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[54] **METHOD AND APPARATUS FOR THE AUTOGENOUS CRUSHING OF STONE AND THE LIKE**
16 Claims, 8 Drawing Figs.

[52] U.S. Cl. 241/18, 241/26
[51] Int. Cl. B02c 19/00, B02c 17/14
[50] Field of Search .... 241/18, 19, 26, 47, 49, 58, 79, 284, 274, 276, 275(cursory), 252(cursory), 202(cursory)

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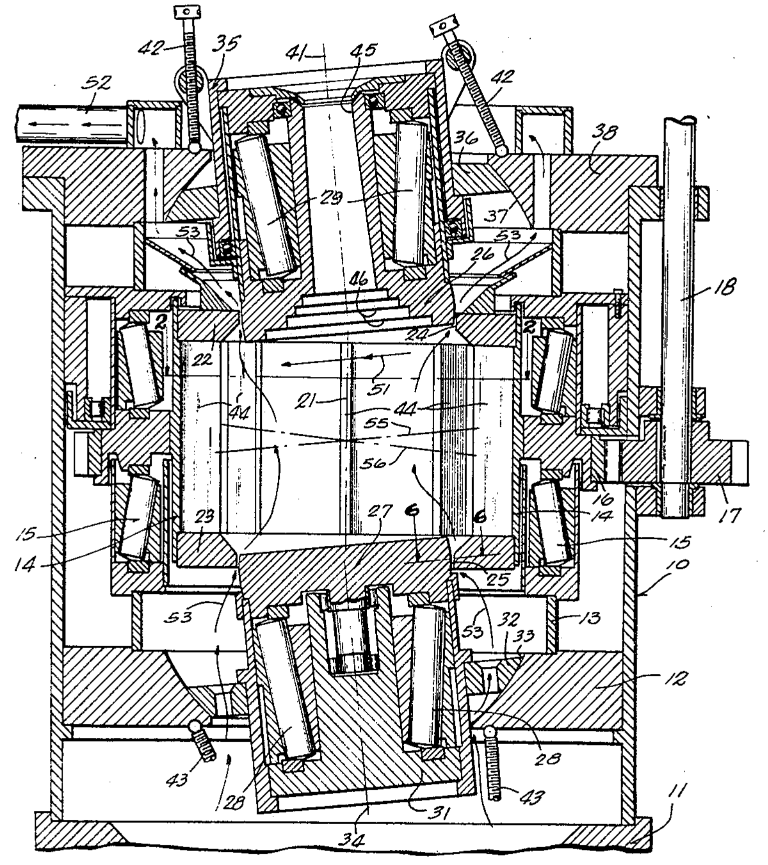
ABSTRACT: This disclosure relates to a high pressure autogenous stone crushing method and apparatus. A large volume of chunks of stone or like fracturable material is assembled in a deep bed or mass in which proximate chunks are in mutual engagement, with voids intervening therebetween. High pressure is imposed on the mass, and a portion of the mass is then sequentially reciprocated with respect to other portions to mutually shift the chunks and develop chunk rupturing stress between chunks. The comminuted particles are removed pneumatically or by gravity through a screen.



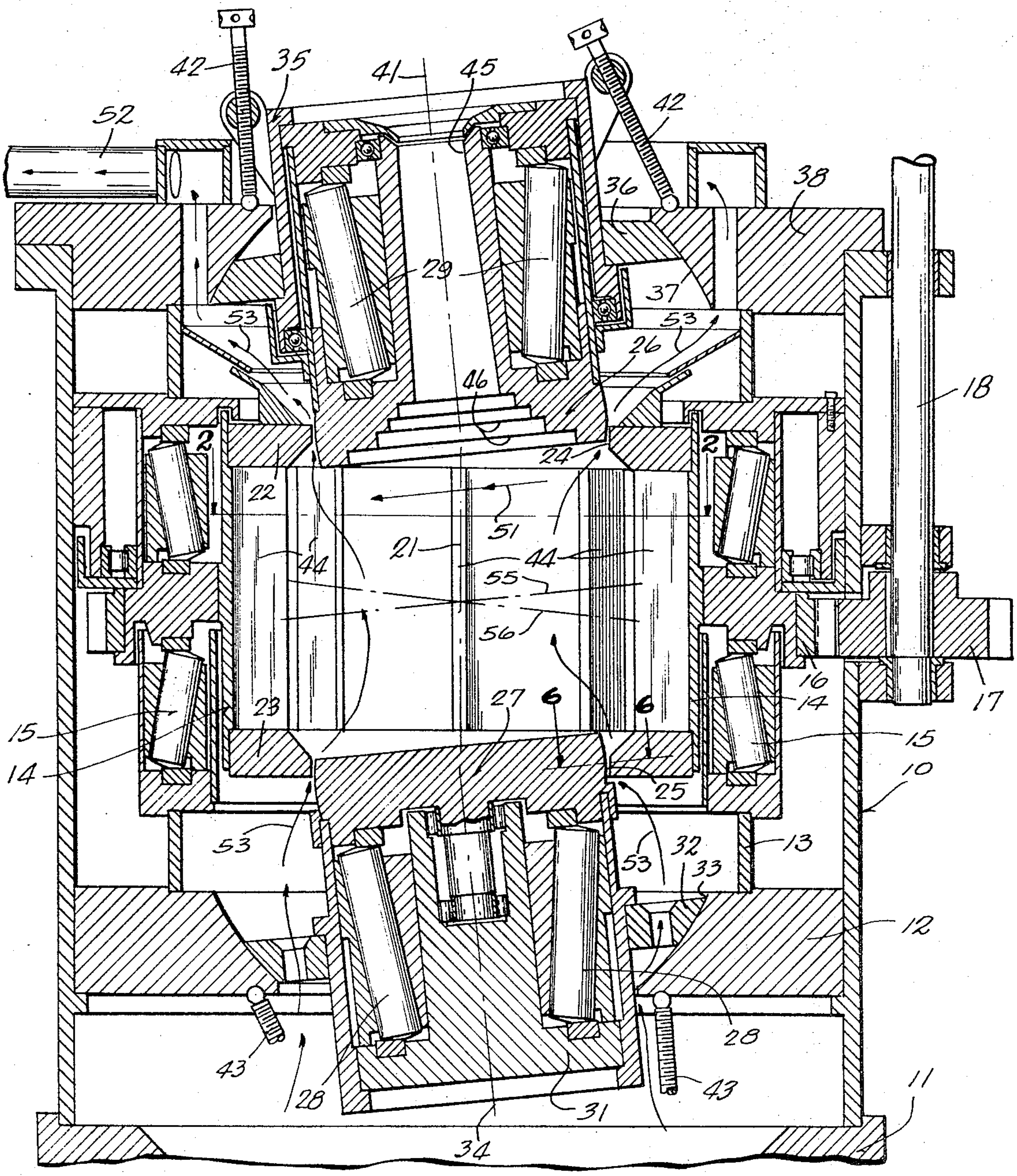


Fig. 1

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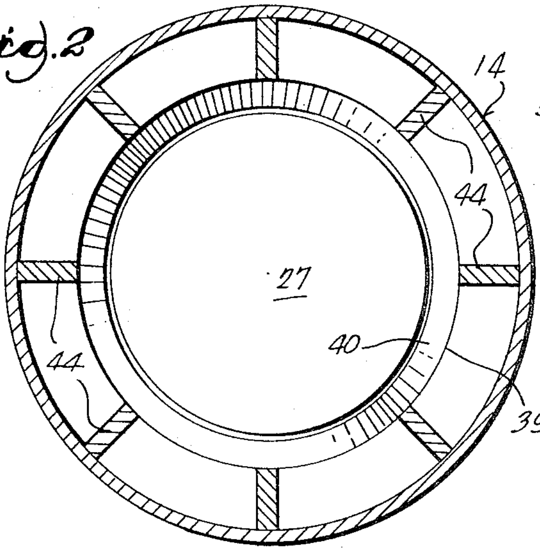
Fig. 2



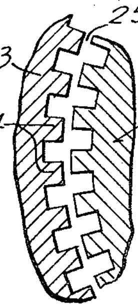


Fig. 6

Fig. 3

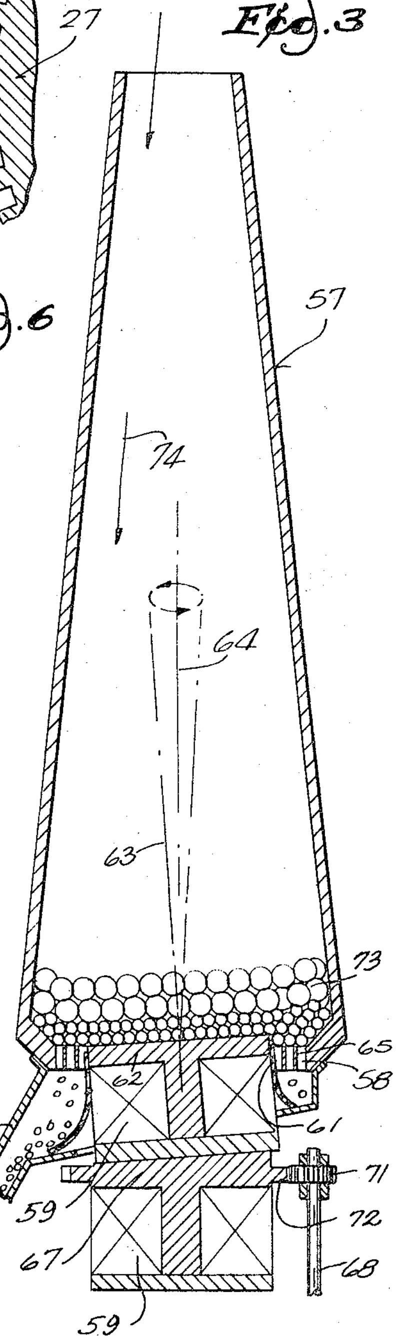


Fig. 4

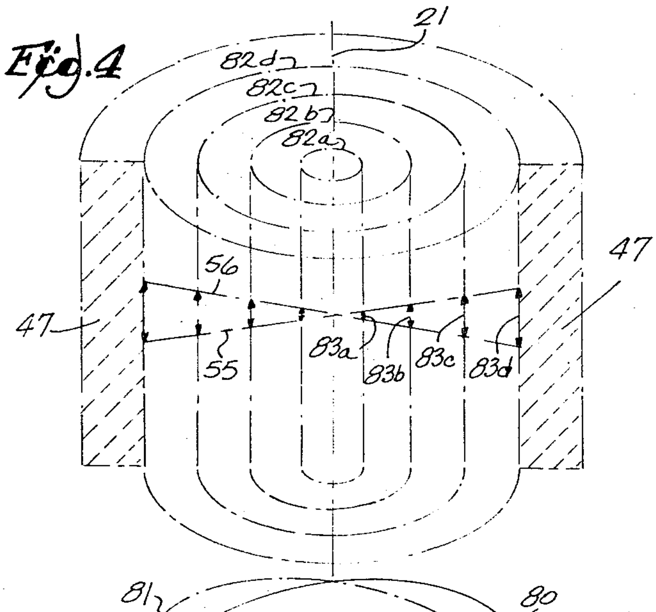


Fig. 5

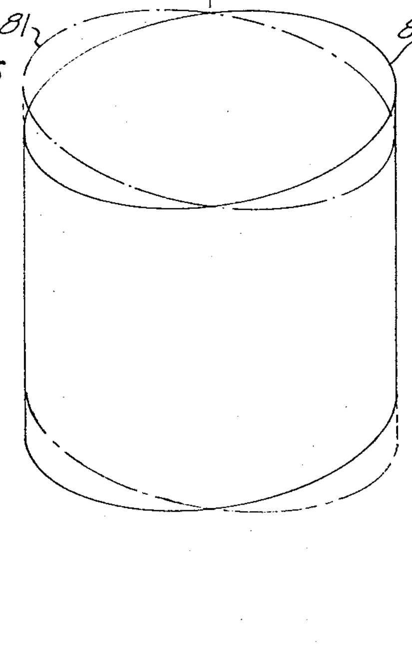


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Fig. 7

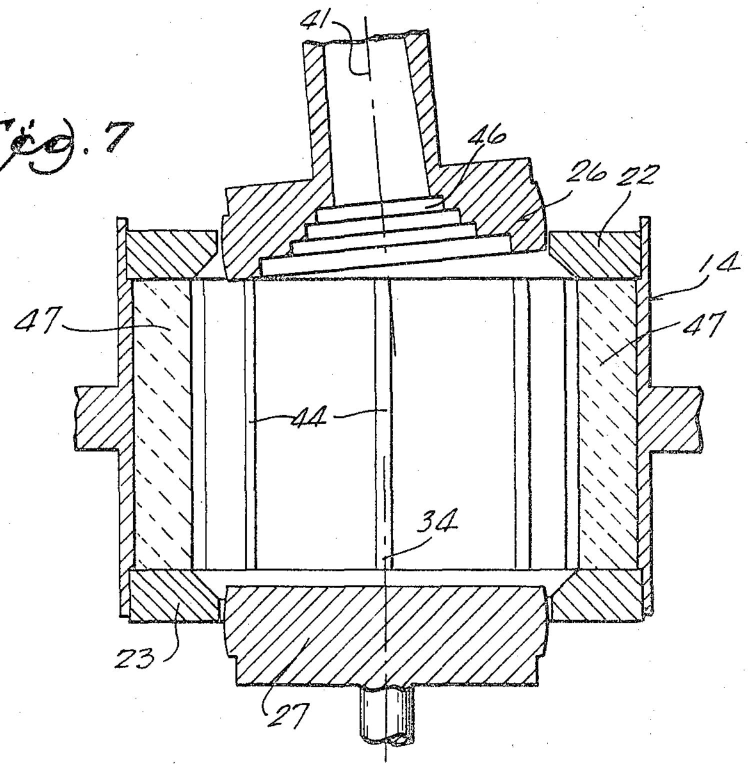
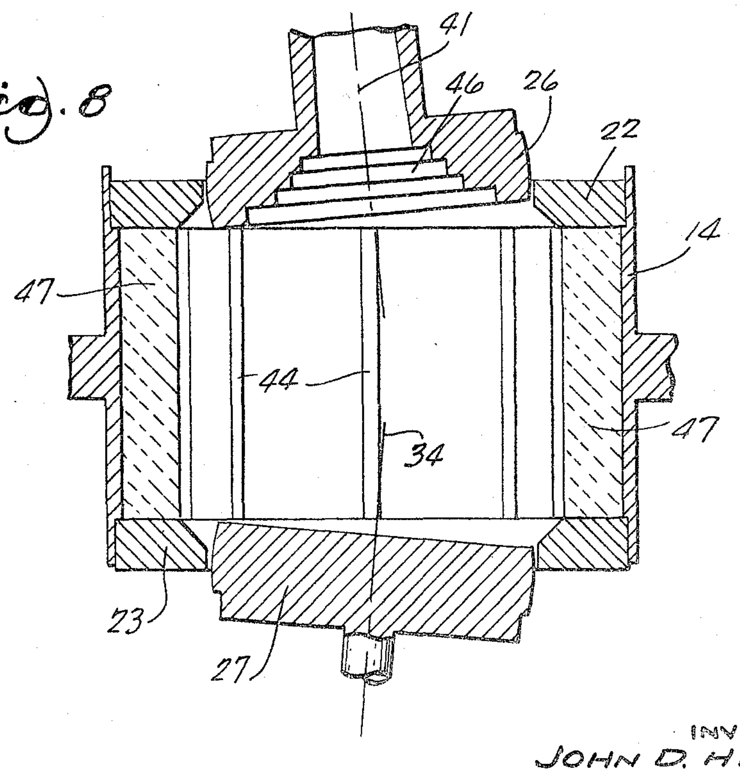


Fig. 8



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METHOD AND APPARATUS FOR THE AUTOGENOUS CRUSHING OF STONE AND THE LIKE

BACKGROUND OF THE INVENTION

Prior art stone crushers, such as the Symons crusher, crush stone directly between gyrating and fixed cones or similar metal surfaces. The abrasive contact of the stone with the cones and the development of rupturing stress directly between the metal parts and the stone results in heavy wear of the metal parts.

To some extent, autogenous grinding is achieved in cascade grinders, but these are relatively inefficient because they depend primarily on impact and abrasion and only incidentally on break and flow phenomena which characterize high pressure autogenous crushing.

SUMMARY OF THE INVENTION

The present invention involves both method and apparatus for autogenously crushing stone and the like in a large chamber which contains a mass of stone in mutual engagement with intervening voids. One form of the grinder has a gyrator which causes break and flow of the stone within a mass of stone and without any substantial wearing contact of the stone with the metal elements of the grinder. Unlike the Symons crusher, the present invention requires proximate stones or chunks to sequentially reciprocate in a large mass in which stone rupturing stress is developed within the mass and between proximate stones, thus producing autogenous crushing and avoiding heavy wear which characterizes any crusher in which most of the stone is crushed by reason of direct pressure contact with the metal parts of the crusher.

In one embodiment of the invention, high pressure force is imposed on the stone mass which is confined between distantly spaced rotating heads which close the top and bottom of a rotating drum. The heads rotate on axes inclined to the axis of rotation of the drum, thus causing nutation of the heads relative to the stone mass and sequential reciprocation or rocking of the closely packed mass within the drum and setting up shear or slip planes within the mass on which the rupturing stress is developed as the parts rotate as a unit. Such apparatus can impose pressure on the order of 2,000 pounds per square inch of head area for crushing ore, limestone, etc.

In another embodiment of the invention intended primarily for softer minerals, such as coal, adequately high pressure is achieved by confining the chunks in a tall stack which may be on the order of 100—150 feet high. The bottom of the stack is sequentially reciprocated by a swash plate which gives a wobble motion to the stack bottom. This motion in conjunction with the force of gravity develops the movement of the mass, and the chunks fracture along a multiplicity of shear planes developed by the sequential reciprocation of the two counterforces.

In all embodiments, the chunks are autogenously crushed. Stone rupture stress is predominantly effective within the mass, rather than between the metal parts of the grinder and the stone.

Other objects, features, and advantages of the invention will appear from the following disclosure.

DESCRIPTION OF DRAWINGS

FIG. 1 is a cross section taken through one embodiment of autogenous grinder embodying the invention. In this invention embodiment there are top and bottom heads which progressively reciprocate with respect to an intervening chamber which rotates with the heads.

FIG. 2 is a horizontal cross section taken through the rotating drum of FIG. 1, along the line 2–2.

FIG. 3 is a vertical cross section taken through a modified embodiment of the invention. In this embodiment a tall stationary stack has a progressively reciprocating bottom.

FIGS. 4 and 5 are diagrammatic views illustrating the progressive, rotary reciprocation imparted to the mass by the end heads of the drum of FIG. 1 and the infinite shear planes which are developed in the mass of stone.

FIG. 6 is a fragmentary cross section taken along the line 6–6 of FIG. 1.

FIG. 7 is a diagrammatic view illustrating the end heads of the drum of FIG. 1 at different relative inclinations.

FIG. 8 is a diagrammatic view illustrating the end heads of the drum of FIG. 1 at a still different relative inclination.

DESCRIPTION OF PREFERRED EMBODIMENTS

Although the disclosure hereof is detailed and exact to enable those skilled in the art to practice the invention, the physical embodiments herein disclosed merely exemplify the invention which may be embodied in other specific structure. The scope of the invention is defined in the claims appended hereto.

The invention is useful for grinding any form of earth materials which are relatively hard and which are ordinarily mined in the form of chunks, such as iron and other metallic ore, coal, limestone, rock, etc. All of these earth materials will be referred to generically in the specification, and the claims appended hereto, as stone.

The embodiment of FIG. 1 illustrates one form of the invention adapted to crush and pulverize hard stone, such as iron ore.

The crusher frame **10** may be circular in plan and is desirably mounted on a concrete base **11**. A heavy mounting platform **12** spans across the interior of the frame **10** and carries a support ring **13** upon which bearings **15** support a rotating, internally hollowed or chambered drum **14**. The bearings **15** must be capable of carrying heavy thrust loads and are desirably of the long radius type shown in my U.S. Pat. No. Re. 26,414. A drive ring gear **16** which is fast to the drum **14** meshes with drive pinion **17** which is connected to a drive shaft **18** by which the drum **14** is rotated about axis **21**.

The drum **14** has a top wall **22** and a bottom wall **23** which respectively have large diameter openings **24, 25**, respectively almost completely spanned by a top head **26** and a bottom head **27**. Bottom head **27** is supported on long radius bearings **28** which are mounted in a bearing carrier **31** which has a support ring **32** with a spherical rim adjustably supported in a spherical seat **33** on the platform **12**. Accordingly, the incline of the axis **34** on which the head **27** is disposed can be adjusted.

The top head **26** is also supported on long radius bearings **29**, and these are similarly mounted in a carrier **35** having a mounting ring **36** which has a spherical rim adjustably mounted in a spherical seat **37** of an upper platform **38**. The axis **41** on which the upper head **26** rotates is thus adjustable. For adjustment purposes, adjusting screws **42** for the upper head and similar adjusting screws **43** for the lower head **27** are shown.

The axes **34, 41** of the two heads **27, 26** will be set to be inclined with respect to the axis **21** on which the chambered drum **14** rotates. In the embodiment of FIG. 1, the axes **34, 41** are parallel, although parallelism is not required.

The sidewall of the drum **14** is desirably provided with inwardly projecting vanes **44**. The inner edges of vanes **44** are disposed on an imaginary cylinder, illustrated as line **39** in FIG. 2, larger in diameter than the heads **26, 27**. Thus there is an annular gap **40** between the periphery of the heads **26, 27** and the inner edges of the vanes **44**.

The top head **26** has a filling throat **45** through which stone is fed. Near the bottom of throat **45**, head **26** has a dome with a stepped or shouldered ceiling configuration **46**. The throat **45** tapers upwardly.

In operation, stone is fed through the throat **45** until the chamber **14** is completely filled. The stone occupies a large volume and is massed in a deep bed in which most of the stone is remote from the heads which exert crushing force on the stone. I prefer the maximum practical volume of stone to be included in the chamber and between the heads. The stone chunks are typically irregular in shape and occupy only about 60 percent of the volume of the drum chamber, because of the voids between chunks. The chunks at the outer wall of the drum key into the spaces between the vanes **44** and are also confined between the top **22** and bottom **23** of the drum to constitute a relatively stagnant stone mass (**47** in FIG. 4) which protects the wall **14** from abrasion. When the drum is filled, the stone chunks interlock throughout the mass within the chamber.

Turning torque is applied to the shaft **18** which rotates the chamber **14**. While only one shaft **18** is illustrated in the drawing, there can be additional shafts **18** and additional pinions **17** distributed around the periphery of the crusher, in order to distribute the load. In a typical embodiment of the invention which has drum volume of 600 cubic feet, the drum can be rotated at about 30 r.p.m.

Rotating of the chamber **14** is communicated through the interlocked stone mass to the distantly spaced heads **26, 27**, thus to cause heads **26, 27** to also rotate at the same speed as the drum **14**. The heads **26, 27**, rotate on their axes **41, 34** which are inclined to the axis **21** of the chamber **14**. Accordingly, as the chamber rotates, the heads nutate relative to the mass of stone, which thus will rotate and progressively reciprocate as indicated diagrammatically in FIGS. 4 and 5 and cause the development of an infinite number of vertical shear planes to impose rupturing stress on the stones within the mass.

In FIG. 5, one extreme position of the stone mass is indicated by the full line distorted cylinder **80**, and the other extreme position of the stone mass is indicated by the broken line distorted cylinder **81**. In shifting from one extreme to the other, an infinite number of substantially vertical shear planes are developed in the stone mass, as represented by the cylinders **82*a***, **82*b***, **82*c***, and **82*d*** in FIG. 4. The amount of vertical shift on each shear plane is indicated by the double headed arrows **83*a***, **83*b***, **83*c***, and **83*d*** in FIG. 4. There is no movement on the central drum axis and maximum movement at the periphery of the heads **26, 27**.

The proximate chunks are in mutual point and surface contact through the mass, except where the voids intervene. As the mass is caused to gyrate, the stones are required to shift position, thus to change the attitude of one stone with respect to its neighbors. This shifting develops rupturing stress along vertical shear planes between the heads **26, 27** and causes autogenous breakage of the stones and flow of reduced size chunks into the voids. Pulverized material is removed by air flow through the voids, and the reduced volume is made up by the addition of fresh stone through the throat **45**. The entering stone lodges beneath the shoulders **46** on the dome of head **26**. As the head **26** rotates, the fresh stone will be forced downwardly into the mass along the path indicated at **51**. The shoulders **46** and the taper of the throat cause "bridging" to prevent back flow of stone. The slope of the stepped shoulders is steeper than the angle of repose of the stone. Accordingly, the stone fills up the dome by gravity on the high side and is carried around to the low side while caught under the shoulders.

In the first 180° of drum rotation from high side to low side, the stone near the periphery of the heads is thrust downwardly the distance **83*d***. Stone nearer the center is thrust downwardly a shorter distance **83*a***. In like manner, all stone in the gyrating mass is displaced a distance depending on its location in the mass and the angle to which the head axes **34, 41** are inclined to the drum axis **21**.

The next 180° of drum rotation will find the same stones lifted a similar amount.

The "core" stone on the axis **21** will not lift or fall by reason of drum rotation as they lie on the neutral axis.

The limits of lifting and falling motion of the stone is indicated by the lines **55, 56**. In effect, the stone is made to reciprocate in vertical planes, **82*a*—82*d***, for example, according to its location in the mass, between the stagnant outer layer **47** and the central core. It is the shifting of the stones relative to each other, while under pressure and confinement, that induces simultaneous breakage throughout the mass. Since the elastic response to the sudden breakage of brittle materials is rapid motion away from the applied force, the mass becomes fluid. Both the imparted motion and its induced dynamic motion combine to preclude impaction.

Breakage occurs autogenously within the mass. There is no substantial abrasion between the stone and the metal parts of the machine, such as would tend to wear out these parts. The sidewall of the drum **14** is protected from abrasion by the stagnant layer **47** of stone which is caught in the vanes **44**. The boundary stones between the stagnant layer **47** and the gyrating active mass between the heads **26, 27** will be subject to some abrasion and rock breakage. The fragments thereof will flow into the voids, and the stones in the boundary layer will be replaced by fresh stones.

Stones in contact with the top head **26** and bottom head **27** have no substantial movement with respect to the heads during gyration, and hence will have little tendency to wear and abrade the heads.

Comminution of the rock by break and flow ill continue during rotation of the drum, as long as pressure is maintained by feeding of material. When the feed is stopped, the comminution will be largely by attrition until the drum is emptied. The fines particles may be removed from the grinder through a sizing filter grate similar to that shown in FIG. 3. Alternatively, as the particles are reduced to air entrainable size, they can be continuously removed pneumatically, as illustrated in FIG. 1. The space beneath wall **23** may be pressurized with air which will flow through the space **25** between head **27** and the wall **23**, thus to aerate the fines and remove them through the space **24** between the top wall **22** and the top head **26** and through an exhaust pipe **52**. The path of pneumatic flow is indicated by the arrows **53**. If desired, the space **25** may be screened somewhat by staggered lugs **54**, as shown in FIG. 6.

In the high pressure autogenous grinder material is never confined in the sense that it has nowhere to go. If a body of crushed rock is confined, as in a cylinder under a piston, then the small particles will be forced into the voids and an incompressible, voidless solid will form, and no amount of pressure will pulverize it. An important characteristic of the present invention is constant motion (under rupturing pressure). Where motion does not occur, as around the sidewalls, the drum will cake up (almost like concrete) in time.

According to the present invention, constant motion is accompanied by a place to which the material can move.

Accordingly, in the high pressure autogenous grinder of the present invention, there is provided a place of low pressure by permitting the lower head **27** to drop away as fast as the upper head **26** advances. The pressure is built up by forcing the material on the left side of the drum (for example) to work against the resistance of the fixed wall or "dead" material **47** and an upward rising body of material on the right side of the drum which, in turn, is locked into the "dead" material on the right-hand side and moving upward to the void provided by the receding top head **26**.

Thus there is a place of zero pressure for the high pressure to move to and constant motion in the zones of rupturing pressure. These pressure zones will occur under the "down" side of the upper head and above the "up" side of the lower head. Elsewhere it will range from light abrasion to heavy abrasion.

When the first charge of stone is introduced with few "-fines," the per cent of voids may be as high as 50 percent, but after a while when the feed rate and exhaust of fines have normalized, there will be a well graded mix of about 35 percent voids and it will stay that way except in the compacted walls **47** which will have a very low percentage of voids. The volume of space in that portion of the drum between heads **26, 27** never changes. The motion of particle relative to particle never ceases; therefore, breakage into finer and finer particle size never ceases. The rate of breakage is determined by the pressure and the pressure is determined by the feed rate since with a constant volume the introduction of more material must increase the pressure provided the bridging pressure is maintained. This can only be maintained by keeping a "stiff" mix in the drum. If the air-entrainable particles are not drawn off, and allowed to increase to any extent, the mass will turn to a souplike consistency and if the feed is continued it will eventually rise up in the stack **45** and pour out like wood ashes or flour or any other finely divided material. The keying action of the rough particles must be maintained by keeping the fines moving out. The depth of the drum must be adequate for the keying (or bridging) strength of the mix to build up the rupturing zones. This combination of factors would be different for each type of material.

The spherical seats **33, 37** provide a convenient means for adjusting the inclination of the end heads on their axes **34, 41**. FIG. **7** diagrammatically illustrates upper head **26** disposed on its axis **41** at about the same incline as in FIG. **1**, but bottom head **27** has its axis **34** substantially vertical. In this arrangement the distance between the two heads **26, 27** is shortened on the left side of the drum, as viewed in FIG. **7**, so that the material is subject to greater pressure when it is at the left side of the drum, than when it is at the right side of the drum. FIG. **8** illustrates an arrangement in which the top head **26** remains in its previous position, but the bottom head **27** is tilted so that its axis **34** is at the opposite inclination.

The arrangement of FIG. **8** gives the effect of two massive rolls forming a nip of large dimension.

The volume of the drum has not been changed, however, so as the heads approach each other on the left side, they recede from each other on the right side, and the material in the nip can flow to the right side of the drum under dynamic force pressure generated by the breakage. In general, the flow will head into the center of the right sidewall **47** and curl upward and downward into the spaces opened up by the receding heads. Under these conditions it will be much easier to build up a pressure. The conditions are somewhat analogous to that in a jaw crusher with these differences: The jaw crusher impedes backflow by metal to stone gripping or friction in a narrow nip; the high pressure autogenous grinder builds up the back pressure by resistance against the right sidewall **47** and the general resistance to flow anywhere on the stationary sidewalls. The jaw crusher releases its crushed product out of the bottom of the nip; the high pressure autogenous grinder forces it into the sidewall on the left side as crushed material and scours it off the right sidewall to be removed by air flow or recycled to the high pressure side. The jaw crusher is subject to compaction if it is used to grind to fine particle size, and this will stop the crusher; the high pressure autogenous grinder has the same zone of little or no movement of the mass at the center of the left wall and compaction can take place; however, whereas this area in a jaw crusher is subjected to the same action repeatedly, the high pressure autogenous grinder reverses the action at 180° and subjects the compacted area of no motion to rapid motion and continuously destroys the impaction.

From the foregoing it is clear that a wide range of pressure developing settings can be obtained to meet the requirements of materials of varying strengths.

Other variations are possible. If, for instance, the natural "-mix" of a material is too plastic and flows too easily, hard balls as used in a ball mill or perhaps hexagonal or rectangular shapes could be included in the mix to work, under pressure, the small particles constricted in the voids between the hard steel mix additive. Their "life" should be much better under the condition of limited motion and maximum pressure of the high pressure autogenous grinder than in the conventional ball mill which utilizes much motion and impact forces. In the ball mill, the balls will roll over the material conforming to the material space requirement whereas when the balls are pressured one against the other the constantly changing position of the balls with respect to each other changes the voids and the material in those voids between the balls must conform to the space requirement of the balls. Thus each void becomes a miniature high pressure autogenous grinder and the geometric progression type breakdown of particle against particle will yield the efficiency possible only under high pressure conditions with constant motion.

With the construction shown, the variable requirements of the different materials can be met in one machine. The essential elements for efficient grinding are constant motion, adequate head pressure, and maximum active material volume.

The embodiment of the invention shown in FIG. **3** is particularly adapted for stone which has a lower rupturing strength, such as coal. In this embodiment, a very tall stationary stack **57**, which desirably tapers inwardly toward its top, contains a mass of coal to a considerable height, for example, 100—150 feet. The bottom wall **58** of the container desirably comprises a grid **65** with a central opening **61** in which there is a nonrotating bottom head **62** whose inclined axis **63** nutates about axis **64** of the stack **57**. The cone described by the nutating axis **63** is indicated diagrammatically in FIG. **3**. The grid **65** has openings through which powered coal, etc., may be removed from the crusher through a rubber boot **66** or the like.

The head **62** may be caused to sequentially reciprocate by any convenient mechanism such as the wedge-shaped swash plate **67** which is powered from shaft **68** which turns a pinion **71** engaged with a gear **72** on the periphery of the wedge **67**. Both head **62** and wedge **67** are supported on long radius bearings **59**, as hereinbefore described.

The bottom of the stack **57** is provided with multiple layers of steel balls **73** graded in size to form a steel ball sizing filter.

In operation, the stack **57** is filled with coal chunks or the like. Confining pressure on the mass within the stack is achieved by the weight of the tall stack material and bridging effect in the tapered stack. This pressure will typically develop interchunk pressure within the mass exceeding the low fracture strength of coal or similar material. When the swash plate is turned, the mass within the stack will progressively reciprocate to cause the development of stress planes on which the coal will rupture and be reduced, and the reduced particles will flow into the voids between the chunks. Fresh chunks of coal will be continuously added at the top to make up for the reduction in volume resultant from the removal of dust particles. The taper of the stack will cause bridging and will prevent reverse flow of the chunks. As breakage continues, the material will be reduced to such a size that it will flow as fine particles or powder through the spaces between the steel balls **73** and will be removed through the rubber boot **66**. This flow may be enhanced by an induced down draft as indicated by the arrows **74**.

I claim:

1. A method of crushing stone and comprising the steps of:
- assembling a large volume of stone in a deep bedded mass in which proximate chunks are in mutual interlocked engagement across intervening voids;
- imposing pressure on the mass such that mutual shifting of the chunks will subject shifted chunks to chunk rupturing stress;
- sequentially reciprocating portions of the mass to mutually shift the chunks and develop chunk rupturing stress between chunks to cause autogenous breakage and flow of crushed stone particles into said voids; and
- removing from the mass crushed stone particles after appropriate size reduction thereof.

2. The method of claim **1** in which the movement of the mass sets up shear planes through the mass along which chunk rupturing stress is developed.

3. The method of claim **1** in which additional stone chunks are force fed to the mass to replace removed stone particles and maintain interchunk pressure engagement.

4. The method of claim **1** which includes establishment of high and low pressure zones within the mass and flow of crushed stone particles from high pressure zones to low pressure zones.

5. A method of crushing stone and comprising the steps of:
- assembling between distantly spaced crushing heads a large volume of stone in a deep bedded mass in which proximate chunks are in mutual interlocked engagement across intervening voids;

maintaining sufficient pressure on the mass to impose rupturing stress at the interlocked contact points throughout the mass;

providing a zone of low pressure to insure fluidity of the mass while constricting flow to the low pressure zone to the extent that breakage rather than attrition occurs at the pressure required to cause flow;

moving each stone or particle of the mass with respect to its neighboring stone or particle, to induce cleavage at the points of rupturing stress, to present new points of stress, to vary the shape of the voids so they cannot become impacted, and to facilitate air and small particle flow;

removing from the mass crushed stone particles after appropriate size reduction thereof, and feeding in uncrushed aggregate; and

performing all of these functions simultaneously to produce a dynamic condition of break and flow throughout a large mass of stone.

6. A high pressure autogenous stone crusher comprising a container for a deep bedded mass of stone in which proximate stones are in mutual interlocked engagement across intervening voids, means for imposing pressure on the mass such that rupturing stresses will develop at the interlocked points of contact, means for progressively reciprocating portions of the mass relative to other portions to mutually shift the stones and develop new points of contact at rupturing stress resulting in autogenous stone breakage and flow of crushed stone particles into said voids and en masse from high pressure zones to low pressure zones, and means for feeding and removing crushed stone particles to and from the mass.

7. The stone crusher of claim 6 in which said container comprises a rotary drum having distantly spaced top and bottom walls, openings in said walls and top and bottom heads in said openings, the means for progressively reciprocating the mass comprising supports for said heads on which they nutate relative to said mass.

8. The stone crusher of claim 7 in which the drum has vanes about its periphery to interlock with the stone mass within the container.

9. The stone crusher of claim 7 in which one of said heads has a filler opening, said head having an entrance port between said filler opening and the interior of the container, said port having a configuration promoting bridging of stone thereacross.

10. The stone crusher of claim 7 in which the angle of inclination of said heads is adjustable.

11. The stone crusher of claim 6 in which said container comprises a tall stack, said stack having a bottom wall with an opening in said wall and a bottom head in said opening, the means for progressively reciprocating the mass comprising a bearing support for said head and a swash plate for nutating said head.

12. The stone crusher of claim 11 in which the bottom of said stack further comprises a loose ball sizing filter.

13. The stone crusher of claim 11 in which said bottom further comprises a grate through which fines are discharged to a fines pit.

14. The stone crusher of claim 11 in which said stack remains stationary with respect to the progressively reciprocating head.

15. The stone crusher of claim 6 in which the means for removing crushed stone particles from the mass comprises means for entraining such particles in a stream of flowing air.

16. The stone crusher of claim 7 in which there are gaps between the said heads and the top and bottom walls of the drum, and means for forcing air into said container through the gap between one end head and its wall and for removing said air from the container through the gap between the other end head and its wall, whereby to remove finely ground stone particles pneumatically.