due to the nature of the mill structures, or the lack of appreciation of the need to control the consistency of the mixtures of various size ranges of material within the grinding zone and it primarily in this area that the new discoveries comprising the present invention have been developed so as to render the autogenous grinding of friable material even more advantageous, efficient, and economical, than the results possible from the process and mill structure comprising the subject matter of said aforementioned last two patents.

It now has been discovered that a very effective means of improving the operation of an autogenous grinding milling system is to condition a portion of the size ranges at or near the discharge end of the mill so that a size dimension of the material, which usually is considerably greater than that removed by procedures used heretofore, is withdrawn from the mill in mixed condition with the fine sizes present. Then, after separating the desired fine product from said material of greater size which is a so-called intermediate oversize range, said oversize material is returned to the mill adjacent the discharge end but to a generally different zone than that from which it was removed from the mill. This operation is effective in reducing the sliding action of the mass at the mill end adjacent the discharge end and causes a higher lift of all sizes in this portion of the mill with more effective grinding action resulting therefrom. A more efficient and faster removal of the fines as produced in the mill is also made possible.

The principal object of the present invention is to obviate the difficulties of prior procedures and especially to provide an efficient and economical autogenous grinding process and a number of embodiments of mill systems capable of achieving the process while grinding the material either in wet or dry condition, by providing a well mixed and efficiently balanced load of so-called run-of-the-mine material throughout the entire charge within the grinding zone of the mill. In particular, a well mixed load is maintained adjacent the discharge end of the mill, whereby certain ranges of sizes of ground and partially ground products are removed continuously and quickly from such discharge end of the grinding zone of the mill and subjected to a rotating sizing device attached to the mill and rotatable therewith. This device also includes means for returning segregated intermediate oversize material back to the discharge area of the grinding zone for further processing, whereby such material is returned to an area where it is immediately and thoroughly mixed with the load being processed and in which a desired coarse fraction in the load efficiently reduces such returned material to desired fine product sizes prior to said material next being discharged from the mill. The return of said oversize adjacent the discharge end also tends to reduce over-grinding which can result if the return were at the feed end.

Another object of the invention is to employ within the mill the size-limiting discharge means through which a mixture of desired fine product sizes and coarser intermediate sizes of material are discharged from the mill, while rotating, and are received in discharge opening means extending from the grinding zone of the mill, past the end wall of the mill, for delivery to additional sizing means, which is directly carried by and is rotatable with the mill so as to require no additional driving mechanism or power. Said sizing means segregates the coarser intermediate oversize material from desired ranges of fine product sizes, the latter being discharged from the mill while the coarser intermediate sizes simultaneously are returned directly and axially, in a direction reverse to that of the discharge movement of the mill, past the initial size-limiting means, and into the grinding zone of the mill for further processing and rapid and thorough mixing with the mixture of run-of-the-mine material being processed by tumbling in the grinding zone. The return of the oversize adjacent the discharge end of the mill, being to a different zone than from which it was withdrawn from the mill,
insures a more thorough mixing of the sizes undergoing autogenous reduction.

A further object of the invention is to provide in at least certain embodiments of the invention a limited number of discharge openings of adequate size to permit relatively large size pieces, usually referred to as pebbles, which are capable of serving effectively as grinding media, to be discharged through said size-limiting discharge means and said additional sizing means permitting the separation of such larger pebbles from the intermediate oversize material and the desired ranges of fine products. The invention also contemplates the provision of adjustable control means to regulate the quantity of said pebbles being discharged through the grinding zone of the mill or for use in additional supplementary mills, as desired.

Still another object of the invention is to provide means for adjustable regulating the quantity of intermediate oversize material to be returned to the grinding zone of the mill from said additional sizing means to control the size of product discharged.

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 a vertical longitudinal sectional view showing one exemplary embodiment of a rotatable autogenous grinding mill having combined therewith one form of size-limiting discharge means and one embodiment of additional product sizing means both carried directly by the mill adjacent the discharge end thereof in accordance with the invention.

FIG. 2 is a fragmentary vertical sectional view of another embodiment of autogenous grinding mill, the size-limiting discharge means of which is different from the arrangement shown in the mill embodiment illustrated in FIG. 1.

FIG. 3 is a vertical transverse sectional view of the discharge end of the mill shown in FIG. 1 as seen on the line 3—3 of FIG. 1.

FIG. 4 is a fragmentary vertical sectional view showing the discharge end of an autogenous grinding mill to which a different embodiment of additional product sizing means is connected for rotation therewith.

FIG. 5 is a fragmentary vertical sectional elevation of the discharge end of an autogenous grinding mill to which still another embodiment of additional product sizing means is connected to the discharge end of the mill.

FIG. 6 is a vertical sectional view of the arrangement shown in FIG. 5, taken on the line 6—6 of FIG. 5.

FIG. 7 is a fragmentary vertical sectional view of the discharge end of an autogenous grinding mill to which still another type of additional product sizing means is connected, the discharge end of the same being associated with an exemplary settling chamber shown in vertical sectional elevation.

FIG. 8 is a fragmentary vertical sectional view of still another embodiment of additional product sizing means connected to the discharge end of an autogenous grinding mill.

FIG. 9 is a vertical sectional view of the arrangement shown in FIG. 8 as seen on the line 9—9 of FIG. 8.

FIG. 10 is a fragmentary vertical sectional view of the discharge end of an autogenous grinding mill to which another embodiment of additional product sizing means is connected, the same being of the type primarily adapted for wet grinding and having externally operable adjustable means thereon.

FIG. 11 is an end view of the product sizing means shown in FIG. 10, part of the exterior housing of said product sizing means being broken away so as to better illustrate details of the embodiment.

FIG. 12 is a fragmentary vertical sectional view of an autogenous grinding mill having a different type of size-limiting discharge means therein from the other embodiments and a still further embodiment of product sizing means connected to the discharge end of the mill.

FIG. 13 is a fragmentarily illustrated vertical elevation of the outer end of the additional product sizing means shown in FIG. 12, part of the structure thereof being shown in vertical elevation to illustrate details.

FIG. 14 is a fragmentary vertical elevation of an autogenous grinding mill having a still different type of size-limiting discharge means from that shown in the preceding embodiments and illustrated in association with another embodiment of additional product sizing means.

FIG. 15 is a vertical elevation showing part of the outer end of the additional product sizing means of the arrangement shown in FIG. 14, a portion of the structure also being shown in vertical section to illustrate details.

FIG. 16 is an end view of the size-limiting discharge means of the arrangement shown in FIG. 14 as seen on the line 16—16 of said figure.

To afford an understanding of the operation of an autogenous grinding mill of the type to which the present invention pertains, there is illustrated in FIG. 1, an exemplary embodiment of autogenous grinding mill highly suitable for having the novel aspects of the present invention associated therewith.

For purposes of achieving lifting action of maximum efficiency in order that the body of material being treated will be subjected to maximum effective impact by the tumbling material and especially the larger pieces thereof, it is preferred in accordance with the principles of the present invention that the length of the interior chamber of the mill be considerably less than the diameter of said interior chamber. The interior chamber preferably is that which is defined by the inner surfaces of the lining plates of the mill and to facilitate an understanding of this, it will be seen that in FIG. 1, the exemplary general diameter of said chamber is indicated D and the exemplary general length thereof is indicated L together with conventional dimension lines.

The autogenous grinding mill 18 has an outer shell comprising a peripheral member 22, to the opposite ends of which entrance end shell or wall member 14 and discharge end shell member 16 respectively are connected. In this exemplary illustration of grinding mill, said end members are conical but it is to be understood that the invention is not to be restricted to mills having conical end members since the invention may also be adapted to cylindrical mills having substantially flat or parallel opposite ends.

Connected coaxially with central openings in the end members 14 and 16 are hollow cylindrical trunnions or journals 18 and 20 which, it will be understood, are rotatably mounted within appropriate bearings carried by pillars, standards, or the like, in accordance with conventional practice, the same not being shown for purposes of simplifying the illustration. The trunnions 18 comprises the inlet or entrance to the mill 18 and a feed chute 22 extends into said trunnion for purposes of feeding run-of-the-mine material into the interior of the mill 10. An entrance cone 24 is formed within the trunnion to guide the material readily into the interior of the mill.

Coaxial with the trunnion 18 and projecting inward therefrom is an annular conical abrasion-resistant ring 26 which provides a circumferential bulge projecting axially into the mill 10 for purposes to be described. Such ring preferably is segmental and the segments are held by bolts 28, whereby the segments may be replaced for any desired purpose, including that of substituting segments of a different size.

The inner face of the end shell 14 is covered by a plurality of segmental sections 30 of abrasion-resistant liner members which are secured by conventional means such as bolts, not shown. The segmental liner sections 30 are provided with radial wedge or lifter bars 36 or liner plates with lifters cast thereon, the same preferably being secured
to the shell by conventional bolts, not shown, it being understood that these bars may be replaced by bars of a different height to suit the most effective grinding of specific materials being handled by the mill, as occasion arises. Details of this are set forth in said aforesaid Patent No. 3,078,049, and to which attention is directed for further information.

The hollow trunnion 20 comprises part of the exit means of the mill. Associated with the discharge end shell 16 of the mill, and spaced inwardly therefrom is size-limiting discharge means 40 which, in the instant illustration, comprises a segmental grate which comprises, essentially, a perforated partition permitting the ready passage of material through and, in effect, is a size-limiting means. The openings in the grate are of a predetermined maximum size to control the maximum size of material to be discharged therethrough. Adjacent the smaller periphery of the grate 40 is another circular conical ring 42 which is for purposes to be described, the same bulging toward the ring 26 adjacent the entrance trunnion 18.

Contiguous with the inner periphery of conical ring 42 is an in-conical exit member 44 having a central opening 46 therein.

Radial lifter bars 60 are disposed preferably between the segmental sections of the grate 40, the same preferably being detachably connected against said grate sections by any suitable means such as conventional bolts, not shown, suitable for such purpose. The lifter bars may be replaced by other bars or plates with lifters thereon of either less or greater height, as the type and condition of the material being ground requires. Further, the grate sections 40 are spaced from the inner surface of the discharge end shell or wall members 16 to provide an annular chamber 68, the outer periphery of which is defined by another annular ring 66 which has an additional purpose to be described hereinafter. Said ring is secured to the shell of the mill by any suitable bolt means or the like, not shown. Liner sections 74 extend radially outward from the annular ring 66 and are secured by radial lifter bars 72 detachably to the end shell member 16 by suitable bolt means or the like, not shown.

Fixed to the peripheral member 12 of the shell of the mill are central liner sections 80 which slope inwardly toward the center thereof, from opposite edges, as clearly shown in FIG. 1. Said liner sections are affixed to the peripheral member 12 by detachably secured, transverse or extending lifter bars 82 which preferably have straight intermost ends, said bars being connected to the shell by any suitable bolt means or the like, not shown.

Oppositely sloping liner sections 86, which have curved outer portions that merge with the adjacent edges of liner sections 30, are secured by complementarily shaped lifter bars 90, the inner edges of which are straight and comprise continuations of the inner edge of lifter bars 82, as clearly shown in FIG. 1. The lifter bars 90 are secured to the shell by any suitable bolt means or the like, not shown. If desired, lifter blocks or members 88 may be disposed between the liner sections 86 and the shell.

Radial plates or lifter partitions 94 are disposed between the discharge trunnion 20 and the inner surfaces of conical ring 42 and also extend radially outward into annular chamber 68, as clearly shown in FIG. 1, to insure lifting of the material discharged into chamber 66 from the lower part of the rotary path of the mill to the upper part. Said partitions 94 also are shown in FIG. 3 to advantage.

In the preferred operation of the mill 10 for autogenous grinding as shown in FIG. 1, run-of-the-mine material of the type hereinbefore described is introduced through feed chute 22 at a rate in accordance with the grinding rate of the mill. As the material is reduced in size, that which is reduced sufficiently fine to pass through the openings of the screen or size-limiting discharge means, such as grate 40, is discharged therethrough into the annular chamber 68. As the mill revolves, the material within said space which is above the axis of the mill will fall onto the conical interior of exit member 44 and slide down the same, to be discharged through the annular opening 56. Lifting of the material within the chamber 68 is accomplished by the radial lifter partitions 94 and, if desired, said plates may be curved so as more closely to resemble spiral scoops.

As the run-of-the-mine or slag material is tumbled within the mill 10, all size ranges thereof simultaneously are gradually reduced in size, with the end result that a desired range of fine sizes of material is produced. The largest size of the material thus produced however, is determined by the size of the openings in the size-limiting discharge or grate means 40 and, in accordance with the principles of the present invention, such openings permit the exiting of not only a range of desired fine sizes of material but also larger particles which, for convenience, are referred to as intermediate oversize material in that the particles thereof are larger than normally is desired in the range of fine products sought to be produced by the mill. A mixture of such range of desired fine sizes and a range of coarser, intermediate oversize material is discharged through the size-limiting discharge means 40 and the same passes into the exit trunnion 20.

As the material is tumbled within the mill 10, it is elevated on the rising side of the mill during rotation, whereby substantial impact of especially larger pieces or pebbles is against a substantially momentarily stationary portion of the bed of material in the lower portion of the mill. This action not only comminutes the finer sizes of material but also the intermediate sizes, as well as the said coarser particles or pebbles likewise being gradually reduced in size.

The radial lifter bars 36 at one end of the mill cooperate with the radial lifter bars 60 and 76 on the opposite end of the mill. In view of the fact that the length or axial dimension of the interior of the mill is relatively short in proportion to the diameter thereof, a substantial quantity of coarse material within the mixture being treated will be elevated to a point higher than the same ordinarily would reach if relatively high transverse lifter bars 82 or 102 only were used.

By using relatively low transverse lifter bars 82 in conjunction with the radial lifter bars 60 or 76 or end shell members of the mill, as illustrated in FIG. 1, particularly where the height of the radial lifter bars is selected in accordance with the overall composition of the material, substantially firm but temporary lodgement of the material takes place between the transverse lifter bars 82. Moreover, there is a tendency especially for the coarser particles of material, when falling or rolling down the sloping mass within the mill, to become momentarily held on the radial lifter bars so that they are elevated to a higher position within the mill than heretofore was possible, even though some of the finer material may fall from between the coarser material. Finally however, the coarser material is freed by gravity from between the radial lifter bars so that it falls and effects impact upon the sloping mass of the bed of material within the mill as well as which is rolling down the upper surface thereof, to effect reduction only of itself but of the material which it contacts. Of even greater importance is the fact that such operation maintains a thorough intermixing action of all sizes of material in an axial direction within the mill, a condition that is highly important to maintain grinding efficiency in an autogenous grinding mill as opposed to the desired classification for best operation of a conventional ball or pebble mill.

It also will be noted that the transverse lifter bars 82 and the additional lifter bars 90, which actually form continuations of the bars 82, have straight upper edge surfaces, while the inner surfaces of the liner sections 80.
and oppositely sloping liner sections 86, adjoining opposite edges of the sections 89, slope inward from the side walls of the mill, toward each other, and radially outward toward the center of the mill 10, as clearly shown in FIG. 1. Said sloping surfaces of the liner sections function to move material from adjacent the end walls of the mill toward the center thereof, thus producing transverse movement of the material. In conjunction with this beneficial result however, the straight upper surfaces of the lifter bars afford greater lifting capacity at the center than if the upper surfaces were not straight for example but, rather, were parallel to the sloping surfaces of the liner sections.

The movement of the material, and especially the larger pieces thereof, by rolling, from adjacent the ends of the mill toward the center thereof, due to the sloping nature of the liner sections, produces faster rolling movement of such larger pieces than the smaller sizes. Thus, such larger pieces will become momentarily trapped between the transverse bars or bars 22 and be covered by the oncoming mass of material, whereby said pieces will not be released for dropping or rolling until they have been elevated to a relatively high position within the mill so as to be free either to drop on to the mass or roll down the same. Some of these pieces will roll more or less centrally, while other particles will tend to roll toward the feed or discharge end of the mill because of the tendency of the mass of the material to assume an angle of repose while being constantly moved by the tumbling action produced by the rotation of the mill. Such rolling displaces the sides of the mass will take place from the theoretical crest of the material within the center of the mill.

At least some of the larger pieces will become momentarily entrapped between the radial bars or ribs along the ends of the mill during such rolling and falling thereof, whereby a thorough mixing of the large, medium and small segments take place. Further, the sloping surface, of the annular ring 42, deflects falling material toward the center of the mill and away from the grate or size-limiting discharge means 48, thereby protecting the surface thereof from direct impact by such falling material. The action also causes returning oversize material to be reintroduced in a different zone than that from which the same size fraction was withdrawn from the mill. This is particularly advantageous in maintaining a good grinding effect. The radial bars 40 which extend across the grate 49 likewise aid in protecting said grate from abrasion action in addition to aiding in elevation and mixing of the material in the zone adjacent to the submerged points of discharge from the mill, namely, through the grate 40.

An action occurs that is far superior to that where other products fines and some oversize are withdrawn by air while in suspension. A much more positive control of particle size and size range is obtained in addition to improved autogenous grinding action within the mill itself.

Particularly to illustrate the mixing, rolling, impacting and deflecting action, especially of the large size particles or pebbles of material within the mill, FIG. 1 shows an exemplary illustration of such action of typical pieces, it being noted that the visualized path of said pieces may be followed by noting the arrows showing directions of movement relative to identically numbered pieces. While this is somewhat imaginary and visualized illustration it nevertheless is believed that such or similar movement takes place within the mill, judging from the results produced by the mill and observation of the load when the mill is examined when stopped under normal grinding conditions and observing the size distribution within the mill. It especially is noted that a transverse and mixing movement of the material, in an axial direction within the mill, occurs to a marked degree. It is also believed this aspect of the operation, together with others as are illustrated in exemplary manner, produces highly desirable results particularly when additional sizing means are employed of which a number of embodiments are illustrated in the drawing and details of which are now to be described.

Considering the size-limiting discharge means or grate 49 as one sizing device, the present invention also comprises an additional sizing device 98 which is interconnected to the discharge transition 20 of the mill end and is rotatable therewith. The embodiment of additional sizing device 98 shown in FIG. 1 comprises preferably a slightly conical shell 169 having a radially extending flange 162 on the inner end thereof, the periphery of which defines the annular opening 96 through which is interposed a desired range of fine sizes of material and intermediate oversize material discharge into the shell 160 and in which, due to the constricting effect of flange 162, a shallow pool is formed.

Fixed to the outer end of the shell 160 is a substantially cylindrical screen 104 which is rotatable with the shell 160 and terminates in an annular flange 105 which extends radially toward the axis of the mill. Due to the sloping nature of the shell 160, which is downward toward the flange 162, the coarser or intermediate oversize material, by natural displacement, gravitates toward the flange 162 as the mill rotates. The mill is of the wet grinding type, liquid also collects therein. The finer particles of material pass through the screen 104.

The mesh or size of the screen openings 104 is such as to permit the passage therethrough of a desired size of fine products which are discharged from the mill 10, for example. The flange 105 will prevent accidental discharge of any of the accumulated oversize material sliding or rolling on the additional sizing means 98 and all of such material that can not pass through the screen 104 will gradually migrate to the inner end of the shell 160.

This material comprises intermediate oversize material which requires further reduction within the mill and, preferably, in a manner and in a zone to achieve rapid disintegration and removal without over-reduction thereof which would more likely occur were this oversize conveyed back to the feed end and reenter the mill through screen 112.

For purposes of returning such intermediate oversize material to the grinding zone of the mill 10, an exemplary simple but effective lifting and directing member 108 is provided, the same comprising a hollow tube having a right-angled exit 110 which is coaxial with the opening 46 in the exit member 44 of the mill. The member 108 extends radially from the axis of the mill toward the shell 100 and the end of the member adjacent shell 100 is provided with an inlet opening 112 of suitable size to receive sequentially, desired amounts of the oversize material. If, under any grinding conditions, adjustment of the amount received is found necessary, any suitable regulating means such as an adjustable eldable gate and appropriate locking means could be used to afford such adjustment.

Referring to FIG. 3, it will be seen that when the mill is rotating in the direction of the arrow at the upper part of the figure, the entrance opening 112 in member 108 is so positioned that such oversize material will be scooped up and drop into the outer end of member 108 and, continued rotation of the mill will cause the outer end of member 108 to rise relative to the axis of the mill and, when it has risen sufficiently, gravity will cause the material to move down the member 108 and be discharged through exit 119. Such material will fall, for example, upon the sloping exit member 44 and be deflected and returned axially, a substantial distance from the grinding zone of the mill 10, and at a different point from where it was discharged from the mill through grate 40. Hence, solely by the employment of the rotation of the mill and gravity, a highly effective sizing and improved grinding action takes place. The character of product produced is closely controlled and the grinding action within the mill is improved.
Referring to FIG. 2, which is a different embodiment of autogeneous mill from that shown in FIG. 1, it will be seen that only a fragmentary portion is shown but sufficient to be compared with the structure of FIG. 1. The mill 10 shown in FIG. 2 has a cylindrical shell comprising substantially flat, parallel opposite ends 114, of which only the discharge end is shown but it will be understood that the entrance end is similarly flat. A peripheral member 116, similar to member 12 of FIG. 1, is connected to the peripheral edges of the end members 114. Sloping liner sections 118 are employed to facilitate axial movement of the various sizes of material while being tumbled within the mill 10, which rotates upon bearings 120, only a fragmentary portion of one of which is shown.

From a comparison of the shells shown in FIGS. 1 and 2 respectively, it will be seen that the annular grate 40 of FIG. 1 extends from the conical ring 42, in a radial direction, a distance substantially less than the radial dimension of the grate 42 of the mill embodiment shown in FIG. 2. The smaller sized grate of FIG. 1 is highly effective especially when the mill is loaded to a substantial extent. Discharge of a mixture of a desired range of fine sizes and larger intermediate oversize material will occur in sufficient quantity through the grate 40 of FIG. 1 to render the mill efficient in operation. However, particularly for purposes of permitting removal of said sizes of comminuted material from the mill adjacent the location of maximum impact of the falling pieces or pebbles of material against the substantially momentarily stationary bed of material within the mill, as well as permitting effective removal of the aforementioned sizes of material from the mill when it is much more lightly loaded than is contemplated while using the mill of the type shown in FIG. 1, extending the grate 122 in FIG. 2 substantially to the inner periphery of the mill is advantageous. In addition, such greater area of grate surface affords a corresponding greater removal capability for the described size ranges of material which it is desired to remove from the grinding zone of the mill for passage into the annular chamber 124 and from there into the shell 126 of additional sizing means similar to means 93 of the embodiment shown in FIG. 1, for example. While this embodiment shown in FIG. 2 has several essential features to cause the necessary lateral mixing action needed for proper autogenous mill operation, namely, laterally projecting monical rings at feed and discharge, large diameter to length ratio, and the liner contoured arrangement 118, particularly efficient at this case, it is not as efficient as the embodiment of FIG. 1 with its tapered end 119 also included. Hence, the embodiment of FIG. 1 or that having the conical shell ends, with full diameter grate as shown in FIG. 12, is preferred.

Referring to FIG. 4, still another embodiment of additional sizing means 128 is shown from that of FIGS. 1 through 3, for example. It is to be understood that said embodiment of sizing means 128 may be connected to any suitable type of autogenous grinding mill and particularly to the two types respectively shown in FIGS. 1 and 2. For purposes of simplifying the illustration of the embodiment shown in FIG. 4, however, it will be assumed that the mill 10 of FIG. 1 will be utilized as a fragmentary portion of the same is illustrated, corresponding reference characters for appropriate elements of the mill 10 being used in FIG. 4 as in FIG. 1.

The additional sizing means 128 in FIG. 4 comprises an inner shell 130 which is slightly conical and closely resembles the shell 100 of the embodiment shown in FIGS. 1 and 3. The larger end of the shell 130 is connected to the interior of trunnion 20 and has an inner radial flange 132 of suitable height fixed thereto. Fixed to and coaxial with the outer end of shell 130 is a material sizing member specifically illustrated as a bar-type trommel 134, for example. The spaces between the bars of the trommel 134 preferably are uniform and of such transverse dimension between the bars as to permit the passage therethrough of a desired range of relatively coarse sizes of material, the maximum of which, for example, can be intermediate between that of the oversize material which is capable of passing through the grate 40, but not capable of passing through the trommel 134. The trommel, at its outer end, also is provided with an annular, radial flange 136 to prevent escape of the coarser, intermediate oversize material from the trommel and thereby insure that the same gradually will be moved, incident to the rotation of the mill, to the larger end of the shell 136, adjacent the flange 132.

Surrounding and coaxial with the shell 130 and trommel 134 is an outer cylindrical shell 138 which, at its inner end, is provided with an annular restricting flange 140 which is connected at its inner end to the trunnion 20 for rotation therewith. The outer end of the outer shell 138 is connected to a cylindrical sizing screen 142, the openings of which are smaller than the spaces between the bars of trommel 134, whereby the screen 142 is capable of separating two relatively fine ranges of material from each other, the finer of which, for example, may comprise a desired range of fine finished product material. Such finer range of sizes of finished product, for example, passes through the screen 142, to a suitable collecting means, not shown, while the relatively coarser but nevertheless relatively fine range of material, that will not pass the screen 142, is retained within the screen and escape is prevented by an outer annular flange 144. However, constant rotation of the screen 142 and shell 138 by the mill causes gradual axial movement of said coarser range of fine sizes of material within screen 142 toward the inner flange 146.

Movement axially of the coarser size ranges is facilitated by the spiral blades 146, or any other suitable means, and in order to enhance the movement of the material and tend to level out the thickness thereof, the outermost convolution of the spiral blade 146 may be spaced at its periphery from the screen 142, as indicated at 148, while the innermost portion or convolution of the blade 146 is connected to the inner surface of outer shell 138. If the operation is wet, then the shell 138 and the portion of the spiral blade 146 act as a pool with liquid that aids in movement of the oversize therein by the same being lubricated by the liquid. Thus, some of the material in the outer portion of screen 142 may pass in a generally axial direction through the space 148 for movement toward the restricting flange 140.

Suitable means for directing the several different size ranges of material, respectively accumulated within the shell 130 and outer cylindrical shell 138, are provided in the exemplary nature of a tube 159 disposed coaxially within the shell 130 and suitably supported therein by radial hollow columns 152 and 154 which, at their inner ends are connected to and communicate with the tube 159, while at their outer ends, the column 152 extends to the interior of outer shell 138 and column 154 extends to the interior of shell 136. Said columns respectively have inlet openings 156 and 158 in the sides of said columns which will receive material by gravity incident to rotating of the shell, as in regard to the opening 112 of directing member 100 of the embodiment shown in FIGS. 1 and 3. As indicated relative to the inlet opening 112 in FIG. 1, if a variation in the amount of material received by column 154 through the opening 153 is desired, such amount may be varied by any suitable means such as a slidable adjustable gate secured by any appropriate means relative to opening 158.

Operation of the columns 153 and 154 during the rotation of the additional sizing means 128 will result in sequential deposition of amounts of material, taken successively during such rotative movements respectively from the intermediate oversize material within shell 130 and the relatively finer oversize material accumulated within the outer shell 138. By such arrangement, a more selective segregating and return of oversize material is possible
with this embodiment. It also has the advantage of reducing materially the wear on the fines screen 142. In other respects, the action in returning the combined oversize components back to the mill is similar to that described for the embodiment shown in FIG. 1.

In FIGS. 5 and 6, there is illustrated another embodiment of the additional sizing means 160 which has several characteristics similar to the sizing means 96 shown in FIGS. 1 and 3. Such additional embodiment is illustrated as being connected to a fragmentarily illustrated portion of the mill 10, as in regard to the embodiment shown in FIG. 4, but neither of such illustrations are to be regarded as restrictive for use with this specific type of mill in that such additional sizing means may be utilized with other types of autogenous grinding mills than those illustrated for exemplary purposes herein.

Preferably in regard to the mill 10 shown in the embodiment illustrated in FIGS. 5 and 6 however, radial partitions or lifters 162 are provided, within the annular space 68 between exit end wall 16 and grate 40.

The discharge ends of the segmental spaces 68 between the partitions 162 communicate directly with one end of the downwardly and outwardly sloping tube-like passage members 164 which are shown in side elevation in FIG. 5 and in end view in FIG. 6. For convenience and durability, said tube-like passage members 164 may comprise castings made from abrasion-resistant material and the same are suitably connected in an appropriate manner to the exit trunnion 20 for example. There are spaces 166 between the members 164 to permit the return therethrough of oversize material as described hereinafter.

Secured within the exit trunnion 20 is a cylindrical shell or tube member 170 which extends outward from ring 42 and has openings coinciding with the ends of passage member 164 which communicate with annular chamber 68. Shell 170 receives the material discharged through the outlet ends of passage members 164 and to cooperate with the directing effect of the downward and outward sloping passage member 164, a deflecting cone 172, provided preferably with circumferentially spaced and radially extending ribs 174, is mounted adjacent the discharge ends of the passage member 164 as best shown in FIG. 5.

Connected to the outer end of shell 170 for rotation therewith is a preferably cylindrical and coaxial sizing device comprising a screen 176 of desired aperture or mesh size operable to pass therethrough the largest desired sizes of a range of fine sized product material to re-enter the outer end 178 of the screen having an annular and radial restricting flange 178 therein. The sloping nature of the passage member 164, in cooperation particularly with the cone 172, aids in directing discharge of the mixture of size ranges of material which passes through the grate 40 effectively into the interior of screen 176, thereby facilitating the operation of the screen function thereof as the mill rotates in order to separate a desired range of fine sizes of products from the immediate coarser oversize products, the latter gradually passing, incident to the rotation of the sizing device 160, through the spaces 164 in an axial direction by natural displacement release to that of the movement of the material into screen 176, for return to the grinding zone of the mill in accordance with the principles of the invention as described in greater detail above relative to the other embodiments of the invention.

FIG. 7 illustrates still another embodiment of additional sizing mechanism associated with the exit end of the mill 10 as employed for dry grinding and concerning which the space 68 in the mill is also provided with substantially radially extending blades or lifters 180 which are similar to the blades 162 in the embodiment shown in FIGS. 5 and 6. In this figure, a further embodiment of additional sizing means 184 is shown which comprises a slightly conical concave shell which is fixed at its inner end within the discharge trunnion 20. Said inner end is provided with a plurality of relatively short downwardly and outwardly extending tubes 186 which direct the mixture of discharging material 188 into the sizing means 182. This material comprises a mixture of a desired range of fine sizes and intermediate oversize material which has passed through the grate 40 and has been elevated to the tubes 166 by lifters 180. It then drops toward the center of the shell 184.

An air stream containing fines and air-borne oversize received from the grinding zone, as indicated by the arrows 190, is directed through the sizing means 184 in an axial direction toward the outer end thereof and passes upwardly through a fixed rigid tube 192 mounted with a lower end to the lower end of which the outer end of sizing means 184 rotates. The upper end of chamber 194 is connectable to an exhaust opening 196. The lower end of chamber 194 is provided with an air lock type discharge means 198 for the product dropping out in the chamber 194.

The operation of this embodiment is such that, as the entrained air stream 190 passes axially outward through the sizing means 184, it will blow the discharging material 188 outward through the sizing means 184 but the heavier particles 200 will fall by gravity onto the inner rotating surface thereof. The fine ranges of sizes of material will also become entrained in the air stream 190 and join that already entrained as the air passes through the mill 10, for passage upwardly through the tube 192 and, finally, through the upper end 196 of settling chamber 194 for movement either to a collection system or other classification means. The air stream 190 moves into upwardly tube 192, however, some of the heavier particles still moving therewith will drop by gravity onto the lower wall of tube 192 and slide back into sizing means 184. Another entrained portion, but not as fine as that which was entrained in the air stream for discharging from the exhaust opening 196, will fall past the upper end of tube 192 for collection in the lower part of settling chamber 194, from which the material is removed at 198, preferably through the air lock arrangement illustrated, or its equivalent.

It will be seen that upon continued rotation of sizing means 184, said heavier particles of material progressively are returned to the grinding zone of the mill by passing through the spaces provided between the slanting tubes 186. Such returned material is directed, as in regard to the other embodiments, a distance in an axial direction into the grinding zone of the mill, axially past the grate 40, by gerial, the outer end 178 therein.

From the foregoing, it will be seen that means are provided for segregating the material discharging through the grate 40 into three ranges of different sizes and at least one of said sizes, comprising the largest, is returned automatically and continuously to the grinding zone of the mill. The rapid removal of the ground and semi-ground product, well within the grinding zone, is of particular advantage when a closely-sized product and a minimum of over-grinding is desired. The grate 40 and lifter 180 are far more instrumental in accomplishing this objective than the air stream 190 which is at relatively low velocity when passing through the mill and is able to entrain only a relatively small amount of the fines and far less oversize material than is present in the mill. With the employment of the grate embodiment, as here illustrated, together with the air, a very close control of the size of the product can be secured. This fact combined with the ability deliberately to remove oversize in one zone and reintroduce it in another zone in the same general area, and do so with less fines present near the discharge, improves the overall efficiency in an autogenous grinding mill considerably, as already stated in part hereinabove.

A still further embodiment of additional sizing means 202 is illustrated in FIG. 8 and 9. This embodiment primarily intended for use in either a wet or dry grinding process. Similarly of the passage members 164 employed in the embodiment of FIGS. 5 and 6, the instant embodiment employs similar, circumferentially spaced tube-like
passage members 204 which receive a mixture of material of intermediate and fine ranges of size which has been discharged through the size-limiting discharge means or grate 40. The members 204 are connected at one end to a slightly conical shell 206 which slopes toward the axis and outwardly form the conical ring 42. The discharge ends of the members 204 communicate with the interior of a second slightly conical shell 208 which slopes outwardly and away from the members 204, whereby material discharging through the passage members 204 rolls by gravity along the sloping surface of shell 208 and is received in an annular, conical receptacle 210 having a discharge rim 212 at the outer end of the sizing means 202.

An annular plate 214 interconnects the larger diameter end of conical receptacle 210 with the outermost end of slightly conical shell 206. Another annular plate 216 has a central opening through which the second conical shell 206 extends and to the outer surface of which the plate 216 is affixed. The outer periphery of plate 216 extends to the terminal cylindrical portion 218 of conical receptacle 210 and has several entrance openings 220 formed therein. These entrance openings communicate with preferably curved conduits 222 which are disposed between the plates 214 and 216, as shown in FIG. 8, and the curved configuration of the conduits is best shown in FIG. 9.

The innermost ends of the conduits 222 discharge onto the exterior of conical shell 208 and move in an axial direction, as well as circumferentially around and along the exterior surface of shell 208, and fall onto the inner surface of shell 206, the slope of which is such as progressively to move the material through the spaces between the passage members 204 and then through the conical ring 42 for axial return to the interior of the grinding zone of the mill.

With regard to the falling and rolling of the heavier particles of material in the embodiment of the invention shown in FIGS. 1 and 3 described hereinafore, so with regard to the embodiment illustrated in FIGS. 8 and 9; the larger particles of the material discharging from the outer ends of members 204 will tend to roll further and more rapidly down the inner surface of conical receptacle 210 than the smaller particles so as to accumulate predominantly in the lower portion of said receptacle as the same is revolved by the mill during rotation thereof. This action is well known as it is basically the same as that which takes place in the Conical mill, well known in the art. It is true that such action will position principally adjacent the bottom of the receptacle 210, it will be in position to pass through the entrance openings 220 for the curved conduits 222 whereby, upon continued rotation of the sizing means 202 in the direction of the arrow shown at the upper part of FIG. 9, such similar batches of material as enter the outer ends of conduits 222 will roll sequentially down to the same to the inner end thereof and be discharged onto the outer surface of conical shell 208 for subsequent deposit into the interior of shell 206 and then back, in an axial direction, into the grinding zone of the mill as described above.

Whereas the larger portion of the material discharged into conical receptacle 210 will go toward the bottom of the receptacle as shown in FIG. 8, the ranges of finer material will tend to remain near the apex of the cone and overlap the discharge rim 212. Thus the discharge will exit from the mill into suitable receiving means not shown here.

The amount of intermediate oversize material entering the openings 220 of conduits 222 for return to the grinding zone of the mill may be adjustably regulated by the employment of suitable means, one simple form of which is illustrated in FIGS. 8 and 9 and constitutes pivoted shutters 224 having arcurate slots 226 therein through which lock bolts pass having wing nuts, for example, on the outer ends thereof so as to clamp the outer ends of the shutters 224 in any position desired. The shutter arrangement 224 can, of course, be arranged so as to slide in a radial direction, in which event, if used for wet separation particularly, such movement may effect the density of the pulp being returned to the mill since the densest pulp zone is nearest the bottom of the pool. By observing operating conditions of the mill and especially of the range of fine sizes of product obtained therefrom from time to time, experience will dictate the size to which the openings 220 should be adjusted to effect the return of the intermediate oversize material to the grinding zone of the mill in proper quantity and consistency, whereby optimum production of desired fine ranges of product size may be obtained and oversize material returned to the discharge end of the mill with similar results as described elsewhere herein.

A further embodiment of sizing means 228 is illustrated in the embodiment shown in FIGS. 10 and 11. In this embodiment, the material which passes the size-limiting discharge means 40 falls from the annular chamber 68 onto an annular conical deflecting member 230 and from there onto a slightly conical shell 232 which is coaxially within an outer slightly conical shell 234 that slopes reversely to shell 232 as is clearly shown in FIG. 10. The outer end of shell 234 is connected to the inner rim of an annular plate 236 comprising one end wall of a cylindrical receptacle 238 which has an opposite annular end wall 240 provided with a central discharge opening 242.

The material discharging from chamber 68 of the mill enters the space between the conical shells 232 and 234 for falling movement by gravity, as the mill and sizing means 228 rotate, into the rotatable receptacle 238. The larger particles of material comprising the exemplary intermediate oversize will tend to accumulate adjacent the cylindrical wall of the receptacle 238 and said material gradually is moved toward the annular end wall 236 by any suitable means such as a spiral plate 244. Such movement is for purposes of positioning such oversize material for being received within the circumferentially extending spaces 246 which are defined by arcuate plates 248 and one end of each of said spaces communicates with a radially extending conduit 250 which extends through the outer end of conical shell 232 for communication with the interior thereof.

The side of the spaces 246 which faces the opposite end wall 240 is open and is arranged either to be partially or completely closed, or left completely open, by suitable arrangement of arcuate closure plates 252 which are fixed respectively to the opposite ends of a diametrically extending arm 254 mounted on a shaft 256 which is coaxial with the axis of the mill 10. A suitable bearing for the inner end of shaft 256 conveniently may be supported upon the outer closure member 258 for conical shell 232, while the opposite end of said shaft is journaled in a bearing carried by transverse plate 260 which extends across the discharge opening 242.

Any suitable position-maintaining means may be provided for the arm 254 and the closure plates 252 carried thereby, such as a radial handle 262 which is fixed to the outer end of shaft 256 and, by means of an arcuate slot 264 formed in plate 260, and through which a lock bolt and wing nut extend, any desired position of the handle 262 and, correspondingly, of the closure plates 252 relative to the spaces 246 may be maintained. This arrangement thereby adjustably regulates the quantity of intermediate oversize material which may enter the spaces and be moved through the conduits 222 to the interior of conical shell 232 in order to be returned, through the operation of gravity and the rotation of the mill and sizing means 228, in an axial direction back into the grinding zone of the mill as hereinafore described. The adjustment for the mechanism by which the return of the intermediate oversize to the grinding zone of the mill is achieved can be operated not only from the exterior of the mill and especially the additional sizing means 228, but such adjustment also may be made while the mill and
sizing means are being operated, for under certain conditions mills of this type operate at such speed that permit this to be done, thereby affording an additional advantage over the embodiment shown in FIGS. 8 and 9.

This embodiment has also the advantage of being capable of an appreciable increase in the rate of discharge to the mill shell 274, if the operation is wet, as compared with such rate of return by the other embodiments herein described. When the closure plates 258 are moved clockwise, as here illustrated, so as to partially or fully close the spaces 256a to form lifting pockets or scoops, the amount of material scooped thereby from the bottom of receptacle 238 and deposited into conduit 259 for return to the mill correspondingly is increased. This is true also if the operation is dry. Such means, as illustrated in FIGS. 8, 9, 10 and 11, where applicable, are contemplated for adaptation to the other embodiments in this invention.

Still another embodiment of additional sizing means 266 is illustrated in FIGS. 12 and 13, such means having the further advantage, over the other embodiments described hereinabove, that additional means are provided for permitting a limited amount of relatively large sized pieces or pebbles, usable, for example, as grinding medium in a subsequent operation, i.e., an additional mill, to be discharged along with the desired ranges of relatively fine sizes of material and additional intermediate oversize material, thereby affording still greater control of the grinding conditions within the mill than under circumstances where such larger pebbles are not removed from the mill.

The desirability of removing such larger pieces or pebbles from the mill is dictated particularly by the nature of the material being comminuted by the mill aside from the use elsewhere or disposal thereof. Certain types of material do not require the withdrawal of a limited amount of such larger pieces or pebbles for maintaining optimum operative conditions while a different material may be comminuted more effectively by permitting such withdrawal. Such pebbles sometimes accumulate too rapidly for highest efficiency in grinding, whereby removal is desired. Such pebbles may be of the order of between one and three inches in diameter, for example, thus being substantially larger than the intermediate oversize material otherwise withdrawn from the mill together with desired ranges of fine sizes of material.

Various means may be resorted to for effecting such withdrawal of said pebbles and one of several effective means of accomplishing this is illustrated in the embodiment shown in FIGS. 12 and 13. In this illustration, the mill 10, which is of an exemplary nature only, is illustrated as being similar to the mills shown in the other embodiments in that the exit end wall 12 is conical but the grate 268 extends, for example, radially substantially from the conical ring 42 to the peripheral extremity of the interior of the mill 10.

The grate 268 has the normal discharge openings therein, which are of a size to control the maximum dimensions of ranges of desired fine sizes of products, together with intermediate oversize material, as described hereinabove relative to the preceding embodiments. In addition, however, a limited number of much larger sized openings 270 are provided at predetermined locations within the grate 268, for purposes of permitting the discharge thereof through a limited but desired quantity and size of oversize grinding pebbles 272. The size, number and location of these larger openings 270 is dictated primarily by the nature of the material being comminuted within the mill and subsequent application thereof.

Mounted within the exit or discharge section 20 and coaxial therewith is a conical shell 274. Said shell extends axially substantially from the conical ring 42, to a substantial distance past the outer end of trunnion 20. The outer end 276 of the shell 274 is closed, while the inner end 278 thereof is open. A mixture of material comprising desired ranges of fine sizes of material and intermediate oversize, such as passes through the normal openings of the grate 268, together with a limited amount of larger pebbles 272, are discharged from the chamber 68 onto the interior of the inner end 278 of shell 274, there preferably being a number of radial vanes 280 fixed thereto as to prevent the material from falling along the curved sides of the shell 274. Instead, the material is not permitted to fall along the sides of the shell 274 until it is at least moved axially outward along the shell a limited distance and thereby falls onto the interior cylindrical surface 282 of the trunnion 20 as clearly shown in FIG. 12.

A spiral rib 284, or equivalent means, is used to insure the axial movement of such material from the outer end of the trunnion 20 and into a rotating sizing means specifically comprising a trommel 286 which is fixed to and is rotatable with the trunnion 20 and also with a coaxial and surrounding further sizing means comprising a cylindrical screen 288, one end of which is supported by an annular plate 290, while the opposite end of the screen 288 is provided with an annular radial restricting flange 292. Thus, this embodiment has a plurality of additional sizing means indicated as 268.

As the rotation of the mill and various components of the additional sizing means 266 proceeds, the mixture of material discharged upon the exterior of shell 274 is moved axially outward from the interior of trunnion 20 onto the trommel 286 which serves to separate from the outermost pebbles 272 that oversize portion passing through the openings 270 with the pebbles but too large to pass through the grate 268, as well as all smaller size fractions that pass through the openings of grate 268. All of the undersize passing through the trommel 286 then drop onto the inner surface of rotating screen 288.

The size of the openings of screen 288 is such that they will not pass intermediate oversize material but they will permit the passage of a predetermined size of desired ranges of fine product material which, depending upon the nature, composition and type of product material being sought, may constitute the end product. The separated ranges of fine product material which pass through the screen 288 are deposited into receiving means 294 of any appropriate type, while the intermediate oversize material is retained within the interior of screen 288.

The outer end of trommel 286 is open except for a certain segment thereof which is adjustable closed by an arcuate segmental end plate 296 which is stationarily but adjustably supported upon the outer end of an arm 298 which is pivotally connected to stationary supporting means 300. In view of the direction of rotation of the trommel 286, as indicated by the arrow at the upper part of FIG. 13, it will be seen that the plate 296 may be positioned relative to the open end of trommel 286 so as to limit the amount of pebbles 272 which are discharged from the outer end of the trommel and into suitable diverting or collection means 302. Control of the quantity of pebbles removed from the mill system, while in operation, is thus facilitated.

Those pebbles 272 which are not removed from the outer end of trommel 286 continue to revolve on the interior thereof until they are disposed opposite the entrance opening 304 of radial conduit 306, the opposite end of which communicates with the interior of conical shell 274 and rotates therewith as the mill and additional sizing means are rotated. When the position of plate 296 approaches the bottom position during its path of movement, the pebbles 272 which pass through the entrance opening 304 are discharged during the next half revolution into the interior of conical shell 274 and roll down the sloping inner surface thereof, as indicated in exemplary manner in FIG. 12, for discharge into the interior of the grinding zone of the mill and are moved axially an appreciable distance past the grate 268, as hereinbefore described.
in the event more than or less than the desired amount of pebbles are returned by conduit 304, closure or scoop means, as illustrated for use in such an event in FIGS. 8, 9, 10 and 11, may be employed.

The intermediate oversize material 308 which accumulates within the screen 288 progressively is removed therefrom by another radial conduit 310 having an outer entrance conduit 312 therein and the inner end thereof extends through conical shell 274 for communication with the interior thereof, whereby successive limited quantities of the intermediate oversize material 308 are removed from the interior of screen 288 and are discharged into the interior of conical shell 274 so as to roll down the sloping inner surface thereof and be discharged in an axial direction into the interior of the grinding product and the mill preferably an appreciable distance therein past the gate 268 so as to become thoroughly remixed with the contents of the grinding zone and thus be subjected to further treatment as hereinbefore explained.

The adjustability of the control for the discharge of the pebbles 272 either from the mill for use in additional mills or otherwise, or returned to the grinding zone of the mill to which the additional sizing means 266 is connected, affords useful and effective control of the grinding conditions, within the mill so as to cause maximum efficiency of operation of the mill to autogenously and simultaneously reduce all sizes of material within the mill progressively and simultaneously to a desired range of sizes of product.

A still further embodiment of additional sizing means as used with the end of the mill is illustrated in FIGS. 14 through 16, which also employs a plurality of additional sizing means, and wherein only a fragmentary portion of the end wall 314 of a rotating autogenous grinding mill is illustrated. Said wall has a gate so arranged that the discharge is directly into the trommel 320 and extends inwardly of the end wall liners 316 of the mill to facilitate removal of the discharge product and assist in securing the desired mixing effect. Appropriate wear-resisting liner plates 316 are employed, as is a conical deflecting ring 318 adjacent the exit trommel 320. Disposed within the conical ring 318 is size-limiting discharge means 322 having a substantial number of relatively small openings 324 therein, of a size variable to pass therethrough desired ranges of fine sizes of material, together with predetermined maximum sizes of intermediate oversize material larger than said ranges of fine sizes of material. Said size limiting or grate means 322 is also provided with a limited number of larger discharge openings 326, one exemplary disposition of which is illustrated in FIG. 16. The openings 326 function similarly to the openings 270 in the embodiment shown in FIG. 12 and are capable of passing therethrough much larger sized pieces which include pebbles 328 that can possibly be discharged from the outer smaller but many more openings in discharge means 322.

Connected to the outer end of trommel 320 and movable therewith is an outer circular housing 330 containing a cylindrical screen 332 to the outer end of which a trommel 334 is connected. As the mill revolves, discharging material progressively passes through the openings 324 as well as the larger openings 326 of the size-limiting discharge means 322 and as the material moves axially outward along the interior of trommel 320, it first passes into the screen 332 which separates, from the coarser material in the mixture, a range of desired fine sizes of material having a predetermined maximum as controlled by the size of the openings in the screen 332. The larger particles of material which do not pass through the screen then continue to move axially outward into the trommel 334, where intermediate oversize material passes through the trommel into the outer housing 330.

Adjacent the outer end of trommel 334 is a radially extending annular flange 336 operable to prevent the free discharge of the pebbles 328 from the outer end of the trommel 334. However, for a short circumferential segment of the trommel, there is provided an opening 338 through which the pebbles 328 may pass for discharge into a suitable conducting or accumulating means 340. The size of the arcuate opening 338 in the trommel may be regulated by an adjustable curved plate or shoe 342 which can be moved various distances relative to the opening 338, the adjusted positioning of the plate 342 being maintained by any suitable clamping means such as bolt and wing nut 344.

Coaxial with the trommel 320 and spaced radially inward therefrom is a cylindrical conductor 346 through which various sizes of material are returned to the grinding zone of the mill. Communicating with the outer end of conductor 346 is a pair of radially extending conduits 348 and 350.

The outer end of conductor 348 has an entrance opening 352 which sequentially receives quantities of the intermediate oversize material from within the housing 330 as the entrance opening 352 reaches bottom in its rotation and gradually approaches the upright position to cause the material to fall by gravity down the conduit 348. Similarly, the conduit 350 has an entrance opening 354 through which the large pebbles 328 pass and subsequently fall or roll down the conduit 350 as it rotates, for discharge into the cylindrical conductor 346.

As is stated in the embodiment shown in FIGS. 12 and 13, the rate of return of pebbles back to the mill 10 may be controlled at entrance opening 354 by the means such as described in FIGS. 8, 9, 10 and 11. Within conductor 346 is suitable movement-insuring means, such as spiral blade 356 which progressively moves the intermediate oversize ranges of material and the large pebbles 328, in an axial direction, back a substantial distance into the grinding zone of the mill, so as not immediately to mix with the material leaving the mill through the size-limiting discharge means 322.

Due particularly to the adjustability of the opening 338 and the suitable selection of sizes of the mesh of screen 332 as well as the sizes of the spaces between the bars of the trommel 334, coupled with the size of the discharge openings 326 as well as the sizes of the small normal openings 324 in the size-limiting discharge means 322, it is possible to provide within the grinding zone of the mill maximum efficient grinding operation by utilizing minimum time and power input. Further, this embodiment of the invention particularly is highly suited to the removal of the ranges of fine product material which passes through screen 332 for discharge into conductor or accumulating means 358 and 360.

In the event the ranges of relatively fine sizes of material as produced by the first or primary mill of which end wall 314 is a part, and which are discharged into the conductor or accumulating means 358 require further reduction in size, this material readily may be fed to a second or supplementary mill 360 and, similarly, desired size and quantities of grading media comprising the larger pebbles 328 may be fed from the conductor or accumulating means 340 to the entrance of such second mill 360 where said ranges of fine sizes of material may be reduced finally to an ultimate desired size range of fine product. Thus, this embodiment of the invention affords means which not only effect maximum efficiency within the primary autogenous grinding mill, by eliminating some of the hard to grind pebbles therein, but such embodiment also effectively and inexpensively provides both the grinding medium and material to be further reduced in size by an auxiliary or supplemental mill.

Although a number of different embodiments of the invention have been illustrated and described in the application, it is to be understood that the same are not the exact equivalent of each other, notwithstanding the fact that certain of these embodiments employ the similar basic principles as other embodiments so illustrated and described. Nevertheless, each particular construction has
been designed for a particular objective that is somewhat different from the objectives of the other embodiments, whereby certain of the structures, for example, are more effective to operate either in a wet or dry grinding state or are more efficient in autogenously grinding certain types of material than certain of the other embodiments. From this standpoint, therefore, the various structures and arrangements of the various embodiments are not to be considered the full equivalent of each other.

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, described and since the same may be carried out in other ways falling within the scope of the invention as claimed.

We claim:

1. A process of wet grinding run-of-the-mine friable material consisting of a fluid mixture of ranges of relatively large, intermediate and fine sizes of solid material and liquid by tumbling such mixture within a mill to reduce autogenously all sizes thereof simultaneously and progressively to a predetermined range of fine sizes, substantially axially mixing all sizes of material within the mill, progressively removing a fluid mixture of such range of fine sizes and some intermediate oversize material from the grinding zone of said mill, sizing said mixture of material by sifting to separate from said intermediate oversize material, a predetermined range of fine sizes of material while said material is tumbled by the rotation of said mill, establishing a pool of said oversize material to maintain the same substantially fluid, returning said separated oversize material with some liquid from said pool to said grinding zone of said mill for further treatment, and discharging said range of fine sizes from said mill.

2. A tumbling type mill for wet grinding friable material autogenously and comprising a drum having opposite end walls respectively provided with feed and discharge openings therein, means supporting said drum for rotation about its axis, means within said drum operable to mix a charge of mixed size ranges of friable material by substantial movement in an axial direction therein while all sizes of material therein are being comminuted autogenously simultaneously in wet condition within the grinding zone of said mill and of which material the maximum sizes thereof are capable of self-reduction, discharge means interconnected to said discharge end wall of said drum and having a discharge opening therethrough, said discharge means being operable to separate from said grinding zone of said drum a wet mixture of a range of desired fine sizes of material and oversize material coarser than said desired ranges of fine material, sizing means interconnected to said discharge end wall and rotatable therewith, said sizing means being spaced axially outward from said discharge means and operable to receive therefrom said wet mixture of ranges of said fine sizes and oversize material discharged through said discharge means and separate a range of desired fine sizes of material from said oversize material, retaining means within said sizing means operable to retain within the oversize material removed from said mill at least some of the liquid contained therein as it was removed from the grinding zone, and means operable to receive said oversize material from said sizing means and return the same in wet condition through and past said discharge means directly into said grinding zone of the mill for further treatment thereby by tumbling and substantial axial movement thereof, the liquid contained in said returned material facilitating the return thereof to said grinding zone.

3. The tumbling type mill set forth in claim 2 further including tube means extending axially of said discharge opening in the discharge end wall of the mill and rotatable therewith, and flow-restricting means adjacent the end of said tube means nearest said discharge opening to induce the formation of a pool including liquid and oversize material, said liquid content of said pool acting to facilitate the movement of the material through said tube means and back to said grinding zone.

4. The tumbling type mill set forth in claim 2 further including concentric tube means rotatable with said mill and extending axially of said discharge opening in the discharge end of said mill and positioned between said opening and said sizing means and one of said tube means being of smaller diameter than the other to provide an annular passage therebetween, the inner tube means receiving said desired ranges of fine sizes of material and oversize material from said discharge means and conducting it to said sizing means, and the outer tube means receiving said oversize material from said sizing means and returning it in an axial direction through and past said discharge means into said grinding zone of the mill for further treatment.

5. The tumbling type mill set forth in claim 2 further including substantially cylindrical and impervious tube means so positioned axially related to said discharge opening and sizing means as to receive a mixture of desired fine size ranges of material and oversize material from said discharge opening and incident to tumbling the same within said tube means causes movement of said mixture axially outward to said sizing means and movement of said oversize material progressively axially inward for return to said grinding zone.

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